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CLASSROOM QUESTIONING STRATEGIES AS INDICATORS OF INQUIRY BASED SCIENCE INSTRUCTION

by

Linda Hale Goossen

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
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CLASSROOM QUESTIONING STRATEGIES AS INDICATORS OF INQUIRY BASED SCIENCE INSTRUCTION

Linda Hale Goossen, Ph.D.

Western Michigan University, 2002

Inquiry teaching often rests upon the assumption that through the use of questioning and response strategies, teachers can stimulate students to actively construct knowledge. Based on this hypothesis, middle-school science lessons were observed and questioning and response strategies were identified that are related to inquiry-based instruction.

Twenty-four science lessons were observed, videotaped, and ranked by inquiry characteristics other than questioning strategy. The video and audio portions of the recordings were analyzed to determine the student and teacher's questioning and response strategies in each classroom. These strategies were then compared to teaching style, along a continuum from traditional to inquiry, to identify questioning and response strategies that stimulate students to ask questions, solve problems, analyze evidence, consider alternative explanations, and other similar inquiry behaviors.

The analyses indicated several questioning strategies of teachers that are related to inquiry teaching and learning and might be used as indicators of inquiry teaching in middle school science lessons. These include the number of content-

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related questions asked by teachers, the number of divergent questions asked by teachers, the number of times teachers probe for the intended response, the number of times teachers answer students' questions, and the number questions per concept asked by teachers. Perhaps more important was the observation that even after several decades of emphasizing the importance of inquiry methods in science education, neither students nor teachers participating in this study are asking higher-level cognitive questions deemed to be an important facet in the effective teaching and learning of science.

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Linda Hale Goossen

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TABLE OF CONTENTS

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Table of Contents – Continued

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Table of Contents – Continued

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LIST OF TABLES

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CHAPTER I

INTRODUCTION

Inquiry is the act of asking questions, seeking information, and making claims about possible answers to the questions, often leading the inquirer to reflect, ponder, and think about the situation at hand. Thus, it naturally follows that the act of questioning is an important part of the process of inquiry in science (Andersen & Ladd, 1971). Science is, by its very nature, an inquiry-based endeavor that should be taught as well as learned by the process of inquiry (Bruner 1960). Ultimately, the learner, often working in cooperation with a teacher or mentor, must initiate this process.

Over the decades Gall (1970), Orlich and Migaki (1981), Penick, Crow, and Bonnstetter (1996), Wilen and Hogg (1970), and many others have emphasized the importance and role of teachers' questions in the effective science classroom. For example, Taba (1966) regards the verbalization of questions by teachers as "the most influential teaching act". Anderson and Ladd (1991) define inquiry teaching "in terms of a teacher's questioning behavior". They maintain that the practice of inquiry by teachers should elicit more student participation and therefore higher student achievement. Redfield and Rousseau (1981) believe that "teachers' questioning of

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students is an important variable in student achievement." Orlich and Migaki (1981) maintain that teachers should be the questioner, not the answerer. Wilen and Hogg (1970), Dillon (1982), Gall (1970), Penick, Crow, and Bonnstetter (1996), Proudfit (1992) and others share the belief that teachers' questioning and response behaviors should be a primary focus of research into effective teaching and learning.

Others also emphasize the role of student questions and inquiry in science education. The National Science Education Standards (National Research Council, 1996) states "Inquiry into authentic questions generated from student experiences is the central strategy for teaching science". Edwards (1997), Brooks and Brooks (1993), Graesser and Person (1994), Deal and Sterling (1997), and Commeyras (1995) also support the thesis that students' questions should be a major strategy of inquiry teaching and thus an indicator of an inquiry-based classroom. They believe that in order to improve science understanding, students must be taught to question, gather information, hypothesize, test, communicate ideas, and confront fundamental concepts and issues in science. In summary, many science educators believe that students should learn science by the same inquiry techniques that scientists apply to solve new problems. This idea of inquiry-based science teaching and learning is not new. Commeyras (1995) states that "A student-centered approach to questioning is consistent with Dewey's recommendation that genuine as opposed to simulated problems be at the center of our educational efforts."

Inquiry teaching rests on the assumption that through their questioning behaviors, teachers can stimulate students' thinking and thus their learning. Wilen

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and Hogg (1976) state, "The success of the inquiry approach is crucially dependent upon the teachers' ability to ask questions that are congruent to the levels of thinking desired". Roth (1996) and Smith, Blakeslee, and Anderson (1993) maintain that in order for deep understanding to occur, teachers must ask questions and thus elicit student explanations, elaborations of previous answers and ideas, and predictions, which result in higher-level thinking. Teachers' questions can also function to help students make sense of their experiences and learning (Roth, 1996) and can influence the depth to which students search for answers. The use of proper questioning techniques by teachers can help motivate students to learn a new concept, to link their previous knowledge with that concept, and to see applications of these concepts in their experiences and in the world around them (Yet, Wang, and Huang, 1998).

However, studies over the past 80 years reveal that while teachers do ask many questions (Dillon, 1982; Gall, 1970; Hyman, 1980), students have not improved their achievement in science (Samson, Strykowski, Weinstein, and Walberg, 1987) as indicated by a number of measures. Specifically, students do not understand many basic concepts and are not able to use the concepts, principles, and processes of science in situations outside the classroom (Cherif, 1993). Thus, some characteristic in the teaching/learning process, other than the number of teacher questions, appears to be related to student achievement in science – that is, the ability to use, reflect upon, and apply those scientific principals deemed important by various national and state organizations (American Association for the Advancement of Science, 1990;

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AAAS, 1993; Michigan State Board of Education, 1991; National Research Council, 1996; National Science Teachers' Association, 1993).

Based upon a review of the literature, it appears that the majority of questions being asked by teachers require recitation and recall and do not ask students to analyze and synthesize data, apply concepts, or evaluate ideas. Thus, higher-level thinking by students is not being achieved. Redfield and Rousseau's (1981) meta-analysis of twenty studies on the relationship between the level of teacher questioning and student achievement showed that "gains in achievement can be expected when higher-level cognitive questions assume a predominant role during classroom instruction". Furthermore, Anderson & Ladd (1991) concluded that a blend of low- and high-level thinking questions – questions requiring students to think at low- or high-cognitive levels – will allow teachers first to discover if the students have the knowledge and then whether they can use that knowledge in a connected and meaningful way. Low-level thinking questions ask for recall of material presented in the curriculum; higher-level questions ask about material not covered directly in the curriculum and require students to synthesize concepts and ideas (Carlsen, 1991; Gall, Ward, Berliner, Cahen, Winne, Elashof, & Stanton, 1978). Thus, in order for meaningful learning and deep understanding to occur, the questions asked in a classroom must include not only lower-level memory and recall questions, but also higher-level cognitive questions, which require the student to think about, process, analyze, and apply ideas.

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How teachers sanction students' responses may also be related to the higher-level thinking that teachers should be eliciting in students. Studies by Hyman (1980), Rowe (1974), and Tobin (1986) provide evidence that teacher behavior following question-asking may be an important intervening variable in the relationship between higher-level questioning and higher-level thinking. Both Rowe and Tobin studied the relationship between the time teachers allow students to reply to a question (wait-time I) and the period following a student answer before the teacher begins speaking again (wait-time II) and the ensuing student and teacher behaviors. Both discovered that more inquiry behavior was observed in classrooms where teachers had longer wait-times (3 – 5 seconds) in both categories. Specifically, students showed longer responses, more higher-order thinking, higher confidence, greater amounts of student-student interactions, more question asking, and fewer failures to respond. It has been speculated that a period of silence by teachers following a question provides the students with an opportunity to consider what has been said and to assimilate new knowledge with previously learned information. The pause following a student's response, a non-verbal neutral sanction of the student's response, provides the responder or other students with the time "to consider what has been said and to formulate a reaction, question, or alternative response" (Tobin, 1986). That is, extended wait-times provide the student an opportunity to think and process additional information (Dillon, 1982; Rowe, 1974; Tobin, 1986).

In addition, Gall (1970) maintains that follow-up questioning of the student's initial response has a substantial impact on student thinking and learning in the

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classroom. She suggests that "follow-up" questions are important because, more than likely, when students answer questions, they are repeating an answer or solution they have heard or read before. Follow-up questions test "the student's ability to think about the problem and stimulates the development of the thinking process" (Gall, 1970). Thus, research suggests a likely relationship between teachers' response strategies and the subsequent cognitive level of student thinking.

A second concern is that students seldom ask questions. The teachers in the role of questioner traditionally and culturally dominate classroom conversations in the United States, while students automatically assume the role of responder and passive participant (Rowe, 1974; Dillon, 1982; Durham, 1997). Durham's study of eight secondary high-school science teachers provided evidence that although instructional activities were designed to elicit and encourage student questioning, the teachers used a variety of discourse strategies that actually discouraged students' questions, specifically the teachers' tendency to dominate the classroom interaction. And, according to Carlsen (1991), teachers often discourage student questions by "dominating the speaking floor, asking frequent low-cognitive questions, and ignoring student bids to change the topic of discourse". Students will not be active inquirers if teachers use their power position as teachers to socially control classroom discourse while students assume the subordinate role of responder (Dillon, 1982).

Dillon (1982), in a review of questioning literature, describes the typical scenario of teacher as questioner and student as responder in which the student is culturally and automatically placed in a subordinate and reactive role. The student as

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responder does not initiate the exchange, does not choose the topic, does not extend the conversation, and cannot redirect or terminate the exchange. The teacher as questioner has control, power, and authority in the exchange and has difficulty relinquishing it to the student. Rowe (1974) agrees with this view of questioning in classrooms; "the pattern of interchange between teachers and children more closely resembled an inquisition than a joint investigation or a reasonable conversation". The effective science teacher should establish a learning environment that encourages the students to actively participate in classroom discussions by raising meaningful questions (AAAS, 1990).

Hyman (1980) maintains that a teacher behavior, not yet analyzed, is responsible for the paucity of students' questions. He states that the key lies in what teachers do when students ask questions. A study by Hyman showed that teachers responded to student questions in a many ways, methods he calls 'fielding'. He believes that teachers are often unaware of how they field questions and that current fielding practices of teachers serve to minimize student questioning. He also contends that teachers are often threatened by student questions or that they feel the need to be in control of the classroom content and procedures. Thus they inhibit student question asking by deflecting student questions in one way or another and thus implicitly convey the message to not ask any more questions. Consequently, teachers' responses to students' questions or answers can result in inhibiting students' questions and, as a result, discouraging student thinking. Good inquiry teachers often respond to student questions in an accepting manner that encourages higher-level

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thinking and increased student verbal interaction (Durham, 1997). The effective inquiry environment should promote not only teacher questions but also student questions and investigation as a vehicle to thinking about and questioning nature (AAAS, 1990).

From an epistemological stance, constructivism – the philosophy that learners construct their own knowledge – views learning as an active process during which the learner interacts in a thoughtful way with phenomena and the ideas of other learners to create knowledge, i.e., ideas or models with explanatory power. Questioning is an important strategy that encourages this behavior. However, it is insufficient to concentrate only on the development of the teacher in the role of questioner. Teachers' responses to both student answers and student questions are also important for encouraging students' construction of knowledge. Classroom questioning can be considered as an interacting dyad in which both the question and the response are critical in stimulating the thought process. "The teacher can facilitate learning through skillful verbal interacting, both as the questioner and the respondent" (Durham 1997). As a result of Durham's (1997) study of teachers' responses to students' questions, she recommends, "further research is needed to identify effective teacher response strategies".

In summary, indicators of inquiry teaching and learning include not only students posing questions, solving problems, and persuading others, but also the nature of teachers' questions and teachers' response strategies. Effective inquiry lessons should result in students using critical and logical arguments, considering

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alternative explanations, and attempting to convince others that their models and explanations are valid. Teachers' must use effective questioning and response strategies to elicit such behavior in students. If one way inquiry teaching can be characterized is in terms of teacher and student questioning behaviors, those questioning strategies may be useful as indicators of inquiry-based science classrooms and also serve as a means of improving the teaching and learning of science. Therefore, this study is aimed at addressing the following problem.

The Research Problem

The general problem is: What questioning and response strategies are related to or may be used as indicators of inquiry teaching and learning in the science classroom? Specifically, which of the following factors, if any, are linked to an inquiry-based pedagogy:

(a) characteristics of student questions

  (i) number of student questions

  (ii) type of student questions

(b) characteristics of teacher questions

  (i) number of teacher questions

  (ii) type and level of teacher questions

(c) teacher use of wait-time I

  (i) length of wait-time I

  (ii) other non-verbal behaviors during wait-time I

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(d) verbal response strategies of teachers following wait-time I, if no student response is forthcoming

(e) use of wait-time II

 (i) length of wait-time II

 (ii) other non-verbal behaviors during wait-time II

(f) verbal response strategies following wait-time II (following student response)

 (i) by the teacher

 (ii) by the student

 (iii) by other students

(g) how teachers field student questions

 (i) questions related to a teacher question or statement

 (ii) questions related to a student question or statement

 (iii) questions not apparently related to other discourse

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CHAPTER II

LITERATURE REVIEW

Status of Science Education

The nation's goals of what our children should know and be able to do with science and technology has changed through the decades, often reflecting national and international, social, and economic trends. When the Russians became the first to put a manned flight in space, the United States was apparently relegated to second-class status in science and space programs and, as a result, the emphasis on science and technology education was expanded. Millions of dollars were invested in developing new science curricula.

During the 1980's, several reports were written about our nation's lack of science literacy. *A Nation at Risk: The Imperative for Educational Reform* (American Association for the Advancement of Science, 1990) warned of a national education crisis if we did not modify our educational practices. American students' low test scores were compared with those of other nations and used as an indicator of our students' academic status. This report suggested that our nation was declining as an economic and technological leader in the world.

These reports indicated a need for improving our education system – especially in science and technology – in order for our citizens to compete in an increasingly complex technological and competitive world (AAAS, 1995). The

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warnings were used as a catalyst by several groups of scientists and educators, such as The National Science Teachers Association, American Association for the Advancement of Science, and state education associations, to assess where we were, where we wanted to be, and how we could get there in science and technology. Research, discussions, and recommendations were made in the areas of "what" – what do our students need to know to be science literate, "when" – when are children ready to understand the ideas they need (Bruner, 1960), and "how" – how do individuals learn and how can teachers best facilitate students' learning the science content.

The "what" of science literacy – the content – has been addressed by various national and state organizations. Benchmarks (American Association for the Advancement of Science, 1993), Michigan Essential Goals and Objectives for Science Education (1991), Scope, Sequence, and Coordination of Secondary School Science, Volume I, The Content Core (National Science Teachers' Association, 1993), and National Science Education Standards (National Research Council, 1996), all contain lists of content ideas that these organizations of scientists and teachers believe students need to know and understand in order to be science literate.

Before the content can be prescribed, however, a working definition of science literacy must be developed. While many have tried to define science literacy, Miller (1995) describes scientific literacy quite well; "Science literacy should be viewed as the level of understanding of science and technology needed to function minimally as citizens and consumers in our society". Miller maintains that such

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scientific literacy demands basic vocabulary of scientific and technical terms, an understanding of the process of science, and an understanding of the impact of science and technology on society. From an educator's point of view, understanding science means being able to use it, reflect upon it, and apply it to the world around us.

The "when" of science literacy has been the subject of much discussion. Students' cognitive or intellectual development is a factor in their learning (AAAS, 1990; Brooks and Brooks, 1993; Bruner, 1960; Guilford, 1956; National Science Resources Center, 1997; National Science Teachers' Association, 1993). Students progress in their learning from concrete to abstract (Taba and Elzey, 1964). The skills for grasping abstract concepts develop slowly and generally rely on concrete examples in the "context of some relevant conceptual structure" (AAAS, 1990). If the developmental steps are not taken into consideration in the science teaching methods, there will be a mismatch between what children are capable of learning and what they are expected to learn. If this mismatch occurs, children will not learn as much as they could, and if this leads to failure, students will not enjoy or pursue science (National Science Resources Center, 1997).

Bruner (1960) believes that "the foundations of any subject may be taught to anybody at any age in some form" and to learn the concepts of science demands that students learn to use concepts in progressively more complex forms. The curriculum documents (AAAS, 1993 and National Research Council, 1996) address this concern for the developmental status of the student as a part of the "scope and sequence" of the recommended curriculum and is demonstrated when districts use a spiral

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curriculum, in which the same information is presented at increasingly complex and abstract levels as children progress through school (NSTA, 1993).

The "how" of science literacy is relatively young in its development. How science is taught for knowledge and understanding is equally as important as what and when students are taught (AAAS, 1990). Cognitive science is becoming more sophisticated due to computer technology and brain science. There is a growing body of knowledge about the nature of learning; studies have been ongoing since as early as the 1920's (Watson and Konicek, 1990) about how people learn and how knowledge is structured (Wandersee, Mintzes, and Novak, 1994). Constructivism, conceptual change, and inquiry-based learning are all terms used in discussing the "how" of science education (Anderson, 1987, Roth, 1992, Matthews, 1992). These terms are not mutually exclusive.

Constructivism

Studies of science learning show that humans do not learn by just taking in and memorizing material (Zemelman, Daniels, and Hyde, 1993). They use their own prior knowledge and experience to help make sense of new information (Brooks and Brooks, 1993; King, 1994). During this meaning-making process, individuals may draw inferences about the new information, take a new perspective on some aspect of their existing knowledge, elaborate the new material by adding details, and generate relationships between the new material and information already in memory. Each of these steps helps learners reformulate the new information or restructure their existing

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knowledge and achieve deeper understanding. "During the process of reformulating information or constructing knowledge, new associations or links are formed and old ones are altered within the student's knowledge networks. These links connect the new ideas together and integrate them into the learner's existing cognitive representation of the world. Adding more and better links results in a more elaborate and integrated cognitive structure that facilitates memory and recall" (King, 1994).

Because self-constructed knowledge is personally meaningful and is anchored in students' own experiences (King, 1994), understanding and memory of material are enhanced when students actively construct knowledge and integrate it in these ways, rather than simply memorizing information as presented (Taba, 1966; Wilson, 1999). In contrast, Kelly, Brown, and Crawford (2000) report that various studies of classroom discourse found that science is often presented to students through whole-class conversations, controlled and dominated by the teacher's discourse, and oriented toward the transmission of scientific facts.

If educators accept the proposition that meaningful learning occurs by constructing new knowledge and modifying prior knowledge, then teachers must challenge all students to understand the world by allowing them to experience the world, ask their own questions about the world, and seek answers. A constructivist framework challenges teachers to create an environment in which both they and their students are encouraged to think, question, and explore and thus construct their own understanding (Good, Slavings, Harel, and Emerson, 1987; Brooks and Brooks, 1993; Zemelman et al., 1993; Wilson, 1999; Marback-Ad and Sokolove 2000). Schools and

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classrooms should provide environments that invite students to "search for understanding, appreciate uncertainty, and inquire responsibly" (Brooks and Brooks, 1993). When teachers create an appropriate and stimulating environment, children's urge to make sense of the world around them propels their own learning (Zemelman et al., 1993).

Conceptual Change

As students are constructing new knowledge, they are modifying their existing conceptions. Thus, constructing new scientific knowledge means that students are changing or replacing their existing conceptions about the world to accommodate new ideas (Smith, Blakeslee, and Anderson, 1993; Taba and Elzey, 1964). This process is called conceptual change.

Wandersee et al. (1994) make several claims about conceptual change: learners come to the classroom with preconceived ideas about the natural world around them; their ideas are often at odds with the scientifically accepted views about physics, chemistry, and life science; teachers need to know what ideas their students hold; and, children hold these alternative conceptions with varying tenacity. It therefore becomes the teacher's responsibility to facilitate change in these previously constructed conceptions.

Posner, Strike, Hewson, and Gertzog (1982) suggest that four conditions are necessary for conceptual change to occur: (1) the learner must have dissatisfaction with existing conceptions; (2) the new conception must be minimally understood;

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(3) the new conception must appear initially to have the ability to solve problems and fit with prior knowledge and experience; and (4) the new conception should show potential to be extended, to open new areas of inquiry, and to have explanatory power. "If students are to engage successfully in conceptual change, teachers must help them to meet each of the criteria" (Smith et al., 1993).

The origin of students' conceptions about the world involves interaction with the world and with others through direct observation and personal experiences. These interactions with the world are also related to the way children will "reconstruct" their knowledge in the classroom. If children base their thinking on what they have observed and felt, then their experiences in the classroom must be structured to challenge their erroneous beliefs (Watson and Konicek, 1990) and thus initiate conceptual change. Thus, the role of teachers in conceptual change is to become aware of their students' scientific preconceptions so they are "better informed as instructional decision makers" (Anderson, 1987). With adequate knowledge of students' beliefs, teachers can then provide students with new experiences that challenge their preconception, establish minimal understanding and initial plausibility for the new idea, and help students to see how the new idea makes sense of novel experiences and explains complex and unfamiliar phenomena. Thus, teaching strategies for conceptual change are designed to engage students in activities like those of scientifically literate adults. " In doing so, conceptual change teaching strategies should promote not only mastery of specific conceptions, but also a more general understanding of the nature of science" (Smith et al., 1993).

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Inquiry-based Science Teaching

How can teachers effect the construction of new knowledge and the modification of existing conceptions by students? They do this by encouraging students to observe, interact with, and question nature. "Meaningful learning of science involves coming to understand scientific ideas as they are used for their intended purposes, including description, prediction, and explanation of phenomena in the natural world. Thus, teachers need to pursue class activities that engage students in using scientific conceptual schemes to describe, explain, or make predictions about the world around them" (Smith et al., 1993). This type of classroom behavior is termed "inquiry".

Scientific inquiry refers to the way that scientists learn about the natural world and the way in which children can best learn science (Bruner, 1960). In other words, the inquiry philosophy of teaching and learning contends that "students will develop better understandings of the nature of science and will be more interested in science if they are engaged in 'doing' science" (Roth, 1992). This includes "using expertise, identifying and acknowledging experimental variables and contingencies, making decisions in the absence of certainty, considering theoretical predictions, and creating new conditions to explore the consequences of various ideas" (Kelly et al., 2000).

Student investigation into phenomena is the backbone of the inquiry classroom curriculum and the focus of these student investigations should be the use and development of the process skills of predicting, hypothesizing, observing, recording data, making inferences and generalizations (Roth, 1992), organizing

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information, thinking critically, applying knowledge to new situations (National Sciences Resource Center, 1997), making choices about experimental procedures, listening and considering different points of view, achieving consensus from multiple perspectives, and taking action as a collective (Kelly et al., 2000). In inquiry classrooms, students use and develop scientific thinking skills to construct knowledge and understanding in the same way that scientists use experimental work to construct new knowledge, concepts, and theories (Roth, 1992).

The inquiry movement of the 1960's and 1970's was the driving force behind the National Science Foundation programs in curriculum development and professional development of teachers (Roth, 1992). In addition, inquiry-based teaching and learning is a teaching standard of the National Science Education Standards (National Research Council, 1996).

Questioning plays an integral role in inquiry-based teaching and learning. Orlich (1981) and Hinton (1994) believe that questioning is the most critical aspect of the concept of inquiry because asking the right questions and answering them is at the root of all scientific investigation. According to Orlich, "the single most common teaching method employed in the schools of America and, for that matter, the world seems to be that of asking questions". Furthermore, other researchers say that: "Inquiry is the act of inquiring or seeking information by questioning" (Andersen and Ladd, 1971); "To inquire is to seek knowledge and understanding by questioning, observing, investigating, analyzing, and evaluating" (Cherif, 1993); and "The

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principle of active learning calls for heavy emphasis on question-asking instead of answer-giving" (Taba, 1966).

Teacher-generated Questions

Teachers' questions are the basic unit underlying most methods of classroom teaching in America (Gall, 1970; Orlich, 1980). Research has shown that teachers ask approximately 300 – 400 questions during a typical day (Gall, 1970; Wilen and Clegg, 1986) at a rate of between 30 and 120 questions per hour (Roth, 1996). However, Gall adds that in the last fifty years, there has been no essential change in the types of questions teachers ask; "about 60% of teachers' questions require students to recall facts, about 20% require students to think, and the remaining 20% are procedural".

For what purposes are teachers asking questions of students? Teachers need to question students in order to discover what their ideas are when they enter the classroom (Watson and Konicek, 1990). Teachers use questions to direct the classroom activities, review concepts, initiate or redirect discussions, monitor student behavior, guide students' learning of a problem-solving skill, solicit student feedback, raise new ideas and suggestions, stimulate curiosity and inquiry, and maintain student attention (Brooks and Brooks, 1993; Cherif, 1993; Gall, 1970; Penick, Crow, and Bonstetter, 1996; Tinsley and Davis, 1971; Yet, Wang, and Huang, 1998). Teachers also need to question students as the students modify or change conceptions to be sure

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they are not clinging to their previous conceptions or hybridizing the new ideas with those previously held (Brooks and Brooks, 1993).

In a quote from Roth's (1996) study, questions serve at least six additional functions: (1) to focus student's attention on a concept by drawing it out from their experience; (2) to help students develop a language for talking about the concept; (3) to stimulate students to improve their cognitive model of the concept; (4) to make sense of students' experience and learning; (5) to help students succeed in their understanding; and (6) to help students cope with temporary failures.

In addition, questions can be used for formative assessment in the classroom, not necessarily looking for the "right" answer, but to see what the student is thinking and why (Brooks and Brooks, 1993; Penick et al., 1996). By asking such assessment questions, the teacher is able to monitor concurrently the cognitive functioning of the student, the disposition of the student, and the status of the teacher/student relationship (Brooks and Brooks, 1993).

An important outcome of effective teacher questioning is that it can also serve as a model for children to develop their own questioning strategies. One teacher discovered that once students began to learn appropriate questioning strategies, they became more independent in their learning, supported each other's learning, and became more aware of their own learning; in other words, a culture of questioning developed (Roth, 1996). Penick et al. (1996) agree that the best science teachers model the effective use of questioning in scientific inquiry. These teachers understand, often implicitly, that science students who learn both the questions and

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the logic of science develop appropriate thinking skills as well as scientific literacy. However, while Good et al. (1987) admit that teacher behavior may have a direct effect on student performance, they maintain that the students must first consciously perceive and interpret teacher behavior if it is to affect their motivation and effort.

King (1994) reports on several studies that indicate that construction of knowledge can be stimulated in students by using various questioning procedures. The teacher can use questions to guide the students into relevant problems, rather than subordinating the curriculum to the interests of children; thus relevance in learning can emerge through teacher mediation with the proper use of questioning (Brooks and Brooks, 1993). However children will not necessarily make the connections on their own, and thus teachers' questioning strategy can help students make the connection. Thus, when student-centered inquiry is combined with appropriate teacher questioning strategies, science content knowledge does not have to be compromised (Roth, 1996).

The "effective" use of questions includes a teacher deciding which questions to ask, when to ask them, and in what order. To do so, teachers must become cognizant of where to begin questioning, how one question leads to another, and where the questions are leading. This is a teacher's questioning strategy (Taba, 1966; Penick et al., 1996; Kelly et al., 2000).

A science teacher's questioning strategy includes ways to ensure that the student will answer the first question in a manner that will enable the teacher to learn about the student's level of knowledge and thinking and to devise further questioning

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that will help students to develop new and more accurate conceptions to replace their old ones. Through questioning, the teacher can and should develop an environment where the new concept or idea is available for exploration, analysis, and consideration. The order of questions in a particular instance should be logical, beginning with a few assumptions about the learner, and progressing to a level that allows for considerable depth in the thinking. In addition, the pace of the questions must be matched to the students' capacity for mastering the skills at each step – allowing the students to absorb sufficient descriptive information before being asked to explain an item (Taba, 1966). "As we present questions and our students respond, the students come to see the step-by-step logic of our questions, their own questions and answers, and the nature of science itself" (Penick et al., 1996).

Wilen and Clegg's (1986) review of questions and questioning literature presents eleven questioning strategies that correlate with positive student achievement: (1) "effective teachers phrase questions clearly"; (2) "effective teachers ask questions which are primarily academic"; (3) "effective teachers ask high frequencies of low cognitive level questions with low SES (socioeconomic status) students in elementary settings"; (4) "effective teachers ask high cognitive level questions"; (5) "effective teachers allow 3-5 seconds of wait time after asking a question before requesting a response, particularly when higher cognitive level questions are asked"; (6) "effective teachers encourage students to respond in some way to each question asked"; (7) "effective teachers balance responses from volunteering and nonvolunteering students"; (8) "effective teachers permit student

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call-outs in low SES classes while suppressing call-outs in high SES classes"; (9) "effective teachers encourage a high percentage of correct responses from students and assist with incorrect responses"; (10) "effective teachers probe students' responses for clarification, support for a point of view, or to stimulate thinking"; and (11) "effective teachers acknowledge correct responses from students but are specific and discriminating in their use of praise".

Moreover, the nature of the questions posed to students is an important aspect of a teacher's questioning strategy as it greatly influences the depth to which students search for answers (Brooks and Brooks, 1993). Open-ended questions provide the opportunity for students to respond on different levels of depth and abstraction and from different perspectives (Taba, 1966). Complex, thoughtful questions can challenge students to look beyond the apparent, to delve deeply and broadly into issues, and to form their own understanding of events and phenomena (Brooks and Brooks). Proper questions by the teacher can encourage students to elaborate on their initial responses to a question or problem. Through this elaboration, students can often see and assess their own errors in thinking. In addition, the type of questions asked by teachers will be viewed by students as indicating the types of learning that are important (Orlich, 1980). From a constructivist point of view, proper questioning of students can help students become motivated to learn a new concept, to link their previous knowledge with the new concept, and to integrate previous associations (Yet et al., 1998).

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A study by Morine-Dershimer and Tenenberg (Good et al., 1987) found that teachers' questioning strategy corresponded to differences in students' performance, participation, and achievement. In particular, student reading achievement was higher and student participation rates were greater in classrooms in which students believed the teacher asked "real" questions for which the teacher has a real need to know the answer.

The importance of teachers' questions is summarized well by Wilen and Hogg (1976); "Inquiry teaching rests on the assumption that teachers can stimulate thinking through their verbal questioning behaviors". Questions guide students to formulate hypotheses, project generalizations, offer opinions, make predictions, devise plans, arrive at decisions, and draw conclusions as they analyze problems within a structured framework. Teachers' questions serve as a stimulus to higher thought processes of students. "The success of the inquiry approach is crucially dependent upon the teachers' ability to ask questions that are congruent to the levels of thinking desired" (Wilen and Hogg, 1976).

Student-generated Questions

Just as teacher questioning is integral to inquiry-based teaching and learning, so is student questioning. According to the recommendations of Project 2061:Science for all Americans (AAAS, 1989) "Science teaching should be consistent with the nature of scientific inquiry and include opportunities for the student to personally investigate natural events, ask questions, argue ideas, and try to find answers to their

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own questions". Teachers are encouraged to incorporate strategies that promote the discovery of information. This inquiry approach should be oriented toward student questions as well as teacher questions. The effective science teacher should establish a learning environment that encourages the students to actively participate in classroom discussions by raising questions.

Questioning by students is a key component of their learning of science (Commeyras, 1995). The questions asked by students are central to the concepts they will learn. Teachers must encourage students to experience the world's richness, empower them to ask their own questions and seek their own answers, and challenge them to understand the world's complexities (Brooks and Brooks, 1993). Based on the premises of Anderson and Ladd (1971), Bruner (1960), Cherif (1993), Hinton (1994), Roth (1992), and others, students need to actively construct their own knowledge, and this process includes students asking relevant questions. "Inquiry into authentic questions generated by student experiences is the central strategy for teaching science" (National Research Council, 1996).

Just as questions serve various purposes for teachers, they also serve many purposes for students. Questioning is an essential component of concept formation, problem solving, and verbal learning (Hyman, 1980). The questions asked by students expose the organization or reorganization of their knowledge (Durham, 1997). For students, questions serve as a way to gain information, to clarify an idea, to shape their thoughts, to assess someone else's point of view, and to seek solutions to problems. Questions are essential for critical comprehension, critical reasoning,

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and creative thinking (Costa, Caldeira, Gallastegui, and Otero, 2000; Hyman; Marback-Ad and Sokolove, 2000;). Graesser and Person (1994) state, "there is substantial empirical evidence that there are robust improvements in the comprehension, learning, and memory of technical material after students are trained how to ask a good question". Marback-Ad and Sokolove contend that students' questions can increase their understanding and retention of textual narrative. Sutton (1996) claims that learning science means learning the language of science. The language of science means, among other activities, questioning.

Dillon's (1982) socio-linguistic description of the function of questions proposes that questions stimulate the thinking process of the questioner but not necessarily the thinking of the responder. While various kinds of questions may have different functions, such as to express perplexity, motivate various levels of thinking, and request various kinds of information, these questions cannot be defined as causing specific kinds of thinking in the respondent. Merely hearing a question does not of itself result in experiencing the perplexity and knowing the answer is not equivalent to wanting or needing the information. It follows that students must be active questioners, not merely respondents in science classrooms.

Good et al. (1987), on the other hand, warn that students may ask questions to distract the teacher and the classroom from their learning process, to embarrass the teacher, or to hide the fact that they have not read the material or were not paying attention. In addition, students' questions could also indicate a need for assurance or an inability to think clearly and independently. Their data suggest that relatively few

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secondary students' questions are about the understanding of concepts; rather, the authors contend, "most questions are simply attempts to obtain procedural or simple, factual information" (Good et al., 1987). Thus, one cannot assume that in classrooms in which students ask more questions, more learning automatically follows.

While question asking is one of the most frequent act of teachers (Gall, 1970; Orlich, 1980), students do not ask many questions (Dillon, 1982; Durham, 1997; Gall, 1970; Hyman, 1980). Graesser and Person (1994) report that while teachers ask from 30 to 120 questions per hour, students ask only 1.3 to 4.0 questions per hour, and those questions are typically at a low cognitive level. However, Good et al. (1987) concluded from their study of student passivity that the number of questions students ask per 50-minute lesson remains reasonably constant for all grade levels. They contend that while the number of the number of procedural question remains relatively constant, students' on-task attention questions decrease and the number of explanation questions increases over time. Dillon notes that "those who ask questions – teachers, texts, tests – are not seeking knowledge; those who would seek knowledge – students – do not ask questions".

There is speculation about the reasons students are not asking many questions in the classroom. Good et al. (1987) found a radical drop in seventh-grade classrooms of on-task attention questions and surmise that this occurrence probably indicates that students do not want to call teachers' attention to themselves. This trend continues throughout secondary school. The authors speculate that students quit

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asking questions because low-achieving students ask more questions in kindergarten, and thus other students may perceive that asking questions in class is undesirable.

Costa et al. (2000) offer additional explanations for the dearth of student questions. First, the authors maintain that students have difficulties detecting anomalies with their own knowledge, thus preventing them from asking any question geared at solving the comprehension problem. Second, there are personal variables such as achievement, motivation, and self-esteem that influence question asking; and third, "contextual variables and those related to social constraints may prevent students from asking questions as well."

Costa et al. (2000), Greasser and Person (1995), and others believe that students are capable of engaging in meaningful question asking, but the classroom environment does not foster it. "Teachers do not encourage pupils to air their own views, and the outcome is predictable: students learn not to ask questions in class" (Marback-Ad and Sokolove, 2000). Commeyras (1995) and Roth (1996) maintain that encouraging student questioning requires a student-teacher dynamic that is quite different from that seen in most classrooms. Good et al. (1987) maintain that although their findings are tentative, the data clearly reflect the effects of individual teachers on student questioning rates.

Hyman (1980) and Durham (1997) also believe that the deficiency of student questions is related to teachers' behavior, specifically how teachers respond when students do ask questions. Hyman refers to these response strategies as the 'fielding' of students' questions. Both Hyman and Durham examined teacher response

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strategies to student questions. Their studies indicated that teachers' responses to student questions serve to minimize further student questioning.

A study by Hyman demonstrated that teachers fielded student questions in many ways. Teachers can field student questions by (a) relaying the question to the class or a classmate, (b) returning the question to the questioner, (c) praising the question, (d) rejecting the question, (e) waiting silently for the questioner or another student to respond to the question, (f) seeking clarification of the question, (g) asking a different question or launching into a new topic leading to the desired response, (h) excluding the new topic inherent in the question, (i) calling for further research, or (j) continuing with the interaction as if the question was not asked. Hyman believes that teachers are often unaware of how they field questions and that current fielding practices of teachers serve to minimize student questioning. Good inquiry teachers must respond to student questions in a manner that encourages higher-level thinking and student verbal interaction (Durham, 1997).

While the classroom activities in Durham's study were designed to encourage and elicit student questioning, the data reflect that teachers dominated classroom interaction. Her findings suggest that student participation in classroom discussion may be restricted by both the type of response employed by the teacher to student questions as well as how the teacher, in the role of primary questioner, controls student responses and verbal participation. "The teacher determines the purpose, topic, format, sequence, type of question, who can participate, and how long a student

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can participate. The student is placed in a passive, subordinate position" (Durham, 1997).

In addition, Hyman (1980) contends that teachers feel a need to be in control of both the content and the procedures in their classrooms and that teachers discourage student questions because they feel such questions are a threat to the teachers' ability to control the lesson. According to Sirotnik (1983), "Nearly 100 percent of the elementary classes are entirely teacher-dominated. Moreover, the junior and senior high school classes are highly teacher-dominated, averaging nearly 90 percent and 80 percent, respectively". He maintains, "teachers outtalk students at a ratio of nearly three to one". Taba's (1966) study also indicates the centrality and power of the teacher's role in initiating cognitive operations and determining which kinds are open to students.

Roth (1996) maintains that in inquiry classrooms, which by definition should be student-centered, teachers' use of questioning must not be about control. Kelly et al. (2000) suggest that teachers can relinquish total control of the classroom discourse. The teacher in their study was able to redistribute power by using discourse strategies that encouraged student participation and talk with and about science. These questioning strategies included "requesting specific information, students' ideas, description of events, clarification of student talk, extension of student talk, students' confirmation, and student predictions" (Kelly et al., 2000). The strategies enticed students into conversations about the nature of scientific knowledge. Thus the teacher acted in a facilitative, rather than authoritative role.

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Orlich's (1980) review of questioning and teaching science reports that students can be encouraged to ask productive or higher-order questions; that students are more involved in the classes in which they are encouraged to ask questions; and that the more questions a student asks, the greater the chance that the questions will be at higher levels. Edwards (1997) recommends three strategies for teachers to encourage students to ask questions: (1) provide students with an observable phenomenon to ask questions about; (2) have students read articles regarding interesting happenings in science; and (3) suggest possible topics for investigation to the students.

Others agree that teachers can foster student question-asking. Roth's (1996) study demonstrates that student questions increase in number and depth as the teacher exposes them to proper questioning techniques. Penick et al. (1996) agree that teachers should "model the effective use of questions in scientific inquiry" so that students can learn both the questions and the logic of science and thus develop thinking skills and science literacy. Hyman (1980) suggests that teachers must interact with students and develop activities that foster and promote questioning. Gall (1970) and Orlich (1980) also recommend that students be trained and encouraged to ask questions. Graesser and Person's (1994) study provided evidence that students are able to ask questions on a scientific subject matter in a tutoring setting and Costa et al. (2000) maintain that conditions provided by computer-aided teaching systems are conducive to students asking meaningful questions. Yet Commeyras (1995) reminds us that allowing students to ask questions that naturally occur to them is quite

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different than training them to ask the kinds of questions that will lead to meaningful learning.

Classification of Questions

Many authors (Arlin, 1977; Costa et al., 2000; Gall, 1970; Gall, Ward, Berliner, Cahen, Winne, Elashoff, and Stanton, 1978; Good, Slavings, Harel, and Emerson, 1987; Hinton, 1994; Marbach-Ad and Sokolove, 2000; Orlich, 1980; Orlich and Migaki, 1981; Penick et al., 1996; Roth, 1996; Sanders, 1972; Tinsley and Davis, 1971; and Wilen and Hogg, 1976) have classified questions into various categories. Both Arlin and Tinsley and Davis have used Guilford's (1956) "structure of the human intellect" as a basis for their questioning categories.

Guilford (1956) theorizes the structure of human intellect in terms of intellectual factors. His system divides intellectual factors into two major classes: thinking factors and memory factors. Within the thinking class are cognition factors, production factors, and evaluation factors. Guilford's cognition factors have to do with comprehending, constructing, or the discovery of a concept or construct. The production factors are subdivided into convergent and divergent thinking abilities.

The convergent production factors are those in which a specific type of end result is produced after comprehension. Generally one correct answer or conclusion is indicative of convergent thinking, such as in multiple-choice questions. For example, "What is the formula for work?" is a convergent question.

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In divergent productive thinking, on the other hand, there is no one correct answer; the answerer may go off in various directions to answer the question. For example, "In what ways can you use a lever?" would be classified as a divergent question, since there are many unique and reasonable answers.

Guilford's evaluation factors are those by which a person makes decisions about the goodness or "value" of the results of thinking. After a discovery is made and a product is achieved, is it correct or the best we can do? Will it work? Evaluation factors deal with judgments. Guilford considers the evaluation factors to be similar to wisdom or common sense.

Guilford (1956) maintains that thinking factors are of importance in the investigations of learning and learning theories since thinking has connections to learning and is sometimes regarded as a form of learning. If learning is associated with the development of these thinking factors, we as educators and researchers need to know and understand the factors and how to promote their development in the classroom.

Arlin (1977) uses Guilford's (1956) thinking factors to classify cognitive questions. Arlin maintains that the types of questions posed reflect individuals' developmental capacity in the situation, their approach to problem finding, and what they are capable of discovering. Tinsley and Davis (1971) also use the Guilford model to classify questions. Their study, to determine the cognitive nature of the questions social studies teachers use in junior and senior high school American history classes, was based on the theory that questions and questioning are one of the

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most important tools for developing knowledge and thinking skills in students. Their study demonstrated a lack of attention by student teachers to questions that stimulate high-level cognitive processing by students and no differences in cognitive opportunities between junior and senior high-school students.

Orlich (1980) uses three categories of cognitive questions, which are similar to Guilford's thinking factors, in his discussion of the classroom: convergent, divergent, and evaluative. Convergent questions are at the knowledge or comprehension level, with a single correct answer. Divergent questions have longer responses and multiple appropriate responses. Evaluative questions are divergent questions with a built in "judgmental set of criteria".

Gall (1970) developed a table of five categories of cognitive questions based on her review and comparison of eight question-classification systems. She maintains that the various classification schemes omit several other worthwhile question types such as "questions which cue students to improve on an initially weak response to a question; questions which create a discussion atmosphere; questions which stimulate students' sense of curiosity and inquiry; and questions that guide students' learning of problem-solving, behavioral, or affective skills."

High-level Inquiry Questions

Andersen and Ladd (1991) examined various classification schemes of cognitive questions and developed a two-level category – lower-level inquiry and high-level inquiry. The lower-level inquiry questions require little thought or inquiry

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of the respondent, while the high-level inquiry questions require more thought or inquiry. Lower-level inquiry questions direct students to define, describe, designate, state, report, substitute, or classify. High-level inquiry questions direct students to evaluate, compare and contrast, conditionally infer, or explain. Their study allowed them to conclude that the level of teachers' questions strongly influences student performance. The students of the teachers who used more high-level inquiry questions surpassed the performance of the other students on both higher inquiry examination questions and lower inquiry examination questions.

Gall et al. (1978), Hinton (1994), Penick et al. (1996), Sanders (1972) and others divide questions into a high-cognitive versus low-cognitive level according to question type. Hinton (1994) uses Bloom's (1956) taxonomy to construct a "pyramid approach to reading, writing, and asking questions". Hinton designates the knowledge, comprehension and application questions as lower level questions because they indicate basic knowledge about the topic, and analysis, synthesis, and evaluation questions as higher level because they require a higher level of knowledge about the topic. However, Gall et al. (1978), Penick (1996), and Sanders (1972) consider application questions to be higher order questions because they require answers that are not directly available from the curriculum and thus the answerer must be creative and make new connections.

Gall et al. (1978), Wilen and Clegg (1986) and Yet et al. (1998) consider high cognitive level questions to be those that require divergent thinking because answering them involves more critical and creative thinking and indicates a better

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understanding of the concept than do convergent questions. They contend that higher cognitive questions include those that require students to state predictions, solutions, explanations, evidence, generalizations, interpretations, or opinions. Divergent questions have longer responses and multiple appropriate responses. They require answers that are not directly available from the curriculum and thus the answerer must think and make new connections. Questions that do not meet these criteria are recall or memory questions.

Evaluation questions are divergent questions requiring judgements. Because it is possible for an evaluation question to elicit nothing more than an uninformed student opinion, the teacher must emphasize the criteria by which a student renders a judgement. The criteria should concern the worthiness or the inappropriateness of an object or an idea. The evaluative question differs from other divergent questions in that it relies on the establishment of judgmental criteria (Orlich, 1980).

Wilen and Clegg (1986) and Yet et al. (1998) maintain that higher- level, open-ended, and divergent questions are more desirable than lower level questions because answering them involves more critical and creative thinking and indicates a better understanding of the concept. Divergent questions require students to think critically about information and perform original and evaluative thinking. Smith et al. (1993) also maintain that teachers need to ask higher order questions for deeper learning to occur.

Although the data are not overly convincing, there appears to be a direct relationship between the level of questions asked by the teacher and the level of

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thinking in the student responses (Orlich, 1980). Redfield and Rousseau's (1981) meta-analysis of twenty studies on the relationship between the level of teacher questioning and student achievement demonstrated that "gains in achievement can be expected when higher cognitive questions assume a predominant role during classroom instruction". They maintain that the data available from questioning research provide evidence that asking higher-level questions is related to effective teaching. Samson, Strykowski, Weinstein, and Walberg (1987) critically reviewed both Redfield and Rousseau (1981) and Winne's (1979) meta-analyses of questioning research. They determined that "higher cognitive questioning has a small effect on learning measures".

Other authors do not agree with Orlich (1980, Redfield and Rousseau (1981), and Samson et al. (1987). Dillon (1982), Tisher (1971), and Winne (1979) report that the process of teachers asking higher order questions in a classroom may not automatically result in students using the higher order thinking skills. Winne's (1979) meta-analysis of questioning research failed to demonstrate a relationship between teachers' use of higher cognitive questions and student achievement. Carlsen (1991), Dillon (1982), and Winne (1979) maintain that research on the relationship between the cognitive level of teachers' questions and the cognitive level of student responses provides little evidence of "cognitive correspondence". Dillon states, "Only in education are questions asked in the belief that they will stimulate thought."

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Otto (1991) maintains that too many higher-level questions can be frustrating for students and detrimental to the learning process; "Lower-level questions can lay the foundations for meaningful discussion and are helpful in reviewing." Anderson and Ladd (1991) state that low-level inquiry questions that are used to determine if students have essential facts are as important as high-level inquiry questions that will allow teachers to discover if the students can use the knowledge in a meaningful way. Thus, they maintain that good inquiry questioning technique involves using both types of questions concurrently. Hinton (1994) and Orlich (1980) agree that students must master each of the lower levels before they can move on to the higher levels and that both teachers and students need to be taught how to ask questions at each of the levels of learning. Tisher (1971) suggests that asking an equal number of higher- and lower-level questions maximizes student response and achievement. King (1994) adds to the argument of using both lower and higher order questions in a classroom by stating "the use of different types of questions might promote the building of qualitatively different knowledge structures". While the consensus seems to be that asking both high and low cognitive level questions is a important factor for effective teaching and learning, Otto (1991) reports that 60-80 percent of teacher questioning requires a response at the lowest cognitive level of thinking.

Wait-time

Studies by Hyman (1980), Rowe (1974), and Tobin (1986) provide evidence that teacher behavior following question asking may be an important intervening

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variable in the relationship between higher-level questioning and higher-level thinking. Both Rowe and Tobin studied the relationship between the time teachers allow students to reply to a question (wait-time I) and the time following a student answer before the teacher begins speaking again (wait-time II) and the ensuing student and teacher behaviors. Both discovered that more inquiry behavior was observed in classrooms where teachers had longer (three to five seconds) wait-times I and II. Specifically, students demonstrated longer responses, more higher-order thinking, higher confidence, greater amounts of student-student interactions, more question asking, fewer failures to respond, as well as "speculation, sustained conversational sequences, alternative explanations, and arguments over interpretation of data" (Rowe, 1974). Tobin's study also demonstrated increased achievement in classrooms with extended wait time. Dillon (1982) determined, through his review of questioning in classrooms, that between-speaker silence is positively related to the frequency of responses, the length of responses, and the cognitive level of responses. Thus, he concludes that these studies make the case that teacher silence has a positive effect on participation.

It is hypothesized that a period of silence by teachers following a question – wait-time I – provides the students with an opportunity to consider what has been said and to assimilate new knowledge with previously learned information. The pause following a student's response – wait-time II – provides the responder or other students with the time "to consider what has been said and to formulate a reaction, question, or alternative response" (Tobin, 1986). That is, extended wait-times provide

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the student with an opportunity to think and process additional information (Rowe, 1974; Dillon, 1982; Tobin, 1986).

Tobin (1986) and Rowe's (1974) studies of extended wait-time II demonstrated that wait time may also benefit the teacher. The pause might provide an opportunity for the teacher to reflect on what has been said and to consider what to say or do next. For example, "The teacher might decide to react to what the student has said, paraphrase the student answer, provide an explanation, ask a question, move on to a new topic, allow the student to continue to speak, or call on another student to respond or react" (Tobin). The teacher's choice of action is likely to have an important effect on student learning.

Tobin (1986) determined that teachers in classrooms with extended wait-times asked an increased proportion of questions requiring student application and a decreased proportion requiring comprehension. Tobin also discovered a tendency for teachers in extended wait-time classes to probe for additional information from students. Rowe's (1974) data demonstrated that in classes with extended wait-times, teachers exhibited greater response flexibility rather than following a structured sequence of discourse. She also determined that with extended wait-times the total number of teacher questions decreased. This finding is explained by the fact that as students' responses become longer and unsolicited, student responses increase and there are more pauses between speakers as well as within the speech of speakers, thus the rate of questioning decreases. Rowe concludes, "pausing and complex cognitive processes may be related in the context of inquiry".

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Carlsen (1991), however, questions the wait-time theory from a sociolinguistic point of view; "Even if the thinking time explanation is accepted, what evidence is there to suggest that wait-time is an adequate measure of thinking time?" Because teachers frequently take a while to ask a question, with preludes, rewording, and redirecting, Carlsen maintains that the students may have had a great deal of time to formulate a response prior to the final termination of the teacher's question, especially with low-level questions. And, if a teacher typically asks questions in a topically related series, students may anticipate the teacher's next question before it is even asked. Carlsen continues to argue that the think-time explanation is built upon the "unlikely premise" that questions are topically discrete and processed by students only during a period of silence.

While Carlsen (1991) makes a good point, most of the evidence supports the relationship between wait-time and higher-level thinking. However, Taba (1966) maintains that teachers find it difficult to accept the slowness of the process of developing ideas inductively and "waiting out the students". As long as teachers' expectations are focused on the final product instead of the process, the pacing required for students to develop the appropriate cognitive skills inductively seems intolerably slow, and perhaps unproductive. Dillon agrees; " Educators regard silence as a sort of passive adjunct to the primary techniques of questioning". Thus, the teacher must consciously manage the duration of pauses after solicitation of ideas or answers as well as provide regular intervals of silence during explanations (Tobin, 1986).

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Analysis Techniques

Many researchers have analyzed classroom discourse by classifying teacher and student statements into various categories and reporting frequencies and percentages of the various categories. For example, Tisher (1971) analyzed verbal interaction in science classrooms by calculating percentages of various discourse behaviors and comparing these between American, New Zealand, and Australian teachers. Durham (1997) presented her analysis of classroom discourse in a table displaying the "frequency and percentage of teacher response strategies to cognitive student questions" and a figure listing the teacher response strategies compared to the student reaction to that response. Yet, et al. (1998) compared proportions of various types of questions posed by biology teachers in various stages of their teaching.

A few researchers have used inferential statistics to determine the level of significance in their studies of questioning in the classroom. Gallagher and Aschner (1963) used the Mann-Whitney U test to determine whether there was a significant difference between the level of expressed thought between boys and girls and presented a graph to show the relationship between teacher questions and student divergent thinking as expressed in verbal responses. Graesser and Person (1994) compared percentages of types of tutor and student questions and analyzed the data for significance, using analysis of variance (ANOVA). Tinsley and Davis (1971) also used ANOVA to compare six categories of teacher questions, ranging from low-level to high-level cognitive categories.

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To measure wait-times, Tobin (1986) and Rowe (1974) used servo-chart recorders. Rowe then analyzed the wait-time data by plotting wait-time versus various factors, including mean number of solicitations, mean number of evidence-inference statements, and mean length of response. Both Tobin and Rowe classified teacher and student discourse into four categories – structuring, soliciting, responding, and reacting. In his analysis of the relationship between wait-time and discourse, Tobin collected discourse data from a five-minute interaction at the beginning of class time and a five-minute interaction toward the end of class time. He combined wait-times I and II, defining this as "the length of pause following any teacher utterance" and measured wait-times from random samples taken from each audiotape. He then analyzed the data using ANOVA by comparing the mean number of discourse strategies between two groups of teachers, one with wait-times averaging 3.3 seconds and the other with wait-times averaging 0.9 seconds.

Summary

Inquiry teaching and learning of science depends upon teachers asking questions in order to discover students' ideas, guide students' learning, and model the scientific approach to problem solving. Teachers can use questions to elicit student explanations, predictions, and opinions. Through this process, teachers can stimulate the construction of knowledge in their students.

A teacher's questioning strategy includes the nature of the questions posed. Convergent cognitive questions are low-level questions used by teachers to monitor

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students' recall of material covered in the classroom. Higher-level divergent questions are those requiring students to predict, explain, analyze, apply or use their knowledge in meaningful ways in order to answer the question appropriately. Many authors believe that higher-level questions must be asked by teachers in order for deep understanding to be attained by their students (Orlich, 1980; Smith et al, 1993, Wilen and Clegg, 1986; Yet et al 1998).

Carlson (1991), Dillon (1982), and Winne (1979) maintain that teacher's use of higher cognitive questions is not necessarily related to higher achievement in students. Dillon proposes that it is through the construction and asking of higher-level questions that deeper thinking is stimulated. Accordingly, students must also be asking questions in classrooms (Commeyras, 1995; Brooks and Brooks, 1993; Anderson and Ladd, 1971; Bruner 1960; Cherif 1993; Hinton, 1994; and Roth, 1992). Question asking by students is thought to be essential for concept formation, problem-solving, comprehension, and critical thinking (Costa et al, 2000; Hyman, 1980; Marback-Ad and Sokolove, 2000). Thus, questioning by students is a key component of their learning of science (Commeyras, 1995).

Research indicates that students are not asking question in the classroom (Dillon, 1982; Durham, 1997; Gall, 1970; Graesser and Person, 1994; Hyman, 1980). Explanations for the dearth of student questions include teacher's use of power in the classroom (Durham 1997; Hyman, 1980; Roth, 1996; Sirotnik, 1983; Roth, 1996) , a lack of encouragement for students to ask questions (Costa et al, 2000; Graesser and Person, 1995), as well as teachers' response strategies that discourage question-asking

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by students (Hyman,1980; Durham 1997). Teachers are thus recommended to model effective question-asking, encourage their students to ask questions, and work with students in activities that promote questioning.

One questioning strategy that is hypothesized to promote deeper thinking in students is the use of wait-time by teachers following question-asking (Hyman, 1980; Rowe, 1974; Tobin, 1986). Tobin and Rowe suggest that extended wait-times are related to more inquiry behavior, higher-order thinking, and questioning by students. Teachers are also positively affected by employing wait-times in their classrooms. Teachers who grant extended wait-times have time to reflect on the question or answer and decide how to react; they also tend to ask higher-level questions and probe for additional information from their students. Thus, allowing students time to think about a question or answer appears to be related to inquiry teaching and learning.

In summary, the act of questioning is an important component of the process of inquiry teaching and learning in science. Inquiry teaching rests upon the assumption that through their questioning and response strategies, teachers can stimulate students' thinking and thus their learning. The inquiry classroom must focus upon students understanding and using the scientific process skills of questioning, predicting, hypothesizing, observing, analyzing, making inferences. In this way, students will construct knowledge via the same methods that scientists use to construct new knowledge, concepts, and theories (Roth, 1992) Therefore, inquiry

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teaching and learning include not only teachers' questions and response strategies, but also strategies to help students pose questions, solve problems, and persuade others.

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CHAPTER III

METHODS

Effective inquiry teaching results in students posing questions, solving problems, and persuading others about the validity of scientific claims. Teachers' questioning and response strategies are often required to elicit such behavior in students. The purpose of this study is to determine whether teachers' questioning and response behaviors are related to students' critical thinking strategies, use of alternative explanations, and attempts to persuade others about their claims.

Participants

A group of science classrooms where teaching pedagogies range from traditional to inquiry-based were needed. Identifying a spread of pedagogical strategies was necessary in order to collect that set of discourse data, particularly the questioning and response strategies, required for determining whether there is an observable difference between the questioning and response strategies of teachers along the spectrum of teaching styles ranging from traditional expository methods to inquiry-based strategies.

In order to facilitate the informed consent process and select suitable classrooms for the study, the study was divided into two parts. In Part I, the researcher observed a wide range of volunteer classrooms to determine the

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pedagogical strategies employed by the teacher in each classroom. Part II of the study consisted of videotaping those classrooms selected for the study based upon selection criteria and the observations from Part I. Telephone scripts for the initial contact with principals and teachers, letters of invitation to the study, and consent forms were approved by Western Michigan University's Human Subjects' Institutional Review Board (Appendix A).

The classrooms observed in Part I of the study were selected based on the recommendations of educators, including principals, curriculum specialists, and educational researchers. In order to limit the variables in the study, the study was restricted to middle school classrooms. This decision was based on the assumption that middle school classrooms would provide the range of teacher-student interaction necessary for the study. The researcher contacted eight middle-school principals by telephone, discussed the study with them, and asked for their permission to invite teachers from their school to participate in the study. Seven principals agreed. The researcher then visited each principal and obtained informed consent for Part I and Part II of the study.

The researcher mailed letters inviting twenty-one teachers from the seven schools to participate in the study. The letters were followed by a telephone call to the teachers and any questions regarding the study and their participation were answered. Fifteen of the twenty-one teachers agreed to participate in part I of the study. A schedule was developed and fourteen of the fifteen teachers were scheduled for observation on two separate days with the same class and children. The

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researcher was not able to make further phone contact with the fifteenth teacher since she did not return call back messages.

After obtaining informed consent, the researcher observed the twenty-eight lessons (two for each teacher in the study) in order to identify the type of instructional methods employed by the teacher. The "K-12 Science Teaching Practices Observation Form", developed by Jenness and Barley (1999) (Appendix B), was used to assess each lesson.

The fourteen teachers were then ranked according to level of inquiry observed in the classrooms. Scores of the fifteen items on the form that are indicators of inquiry were added together and the average score from the two observed lessons gave the final score of that particular teacher and class. This process yielded very little difference between classrooms. After consultation with Dr. Jenness (personal communication March 2001), some of the inquiry indicators were judged to be more important to inquiry teaching and were subsequently weighted more heavily than others (Table 1). This weighting of specific observed characteristics yielded a larger numerical spread between the classes (Table 2). The two teachers who ranked the lowest, the two teachers who ranked in the middle, and the two teachers who ranked the highest on this inquiry ranking were selected for Part II of the study. An alternate at each level was also identified at this time.

After Part I – the selection process – was concluded, the researcher mailed letters inviting the six selected teachers to participate in Part II of the study. They all agreed and appointments for taping four lessons for each teacher were scheduled.

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Before the videotaping was completed, one teacher called to rescind her agreement. A recent rain had recently flooded her classroom and she had lost many teaching materials; thus she did not feel like she would be comfortable being taped at this time. Her alternate was invited, and he agreed to participate in Part II. Since students in the classrooms could be videotaped only if both their parent or guardian and themselves gave consent by signature, informed consent forms for parents or guardians were given to each of the six teachers to send directly home for signatures and each student also received a shortened version of the consent form to sign.

Table 1

Items Scored to Rank Lessons for Inquiry Characteristics from
The K-12 Science Teaching Practices Observation Form

Category on Instrument	Item Number	Item Weight
Implementation	2, 5	2X
	3	1X
Content	1, 3, 5, 7, 8	1X
	2	2X
Classroom Culture	1, 3, 5, 6	1X
	2, 4	2X

Data Collection

Data collection was another important consideration. In the past, researchers used audiotapes to record classroom discourse (Barth & Shermis, 1980; Hyman,

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1980; Rowe, 1974; Tobin, 1986). In recent years, with advances in technology, Durham (1997), Yet et al (1998), and others have videotaped classrooms in order to study questioning. This researcher used two video cameras in order to capture the context surrounding the questions and conversation in the classroom. One camera was dedicated to following the teacher. Each teacher wore a remote lapel microphone so that discourse could be distinguished and transcribed more easily. The second video camera was focused on the students. Two students in one classroom did not have parental consent to be videotaped. The videographer was informed and did not videotape these students. A zoom microphone was used to capture student talk during classroom discourse and a cordless microphone was placed on tabletops during group work in order to eliminate as much extraneous noise as possible from surrounding groups.

Four lessons were videotaped and observed for each of the six teachers identified, resulting in twenty-four tapes of lessons. The videotapes were labeled in a manner that would ensure the confidentiality of the participants. Each videotaped lesson was coded by a set of hyphenated numbers. The first number was the number assigned to the teacher and the second number, following the hyphen, was the number of the lesson taped for that particular teacher. For example, lesson 2-2 is the second lesson taped of Teacher 2. The audio portion of each of the twenty-four sets of tapes was then transcribed into a written record of the classroom discourse, Thus, questioning and response strategies could be identified and analyzed.

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Table 2

Average Inquiry Scores of Fourteen Classrooms Observed - Part I

Classroom code number	Average Inquiry Score out of 7
6	6.13
13	6.02
2	5.97
8	5.95
5	5.82
3	5.6
14	5.55
1	5.37
11	5.34
4	5.29
9	5.26
10	5.18
7	4.53
12	4.47

Because the unit of analysis was intended to be a lesson rather than the teacher, the researcher developed an instrument to analyze each of the twenty-four lessons for indicators of inquiry other than questioning strategy (Appendix C). This instrument contained six items and was composed of four indicators of inquiry from "Observing Teaching Practices in K-12 Classrooms" (Jenness and Barley, 1999) and two additional indicators cited in the literature (Kelly et al., 2000; National Sciences Resource Center, 1997; Roth, 1992) describing inquiry classrooms. Each of the twenty-four transcripts was assessed on each of the six indicators on a scale from 1 through 5.

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Since each transcript was large and the research question had multiple components, the researcher (with the dissertation committee's approval) decided to analyze eighteen of the twenty-four transcripts. The researcher reviewed each transcript and selected three lessons for each teacher that demonstrated the most discourse, as judged by the researcher, so that transcripts would be not characterized by long periods of in-class, non-verbal work, which would not yield data that could be analyzed for questioning strategies. For example, in one lesson by Teacher 4 on the topic of genetics, most of the class time was consumed by students answering questions on handouts. There was very little teacher-student interaction or student-student interaction. Therefore this lesson and five others like it were eliminated from the study. The remaining three transcripts for each of the six teachers were analyzed further for level of inquiry. Thus both the transcripts and the videotapes of eighteen lessons were independently analyzed using the Inquiry Instrument (Appendix C).

The lessons were then scored; each of the six indicators on the instrument was assessed on a numerical scale from 1 through 5. Thus scores for individual lessons could range from a high of 30 to a low of 6. The lessons were ranked numerically from highest score to lowest score, with the highest score being the lesson with the highest inquiry ranking and the lowest score being the lesson with the lowest inquiry ranking. These rankings and scores were then used to divide the lessons into three groups based on inquiry characteristics observed in the lesson – that is a high, middle, or low classification.

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The videotape inquiry ranking and the transcript inquiry ranking for several classrooms were not consistent with each other, e.g. the video ranking placed the lesson in the higher category and the transcript ranking placed the lesson in the middle group. Therefore, the Inquiry Instrument was used to reevaluate those particular classroom videos and transcripts again, to see if more agreement would be forthcoming. An attempt was made to minimize any bias in that the researcher did not memorize the original scores for each lesson and did not refer to the scores before this additional assessment. The new inquiry scores showed greater numerical agreement with each other, and while the scores were not the same, the groupings were the same for both the video and the transcript rankings. This resulted in six lessons in the "higher" inquiry group, eight lessons in the "middle" inquiry group and four lessons in the "lower" inquiry group (Table 3). Because this study is based on a continuum of classrooms, ranked by inquiry characteristics, a large division between the three levels was not anticipated. For example, a one-point gap between lesson 3-4 and lesson 4-1 and a 31/2-point gap between lesson 1-1 and lesson 4-3 were selected as the break points between higher and middle and middle and lower groups, respectively (Table 3). Despite the small numerical differences, the three levels were maintained to facilitate the nonstatistical comparison of questioning strategy with inquiry level.

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Table 3

Inquiry Scores and Groupings

Lesson number	Inquiry Score	Inquiry Group
1-2	27.5	Higher
6-1	26	Higher
2-4	25.75	Higher
3-2	25.5	Higher
4-2	24.75	Higher
3-4	24.25	Higher
4-1	23.25	Middle
1-3	23	Middle
2-2	23	Middle
3-1	22.75	Middle
6-4	22.75	Middle
6-2	22	Middle
2-3	21.5	Middle
1-1	21	Middle
4-3	17.5	Lower
5-4	16	Lower
5-2	15	Lower
5-3	13.5	Lower

Analysis

The nature of this study precludes rigid statistical analysis. The raw data is qualitative in nature and conclusions are based on comparisons of descriptive statistics. The study is qualitative and descriptive and designed to identify questioning and response strategies that are interesting and may thus be the focus of future studies.

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In this study, the data were analyzed to allow the researcher to address the question of whether or not the questioning strategies of teachers are related to inquiry-based teaching and learning strategies. Thus, each transcript and videotape was analyzed to determine the teacher's questioning and response strategies, and these strategies were then compared to the teaching style, along the pre-identified continuum from traditional to inquiry.

The audio portions of the tapes were transcribed into text that could be studied and analyzed. Students' and teacher's questions were first classified by the researcher. HyperResearch® is a software package by ResearchWare (2000) that was used to help count, organize, retrieve, and print data. The program functions much like a spreadsheet, although with greater capabilities. It enables the user to work with multiple data types, including text, audio, and video sources, and provides the ability to integrate all the data and organize the data by case or code name.

Each question was classified as either a teacher question or a student question. The student questions were then classified as those relating to the lesson content or those not related to the lesson content - classified as "other". The student questions were also classified as being directed toward the teacher or directed toward another student or students. The coding system used by Good et al. (1987) presents a set of definitions of student questions, several of which were used in this analysis. Table 4 lists and defines the major types of student questions identified in the transcripts. The compete schema for classifying student questions is displayed in Appendix D.

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Table 4

Classification of Students' Questions

Question type	Definition
Explanation	Requests meaning or reasons that will help the student understand a concept, idea, or procedure
Information	Seeks specific, factual information
Procedural	Concerns classroom/lesson procedures
Clarification	Requests clarification of information, procedures, or comments provided by the teacher or other student(s)
Confirmation	Seeks confirmation of a teacher comment, student comment, or procedure
Rhetorical	Questions for which no answer is appropriate or expected
Other	Off task or unable to be classified into the above categories

The teacher questions were classified as being related to management of the lesson content or management of the classroom. Procedural, clarification, confirmation, and rhetorical questions were classified according to the definitions in Table 4. Each cognitive question was also counted and classified by type and level.

A classification system, similar to that used by Orlich (1980), Wilen and Clegg (1986,) and Yet et al. (1998), all adapted from Guilford's (1956) work on the structure of the human intellect, was used to classify the cognitive questions. This scheme takes into consideration both the type of question and the cognitive level of thinking required for an appropriate response. Certain types of questions –

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convergent – are classified as low-cognitive level because they require little thought or inquiry by the respondent. Other types of questions – divergent and evaluative – are considered to be at a higher cognitive level because answering them involves more critical and creative thinking and indicates a better understanding of the concept (Wilen & Clegg, 1986; Yet et al., 1998). While Hinton (1994) designates application questions as lower level, Gall et al (1978), Penick (1996), and Sanders (1972) maintain that application questions are higher-level because they require answers that are not directly available from the curriculum, and thus the respondent must be creative and make new connections. In this study, higher-level cognitive questions include application questions that require students to state predictions or solutions and questions where the answers are not directly available from authorities such as the textbook or teacher. Table 5 summarizes and briefly defines the classification of the cognitive questions in this study. A complete teacher question classification scheme is in Appendix D.

In order to determine classroom-questioning strategy, each of the eighteen transcripts was coded for the questioning and answering strategies associated with teachers' cognitive questions and the students' content-based information and explanation questions. The transcripts were coded for the following characteristics: (a) convergent versus divergent questions, (b) students' answers, (c) the verbal response strategies of teachers following wait-time I, if no student response was forthcoming, (d) the verbal response strategies of teachers following a student response, (e) the verbal response strategies of the student who answered the question

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following his or her answer or following a teacher response to the student response, (f) the verbal response strategies of a different student, after a student has answered the question, (g) student information and explanation questions, and (h) how teachers field student questions. The compete coding schema is presented in Appendix E.

In addition, the eighteen teacher-focused videotapes were observed for the following: (a) the length of wait-time I – the time teachers allow students to start an answer to a question – was measured using the time track on the videotapes, (b) the length of wait-time II – that period following the student response before the teacher speaks again – was measured using the time track on the videotape, and (c) any significant non-verbal behavior of teachers, such as eye-contact and facial expressions was sought by observing the videotapes. If the videotape did not clearly present the information, the researcher viewed the student-focused video of that lesson, to obtain a more complete interpretation of the behavior in question. The occurrence and timing of wait-time I and wait-time II were recorded on both the complete transcripts and the coded transcripts.

Eighteen transcripts were coded for questioning strategies associated with teachers' cognitive questions and students' questions; however, only twelve of these were thoroughly analyzed for questioning strategy because of the complexity and number of components in this portion of the analysis. Four higher, four middle, and the four lower-level lesson transcripts were selected to be analyzed further. The four lower, the two highest, and the two lessons in the middle of the middle group were

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first selected. Then two additional lessons in the middle and higher groups were selected at random to complete the twelve lessons that would be analyzed further.

Because there were many response strategies employed by teachers and in a variety of situations, six strategies and several sub-strategies were selected to be analyzed further. Specific codes on the twelve transcripts were highlighted and analyzed for patterns of behavior surrounding the highlighted areas. For example, when analyzing "teachers giving the answer to an unanswered question following a measurable wait-time I", the researcher highlighted all wait-times and the code for the teacher answering the question and then examined the transcripts for how many times per lesson this strategy occurred, the length of the wait-time, and whether this behavior followed a convergent question or a divergent question. Times and patterns were then noted.

The twelve coded lesson transcripts were then analyzed in this manner for the following: (1) verbal response strategies of teachers following wait-time I if no student response was forthcoming, including (a) wait-time I of two or more seconds after which the teacher continues with a structured questioning strategy designed to lead to the desired response, (b) wait-time I of two seconds or more after which the teacher continues questioning, and (c) wait-time I of two seconds or more after which the teacher ultimately gives the answer; (2) the number and level of questions students answer following wait-time I of two or more seconds; (3) the strategies of teachers leaving no measurable wait-time I, including (a) the teacher continuing questioning in order to lead to the desired response after no measurable wait-time I

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and (b) the teacher giving the answer after no measurable wait-time I; (4) the verbal response strategies of teachers following student response, including (a) the teachers' verbal response strategies following an incorrect student answer, (b) teachers asking students to explain their answer, and (c) teachers giving the answer to the question; (5) the length of questioning strands and steps; and (6) the manner in which teachers field student questions.

The coded transcripts were analyzed for the number of strands, steps, and questions employed by a teacher while trying to explore a particular concept. A step is defined as any distinct verbal action in the questioning of a particular concept and includes a question, an answer, a teacher accepting or approving a student answer, a discussion, or a student question. A strand is a set of steps in the questioning strategy addressing a particular concept. For example, a teacher might ask a number of questions per strand, including repeating the question, rewording the question, or asking a different question in order to lead to the desired response or asking a different question to get more explicit information. These particular questioning strategies are known as probing. Since a concept might be questioned from several different approaches in order to cover different aspects of the concept, there may be more than one strand associated with a particular concept.

Finally, in order to compare questioning strategies along the continuum from inquiry to traditional teaching style, the researcher counted all the highlighted behaviors in each of the twelve analyzed transcripts. These counts were then attributed to the specific teacher and lesson, so that a comparison could be made

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between the level of inquiry and the questioning strategies associated with that level of inquiry.

Table 5

Classification of Teachers' Cognitive Questions

Question Level and Type	Definition
Lower level convergent questions	The information leads to one right answer or to a recognized best answer (Wilen & Hogg, 1976)
Memory (knowledge)	Students are asked to recall information, ideas, and principles in the approximate forms in which they were learned
Comprehension (understanding)	Students are asked to use the information in their memory and restate it in their own words; answers depend on how well the student has learned the information at the knowledge level; slightly higher level than memory questions, but do not require creative thinking
Higher level divergent questions	Thinking in different directions, sometimes searching or seeking variety; answers not found in the curriculum (Wilen & Hogg, 1976)
Application (solving)	Students are asked to select, translate, and use data and principles to complete a problem with a minimum of directions; solve new problems
Analysis	Students are asked to compare and contrast, distinguish, classify, relate ideas; break the knowledge down into parts so it can be understood
Synthesis (creating)	Students are asked to put information about the topic back together in new and creative ways

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Table 5 – Continued

Question Level and Type	Definition
Evaluation Questions	Reaching decisions as to goodness, correctness, or adequacy of what we know and what we produce in productive thinking (Wilen & Hogg, 1976)
Evaluation (judging)	Students are asked to appraise, assess, or criticize on the basis of specific standards and criteria

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CHAPTER IV

FINDINGS

The audio portions of the tapes were transcribed into text. The classroom questions and questioning strategies were then classified, coded, and analyzed using both the transcripts and the videotapes in order to answer the overarching research question, "Can questioning strategy be used as an indicator of inquiry-based science teaching and learning?" The following ten components and subcomponents of questioning were analyzed: (1) the number, type, and level of questions asked by teachers and students; (2) the length of wait-time I – the time teachers' allow students to start to answer a question; (3) the presence of any significant non-verbal behaviors of teachers during wait-time I; (4) the verbal response strategies of teachers following wait-time I, if no student response is forthcoming; (5) the number and type of questions students answer following wait-time I of two or more seconds; (6) the strategies of teachers following no measurable wait-time I; (7) the length of wait-time II – that period following the student response before the teacher or someone else speaks again; (8) the verbal response strategies of teachers following the student response; (9) the length of steps and strands employed by the teacher; and (10) the manner in which teachers field student questions. The individual data from each lesson for each of the ten components of the analysis are displayed in Appendix F, Tables 1-12.

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The characteristics of the lessons for each of these components of questioning strategy were then compared between three groups of teachers' lessons – lessons of teachers that scored highest on the inquiry scale, lessons that scored in the middle on the inquiry scale, and lessons that scored lowest on the inquiry scale. The results are presented in the tables that follow. Descriptive statistical techniques were used to compare questioning strategies and the inquiry level of the lesson.

Component 1: The Number, Type, and Level of Questions

The transcripts were analyzed and the number, type, and level of questions were counted and compared between the three groups of lessons as measured by the Inquiry Instrument. Both teachers' questions and students' questions were counted and classified. The definitions for question types are described in the methods section of this paper (Tables 4 and 5). In the following tables, the data from the individual lessons (Tables 1 and 2, Appendix F) are averaged by level of inquiry employed in the lesson – the group of lessons scoring higher on the Inquiry Instrument, the group of lessons scoring in the middle on the Inquiry Instrument, and the group of lessons scoring lower on the inquiry scale.

Analysis of Student Questions

Eighteen transcripts were analyzed for the type, number, and level of student questions. These data (Table 1, Appendix F) were then averaged per level of inquiry of the lesson. Table 6 displays the results of this analysis, i.e., the average number of

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questions and the average number of content-related questions asked of teachers by students per level of inquiry of the lesson.

Table 6

Number of Student Questions Averaged per Inquiry Level of the Lesson

Lesson	No. Student questions	No. Content-related student questions
Higher	22.3	3.3
Middle	32.4	4.3
Lower	33.5	5.3

Students in higher-scoring lessons asked fewer questions of all types than did students in lessons that scored in the middle; students from lessons scoring in the middle asked approximately the same number of questions as students in lessons scoring lower on the Inquiry Instrument. Students in lessons scoring higher on the Inquiry Instrument asked fewer content-related questions than students in the middle-scoring lessons, and these students asked fewer content-related questions than students in the lower inquiry lessons.

Analysis of Teachers' Questions

Eighteen transcripts were analyzed for the number, type, and level of teachers' questions addressed to students. These data (Table 2, Appendix F) were then

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averaged per level of inquiry and are presented in Table 7. Since the ratio of convergent questions to divergent questions (CQ:DQ) demonstrated no differences between groups, the number of convergent and divergent questions were added (CQ+DQ) and the percentage this sum is of total content-related questions was calculated (%LQ).

Table 7

Teacher Questions Averaged per Inquiry Level of the Lesson

Lesson	TQ[a]	LQ(%TQ)[b]	CQ(%LQ)[c]	DQ(%LQ)[d]	CQ+DQ(%LQ)[e]
Higher	180.5	155 (86)	55.3 (35.7)	27.0 (17.4)	82.3(53)
Middle	175.3	132 (75.0)	36.6 (27.8)	17.9 (13.5)	54.5(41)
Lower	161.8	121.5 (75.1)	41.0 (33.7)	17.0 (14.0)	58(48)

Note. [a]TQ = the average number of total teacher questions. [b]LQ(%TQ) = the average number of content-related teacher questions expressed as a count and as a percentage of the total teacher questions per lesson. [c]CQ(%LQ) = the average number of convergent questions expressed as a count and as a percentage of the total content-related teacher questions. [d]DQ(%LQ) = the average number of divergent questions expressed as a count and as a percentage of the total content-related teacher questions. [e]CQ+DQ(%LQ) = the total number of convergent and divergent questions and that sum expressed as a percentage of total content-related questions

The data indicate that teachers of higher-level lessons ask more questions per lesson than do the teachers in the middle, and teachers of middle-level inquiry lessons ask more questions per lesson than teachers of lower-level inquiry lessons. The number of teacher questions that are related to the lesson content is greater for the higher-level lessons than for the middle lessons and greater for the middle-level

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lessons than for the lower lessons. The percentage of total teacher questions that are related to the lesson content is higher for the higher-level inquiry lessons than for both the middle and lower-level inquiry lessons. While the teachers of higher-level inquiry lessons ask more convergent questions than the teachers in both the middle and lower-level inquiry lessons, when expressed as a percentage of total content-related questions, there is no apparent difference between the three levels. The teachers of the higher-level inquiry classes ask more divergent questions than do the teachers of the middle-level and the teachers of the lower-level inquiry lessons, both as a number and as a percentage of content-related questions. The ratio of convergent to divergent questions is similar for all groups (2.0, 2.0, 2.4, respectively). Of all the content-related questions, teachers in higher level inquiry lessons ask a higher percentage of divergent and convergent questions – cognitive questions – (53%) than teachers in the middle (41%) and lower level (48%) inquiry lessons.

Component 2: Wait-time I

Length of Wait-time I

The length of wait-time I – the time teachers' allow students to begin to answer a question – was measured with the time track on the videotape. Twelve lessons were analyzed (Table 3, Appendix F). The average number of wait-time I's per lesson and the mean number of seconds per wait-time I were then calculated for each inquiry group. The resulting analysis is displayed in Table 8.

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Table 8

Wait-time I Averaged per Inquiry Level of the Lesson

Lesson	Ave No. of wait-time I	Ave time of of wait-time I	Ave No. of of wait-time I[a]	Ave time of of wait-time[b]
Higher	11.3	4.0 seconds	4.0	2.8 seconds
Middle	8.5	4.0 seconds	3.7	3.6 seconds
Lower	2.3	3.2 seconds	2.3	3.2 seconds

Note. [a] excluding Teacher 3. [b] excluding Teacher 3.

Lessons that scored higher and in the middle as measured by the Inquiry Instrument averaged more instances of wait-time I per lesson than did lessons that scored lower on the instrument (11.3, 8.5, and 2.3, respectively). The average length in seconds of wait-time I is approximately the same for all levels of inquiry.

One contextual factor raises a question about the conclusions drawn from this finding. Teacher 3 was teaching physical science lessons, and the majority of his questions were asking students to solve math problems associated with simple machines. After asking a question, he waited for the students to calculate the answer. Two of his lessons ranked in the higher inquiry group and third ranked in the middle inquiry group. In order to answer most of his questions, students needed additional time to calculate the answer. This extra time was included in wait-time I. Therefore, the data from his lessons about the number and length of wait-times may be

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considered as outliers, and thus this data may have skewed the averages of the higher and middle groups.

Thus, the data were reanalyzed, excluding Teacher 3's lessons. With Teacher 3's lessons excluded, the analysis demonstrates a slight trend, with higher-level inquiry lessons having an average number of 4.0 wait-time I's per lesson, middle-level classrooms with an average of 3.7, and lower-level inquiry lessons with an average of 2.3 wait-time I's per lesson. The average time per wait-time remains similar for the three groups – 2.8, 3.6, and 3.2 seconds, respectively.

Non-verbal Behaviors of Teachers During Wait-time I

The presence of any significant non-verbal behaviors of teachers, such as eye-contact and facial expressions, during wait-time I, was ascertained by observing the videotapes. A careful observation of videotapes of eighteen lessons for non-verbal behaviors of the teachers during wait-time I demonstrated no patterns of recognizable non-verbal expressions that were construed as influencing verbal response.

The Number and Level of Questions Students Answer Following Wait-time I of Two or More Seconds

Because so few lessons demonstrated measurable wait times to any degree, the following characteristic associated with wait-time I was also analyzed: the number of times a student answered a question following a wait-time I of two seconds or more were counted and classified as whether this behavior followed a convergent

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question or a divergent question. These data (Table 4, Appendix F) were then averaged per level of inquiry; the resulting analysis is displayed in Table 9.

Table 9

Wait-time I Equal to or Greater than Two Seconds After Which a Student Answers the Question Averaged per Inquiry Level of the Lesson

Lesson	No.[a]	%[b]	CQ:DQ[c]	%[d]
Higher	5	44%	.67	12%
Middle	4.25	50%	7.5	9%
Lower	1	11%	0	11%

Note. [a]No. = the average number of times a student(s) answered a question following a wait-time I of two seconds or more. [b]% = the percentage of total measurable wait-times this number represents. [c]CQ:DQ = the ratio of convergent to divergent questions answered by students following a wait-time I of two or more seconds. [d]% = the percentage of total measurable wait-times a student(s) answered a question excluding Teacher 3.

Students in lessons with higher-level inquiry scores and middle-level inquiry scores answered the question a higher percentage of the time when wait-time I of two or more seconds was granted than the students in the lower-level inquiry lessons (5, 4.2, 1 time, respectively). As in a previous question about wait-time I, the questions of Teacher 3 required, by their very nature, additional time for students to calculate an answer, and his students appeared to be "trained" to calculate and then offer an answer. In the other teachers' lessons, students' hands were in the air if they knew the answer, most often without a measurable wait-time. Since Teacher 3 had two

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lessons in the higher group and one in the middle group of lessons, the data from his lessons may have skewed the curve and substantially increased the arithmetic means for the higher and middle-level inquiry groups. The data were thus reanalyzed excluding Teacher 3 (Table 9).

Excluding Teacher 3, the students in higher-level inquiry lessons answered the question following a measurable wait-time I the same number of times as students in the middle and lower-level inquiry lessons – 1 time per lesson. The percentages of total wait-time I this represents are similar for the three groups – 12%, 9%, and 11%, respectively. Because the behavior occurred only once when Teacher 3 was removed from the analysis, the CQ:DQ data are not applicable.

<u>Verbal Response Strategies of Teachers Following Wait-time I if No Student Response is Forthcoming</u>

Twelve of the coded transcripts were analyzed for two of the verbal response strategies of teachers following wait-time I, if no student response was forthcoming. The two strategies employed by the teachers were: (1) to reask or reword the question and (2) to give the answer to the question. The analysis of each strategy follows:

<u>Wait-time I of Two or More Seconds After Which the Teacher Continues Questioning in Order to Lead to the Desired Response</u>

The analysis of the transcripts indicates that teachers sometimes reask or reword the question or ask a different question in order to lead to the desired response following a wait-time I of two seconds or more when a student does not answer the

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question. The data of this occurrence (Table 5, Appendix F) were averaged per level of inquiry. The results of this analysis are displayed in Table 10.

Table 10

Wait-time I of Two Seconds or More After Which the Teacher Continues Questioning Averaged per Inquiry Level of the Lesson

Lesson	No./%[a]	CQ-CQ[b]	DQ-DQ[c]	CQ-DQ[d]	DQ-CQ[e]
Higher	6.45/100	2.5	3	.25	.5
Middle	4/91.7	1	2.3	0	.75
Lower	2/87.5	1	1	0	0

Note. [a]No. = the number of times the teacher continues questioning after Wait-time I following no student response; % = this number expressed as a percentage of total number of times the student does not respond to the question following a measurable wait-time I. [b]CQ-CQ = the number of times an unanswered convergent question is followed by a convergent question. [c]DQ-DQ = the number of times an unanswered divergent question is followed by a divergent question. [d]CQ-DQ = the number of times an unanswered convergent question is followed by a divergent question. [e]DQ-CQ = the number of times an unanswered divergent question is followed by a convergent question.

The number of times a teacher reasks or rephrases the question or asks a different question in order to lead to the desired response after a measurable wait-time I not followed by a student answer is greater for teachers in higher-scoring lessons than middle-scoring lessons, and the teachers in middle lessons demonstrated this behavior more often than teachers in the lower-scoring lessons. The percentage of the times this teacher behavior occurred out of the total number of measurable wait-times not followed by a student answer was greater for the higher-level inquiry lessons than

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for the middle lessons and higher for middle lessons than for lower-level inquiry lessons.

Wait-time I of Two Seconds or More After Which the Teacher Gives the Answer

The analysis of transcripts demonstrated that four out of twelve teachers gave the answer to the question after a wait-time I of two seconds or more, when a student did not answer. The analysis of this phenomenon (Table 6, Appendix F) indicates no apparent differences between teachers in the three inquiry levels in the numbers of times a teacher gives the answer to the question after no student reply.

The Strategies of Teachers Leaving No Measurable Wait-time I

The Teacher Reasks or Rewords a Question After No Measurable Wait-time I

Teachers sometimes reasked or reworded the question or asked a different question in order to lead to the desired response after a brief pause but no measurable wait-time I. These questions were not classified as rhetorical because the teacher paused briefly, however, the pause was less than two seconds. In contrast, rhetorical questions were classified as those followed by no measurable wait-time and no pause or when a student answer was required.

The analysis of this data (Table 7, Appendix F) suggests there is no apparent difference between the teachers in the three inquiry levels in the number of times the teacher repeated the question or asked a different question without a measurable wait-

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time I, having received no answer from the student(s). The teachers of lessons that ranked higher on the inquiry scale averaged 2 times per lesson, the middle lessons averaged 2.75 times per lesson and the lower lessons averaged 2 times per lesson.

The Teacher Gives the Answer After No Measurable Wait-time I

The lessons demonstrated no apparent differences in teachers giving the answer without a measurable wait-time. Specifically, this teacher behavior appeared to occur randomly and was observed on only three occasions during the twelve lessons.

Component 3: Wait-time II

The length of wait-time II – the time following the student response before the teacher speaks again, which can be interpreted as a non-verbal sanction of a student response – was measured by the time track on the videotape. There was only one incident of wait-time II in the eighteen transcripts analyzed and therefore this behavior was not observed enough times to be considered significant or relevant.

Component 4: The Verbal Response Strategies of Teachers Following Student Response

The verbal response strategies of teachers following a student response were analyzed by coding the transcripts and then analyzing twelve lessons. The following three verbal strategies employed by teachers following a student response were then compared to the level of inquiry of the lesson: (1) teachers' verbal response strategies

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following an incorrect student answer, (2) teachers asking a student to explain or say more about his/her answer to a question, and (3) teachers providing the answer to a question.

The Teachers' Verbal Response Strategies Following an Incorrect Student Answer

The teachers' verbal response strategies following an incorrect student answer were analyzed. These data (Table 8, Appendix F) were then averaged by inquiry-level ranking of the lesson. Table 11 summarizes this analysis.

Table 11

Teachers' Verbal Responses Following an Incorrect Student Answer
Averaged per Inquiry Level of the Lesson

Lesson	No.[a]	CQ[b]	DQ[c]	%dis/pro[d]	%DQdis/pro[e]	% t-ans[f]
Higher	7.3	5	2.3	65.8%	68.8%	16.3%
Middle	5.8	3	2.8	44.8%	75%	10.5%
Lower	7.8	4	3.8	48%	39.3%	43.8%

Note. [a]No. = the number of cognitive questions per lesson answered incorrectly. [b]CQ = the number of convergent questions answered incorrectly. [c]DQ = the number of divergent questions answered incorrectly. [d]% dis/pro = the percent of total incorrectly answered questions in a lesson following which the teacher discusses further or probes for the desired response. [e]%DQdis/pro = the percentage of divergent questions the teacher discusses further or probes for the desired response. [f]% t-ans = the percent of total incorrectly answered questions in a lesson following which the teacher ultimately gives the answer.

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The teachers in the lessons with the highest scores for inquiry discussed the unknown question or probed for the answer more frequently than did either the teachers of the middle-level or the lower level inquiry lessons. The teachers in both the middle and lower-level inquiry lessons discussed the question a similar percentage of times. In addition, the data indicate that teachers in higher and middle-level inquiry lessons provided the answer to questions that students initially answered incorrectly less frequently than did teachers in lessons ranking lower on the Inquiry Instrument.

Teachers Asking Students to Explain Their Answer

Teachers sometimes asked students to explain their answers to a question. These occurrences were counted and classified by the type of question the teacher asked as well as by the teacher's sanction of that explanation. The teachers' sanctions were classified as neutral, positive, or negative. In some lessons, the teacher provided an explanation if the student did not give an acceptable explanation. The data from this analysis (Table 9, Appendix F) were then averaged per inquiry-level of the lesson. This analysis is displayed in Table 12.

As displayed in Table 12, teachers whose lessons ranked higher on the Inquiry Instrument asked for explanations or extended responses more than the teachers whose lessons ranked in the middle and lower on the Inquiry Instrument. The other questioning strategies, such as the frequency of neutral or positive sanctions or the

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number of times the teacher provided an explanation, did not show a demonstrable difference when comparing the three levels of inquiry.

Table 12

Teachers Asking Students to Explain Their Answer
Averaged per Inquiry Level of the Lesson

Lesson	No.[a]	CQ[b]	DQ[c]	S_P[d]	S_N[e]	T-ans[f]
Higher	4.5	2.5	2	1.25	.25	.25
Middle	2.8	.75	2	.75	1	0
Lower	3.25	.25	3	.75	.25	.75

Note. [a]No. = the number of times a teacher asks a student to explain his or her answer. [b]CQ = the number of times the original question is a convergent question. [c]DQ = the number of times the original question is a divergent question. [d]S_P is the number of times the teacher sanctions the student explanation in a positive manner. [e]S_N = the number of times the teacher sanctions the student explanation in a neutral manner. [f]t-ans = the number of times the teacher ultimately gives the explanation following a request for a student to explain his or her answer.

Teachers Giving the Answer to a Question

Sometimes teachers gave the answer to a question after students attempted to answer it or before a student even attempted to answer the question. The coded transcripts were analyzed for this occurrence. These data (Table 10, Appendix F) were then averaged by inquiry-level ranking of the lesson and the resulting analysis is displayed in Table 13.

As displayed in Table 13, teachers whose lessons ranked lower on the Inquiry Instrument gave the answer to a question slightly more frequently than either teachers

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whose lessons ranked in the middle or higher groups on the inquiry scale. There was no apparent difference between the three groups of lessons in the convergent questions/divergent questions ratio for which teachers provided an answer.

Table 13

Average Frequency of Teachers Giving the Answer to a Question Per Inquiry Level of the Lesson

Lesson	No.[a]	CQ:DQ[b]
Higher	4	0.6
Middle	3.75	1.3
Lower	5.75	.77

Note. [a]No. = the number of times per lesson that a teacher ultimately gives the answer to a question, including both before and/or after the student has attempted to answer the question. [b]CQ:DQ = the average ratio of convergent questions to divergent questions answered by the teacher.

Component 5: The Length of Questioning Strands and Steps

The coded transcripts were analyzed for the number of strands, steps, and questions employed by a teacher while trying to explore a particular concept. A step is any distinct verbal action in the questioning of a concept; it includes a question, an answer, a teacher accepting or approving a student answer, a discussion, or a student question. A strand is defined a set of steps in the questioning strategy for a particular concept. A teacher might ask a number of questions per strand. This includes repeating the question, rewording the question, or asking a different question in order

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to lead to the desired response or asking a different question to get more specific information – probing. Since a concept might be questioned from several different perspectives in order to cover different aspects of the concept, there may be more than one strand associated with a concept. The analysis of steps, strands, and questions (Table 11 Appendix F) was then averaged per inquiry level of the lesson. This analysis is displayed in Table 14.

Table 14

Length of Teachers' Questioning Strands and Steps
Averaged per Inquiry Level of the Lesson

Lesson	A[a]	B[b]	C[c]	D[d]	E[e]	F[f]	G[g]
Higher	5	44.9	18.0	2.3	4.9	11.7	3.8
Middle	7	30.2	8.9	5.8	2.7	12	3.6
Lower	4	29	8.3	2.7	3.7	10	3.0

Note. [a]A = average number of major concepts. [b]B = average number of steps per concept. [c]C = average number of questions per concept. [d]D = average ratio of convergent question to divergent question per concept. [e]E = average number of strands per concept. [f]F = average number of steps per strand. [g]G = average number of questions per strand.

Teachers whose lessons ranked higher on the inquiry scale used more steps, strands, and questions when teaching a concept than the teachers whose lessons ranked in the middle and lower groups on the inquiry scale. However, one strong outlier in the middle group (Teacher 2) who only discussed two major concepts with 18 convergent questions and one divergent question, pulled the average of the middle

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group far to the positive, thus skewing the CQ:DQ ratio. When the data are recalculated without Lesson 2-2, the CQ:DQ ratios are 2.3, 1.8, and 2.7, respectively. Thus, the data on the use of this particular strategy are inconclusive. The range of steps per strand and the range of questions per strand showed no difference between the three groups of lessons.

Component 6: The Manner in Which Teachers Field Student Questions

Twelve coded transcripts were analyzed to determine how teachers field student information and explanation questions related to the lesson content. The analysis of the most frequent fielding behaviors is displayed in Table 12, Appendix F.

The data from the individual lessons were then averaged per level of inquiry. Only two strategies appeared to show a difference between the inquiry levels – the teacher answering the students' questions and the teacher probing for the answer to students' questions. The data from this analysis are displayed in Table 15.

One fielding strategy that appeared to be different between the groups of lessons when the data were averaged per inquiry level of the lesson was that of teachers giving the answer to a student question. Teachers whose lessons ranked higher on the Inquiry Instrument provided the answer to a student question less frequently than did teachers whose lessons ranked in the middle; teachers whose lessons ranked in the middle provided the answer to a student question less frequently than did teachers whose lessons ranked lower on the Inquiry Instrument – 35, 52, and 67 percent of the time, respectively. In addition, when those fielding strategies that in

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one way or another probe the student(s) for the intended response are added together, the data indicate a difference between the three inquiry levels. That is, teachers of the higher and middle inquiry groups probed more frequently for the intended response (50% and 67%) than do teachers in the lower inquiry group (10%).

Table 15

How Teachers Field Student Information or Explanation Questions
Averaged per Inquiry Level of the Lesson

Lesson	No. [a]	Teacher answers[b]	Teacher probes[c]
Higher	3.5	35%	50%
Middle	5.75	52%	67%
Lower	5.25	67%	10%

Note. [a]No. = the number of student information /explanation questions pertaining to the lesson content. [b]Teacher answers = the percent of student information /explanation questions the teacher answers. [c]Teacher probes = the percent of student information /explanation questions for which the teacher probes for the answer.

This analysis also indicates that students in the higher-level inquiry lessons asked fewer content-related information and explanation questions than students in the middle and lower-level inquiry lessons. Students in middle-level and lower-level inquiry lessons asked approximately the same number of information/explanation questions. These data differ slightly from that presented in Table 6 since Table 6 was based on analysis of eighteen transcripts rather than twelve transcripts. The original analysis of eighteen transcripts for the number of student questions indicates students

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in higher, middle, and lower inquiry lessons ask an average of 3.3, 4.3, and 5.3 content-related information and explanation questions per lesson, respectively.

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CHAPTER V

CONCLUSIONS, DISCUSSION, AND IMPLICATIONS

Inquiry teachers often employ effective questioning and response strategies based on the assumption that this approach stimulates students to actively construct knowledge. Based on this general assumption, fourteen middle-school classrooms were identified and observed. These classrooms were then ranked according to level of inquiry observed in the classroom using the "K-12 Science Teaching Practices Observation Form" (Jenness and Barley, 1999) (Appendix B). Six of the fourteen teachers of these lessons – the two ranking the highest, the two ranking in the middle, and the two ranking the lowest for inquiry strategies other than questioning behaviors – were then invited to participate in the study. Each of the six selected classrooms were subsequently observed and videotaped during four lessons – for a total of twenty-four videotaped lessons. The videotapes and transcripts of the audio portions of the tapes of the lessons were ranked along a continuum by inquiry characteristics other than questioning behaviors, using an inquiry instrument developed by the researcher (Appendix C). Next, the videotapes and transcripts of eighteen lessons were further analyzed to determine the teachers' questioning and response strategies. The questioning and response strategies were then compared to the level of inquiry assigned to those lessons to determine which teacher questioning strategies were related to specific student behaviors such as asking questions, solving problems,

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analyzing evidence, considering alternative explanations, and other similar inquiry-related behaviors.

The following components and subcomponents of questioning were studied and are discussed below: (1) the number, type, and level of questions asked by teachers and students; (2) the length of wait-time I – the time teachers' allow students to start an answer to a question; (3) the presence of any significant non-verbal behaviors of teachers during wait-time I; (4) the verbal response strategies of teachers following wait-time I if no student response is forthcoming, including (a) wait-time I of two or more seconds after which the teacher continues with a structured questioning strategy designed to lead to the desired response and (b) wait-time I of two seconds or more after which the teacher ultimately gives the answer; (5) the number and type of questions students answer following wait-time I of two or more seconds; (6) the strategies of teachers following no measurable wait-time I, including (a) the teacher continues questioning in order to lead to the desired response after no measurable wait-time I and (b) the teacher gives the answer after no measurable wait-time I; (7) the length of wait-time II – that period following the student response before the teacher or someone else speaks again; (8) the verbal response strategies of teachers following student response, including (a) the teacher's verbal response strategies following an incorrect student answer, (b) the teacher asks students to explain their answer, and (c) the teacher gives the answer to the question; (9) the length of questioning strands and number of steps; and (10) the manner in which teachers field student questions.

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Conclusions

Can the Number, Type, and Level of Questions Asked by Students and Teachers Be Used as Indicators of Inquiry-based Science Teaching?

Student Questions

The number of questions students ask does not appear to be related to the level of inquiry. This applies to both total questions as well as content-related information and explanation questions. There appears to be a trend in that students in lessons identified as using higher-level inquiry strategies asked fewer total questions and fewer content-related information and explanation questions per lesson than students in lessons scoring in the middle of the inquiry scale (Table 6). The students in the lessons scoring in the middle on the inquiry scale asked fewer total questions and fewer content-related questions than did students in lessons ranking lower on the Inquiry Instrument. However, sufficient data are lacking to confidently conclude that the number and type of student questions is related to inquiry-based teaching in these middle school science lessons.

Teacher Questions

The number of questions that teachers ask is related to inquiry teaching. Teachers in the higher-level and middle-level inquiry lessons asked more questions per lesson than did teachers whose lessons scored lower on the Inquiry Instrument (Table 7). The total number of questions asked by teachers is large, but it includes

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rhetorical, procedural, clarification, and confirmation questions as well as cognitive questions.

Teachers whose lessons scored highest on the Inquiry Instrument also asked more questions about the content of the lesson than did the teachers whose lessons scored in the middle. The middle group of teachers asked more content-related questions than did the teachers whose lessons ranked lower on the Inquiry Instrument. When expressed as a percentage of total questions asked by teachers per lesson, the teachers in the higher ranked inquiry lessons asked a higher percentage of content-related questions than the teachers of the middle lessons, and these teachers asked the same percentage of content-related questions than did teachers in the lower inquiry lessons.

The number of cognitive questions – convergent and divergent questions – related to the lesson content were also counted. The teachers of higher-level inquiry lessons asked more cognitive questions than teachers of middle and lower-level inquiry lessons; however, teachers in the lower inquiry group asked slightly more cognitive questions per lesson than did teachers in the middle-level inquiry group.

The number of divergent questions asked by teachers is also related to level of inquiry, with teachers of higher-level inquiry lessons asking more divergent questions than teachers of middle and lower-level inquiry lessons (Table 7). When divergent questions are expressed as a percentage of all content-related questions, teachers in the higher inquiry group asked a higher percentage of divergent questions than teachers of lessons ranking in the middle and lower on the inquiry scale. Teachers in

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the middle and lower inquiry groups asked a similar percentage of divergent questions.

The number and percentage of convergent questions asked by teachers in the three levels of inquiry demonstrated inconsistent differences between the groups. Therefore, additional data are needed to determine whether the number or percent of convergent questions is related to inquiry teaching.

The ratio of convergent to divergent questions (CQ:DQ) is similar for all groups of lessons. Thus, based on this data, the ratio of lower level questions to higher-level questions is not directly related to inquiry teaching.

In summary, the number of total questions, number of content-related questions, and number of divergent questions asked by teachers is related to inquiry teaching in middle school science lessons. Teachers in the higher-level inquiry lessons ask more questions of all types than teachers in the middle or lower-level inquiry lessons. Teachers in middle and lower-level lessons ask approximately the same number of convergent questions and the same percent of content-related, divergent, and convergent questions.

Can the Length of Wait-time I Be Used as an Indicator of Inquiry-based Science Teaching?

The average length of wait-time I – the time teachers allow students to start an answer to a question, is the same for all levels of inquiry (Table 8). Thus, within the scope of this study, length of wait-time I cannot be used as an indicator of inquiry. However, the number of times wait-time I was observed per lesson is greater for

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teachers in lessons scoring highest on the Inquiry Instrument than for teachers scoring in the middle and for teachers scoring lower on the Inquiry Instrument. Because Teacher 3's lessons skewed the data, they were reanalyzed omitting his data. With this teacher's lessons excluded, the analysis demonstrates a trend, with teachers in the higher-level inquiry lessons using more wait-time I's per lesson than teachers in middle-level lessons; teachers in the middle-level inquiry lessons used more wait-time I's than teachers in the lower-level inquiry lessons. With Teacher 3's data excluded, the average time in seconds remains similar for the three groups of lessons. Thus, the data excluding Teacher 3, suggest that teachers of higher inquiry lessons allow students more frequent opportunities to think about and formulate answers to questions than teachers who demonstrate fewer inquiry characteristics. However, once Teacher 3's lessons are excluded, the higher-level inquiry group contains only two lessons, the middle contains three lessons, and the lower contains four lessons. Thus, sufficient data are lacking to confidently conclude that the frequency of wait-time I per lesson is related to inquiry teaching in science.

Can the Presence of Any Significant Non-verbal Behaviors of Teachers During Wait-time I Be Used as an Indicator of Inquiry-based Science Teaching?

The presence of any significant non-verbal behaviors during wait-time I – that period following a question, before a student answers – was not observed in any of the reviewed videotapes. Thus, no conclusions are possible concerning this component of questioning.

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Can the Number and Type of Questions That Students Answer Following Wait-time I of Two or More Seconds Be Used as an Indicator of Inquiry-based Science Teaching?

In lessons ranking higher and in the middle on the Inquiry Instrument, students answered teachers' questions, given a wait-time I of two or more seconds, more frequently than did students in lessons ranking lower on the Inquiry Instrument (Table 9). When calculated as a percentage of total countable wait-times, the data do not demonstrate a relationship. In addition, the ratio of convergent questions to divergent questions answered by the student(s) after a measurable wait-time I did not indicate a trend or pattern between the three groups of lessons.

As in a previous question about wait-time I, the questions of Teacher 3 required, by their very nature, time for students to calculate an answer, and his students appeared to be "trained" to calculate and then offer an answer. Since this particular teacher had two lessons in the higher group and one in the middle group of lessons, the data were reanalyzed, excluding Teacher 3. Now the students in higher-level inquiry lessons answered the question following a measurable wait-time I the same number of times as students in the middle and lower-level inquiry lessons. The percentages of total wait-time I this represents are similar for the three groups. The recalculated ratio of convergent questions to divergent questions answered by the student(s) after a measurable wait time I is inconclusive, since the behavior happened only once in the three groups.

The data are inconclusive. The strong outliers in the two higher-level groups skew the data and the few occurrences of a measurable wait-time I in the lower-level

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lessons makes it difficult to support any claim. After exclusion of the outliers, the analysis indicates no differences in the number of questions students answer following a measurable wait-time I either as a count or as a percentage of total measurable wait-times. Thus, the data are insufficient to conclude that the number and type of questions students answer following a measurable wait-time I is related to inquiry teaching in science.

Can the Verbal Response Strategies of Teachers Following Wait-time I, if No Student Response Was Forthcoming, Be Used as an Indicator of Inquiry-based Science Teaching?

The Teacher Continues Questioning After a Wait-time I of Two or More Seconds

Teachers of lessons that ranked higher on the inquiry scale repeated or rephrased the question or asked a different question more often than did teachers in lessons that ranked in the middle and teachers who ranked lower on the inquiry scale (Table 10). This frequency, when expressed as a percentage of the total number of times a question was not answered by a student, was also higher for teachers in the higher-level inquiry lessons than for teachers in the middle and lower-level inquiry lessons. Therefore, both the number and percentage of times a teacher probes for the intended response when students do not answer the question, given a measurable wait-time I are related to inquiry teaching in science.

Additionally, while the frequency is very small, the teachers in the higher-level inquiry lessons and middle-level inquiry lessons demonstrated more

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heterogeneity in their follow-up questions not demonstrated by the teachers of the lower-level inquiry lessons. The small numbers of these occurrences suggests a possible trend, however there is not sufficient evidence to state that heterogeneity in follow-up questioning procedures is related to inquiry teaching.

The Teacher Gives the Answer After a Wait-time I of Two or More Seconds

The teachers demonstrated no apparent differences in the number of times they ultimately gave the answer to the question when students did not answer the teacher's question following a wait time I of two or more seconds (Table 6, Appendix F). Teachers, regardless of the lesson's inquiry level, rarely gave the answer to a question when students did not answer. Therefore, teachers providing the answer when students do not answer the question, after a measurable wait-time I, is not related to the level of inquiry.

In summary, the analysis indicates that one questioning sub-strategy associated with measurable wait-time I is related to inquiry teaching. That strategy is that of teachers probing for the intended response when students do not answer the question, after a measurable wait-time I of two or more seconds.

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Can the Strategies of Teachers Following No Measurable Wait-time I Be Used as an Indicator of Inquiry-based Science Teaching?

The Teacher Reasks or Rewords a Question After No Measurable Wait-time I

In this type of situation, a teacher asks a question, and without waiting for an answer, he or she asks the question again, rephrases the question, or asks a different question in order to attain the desired response. There is no apparent difference between the inquiry groups of lessons in this strategy (Table 7, Appendix F). Thus, reasking or rewording a question without a measurable wait-time I does not appear to be related to the level of inquiry teaching and learning in middle school science lessons.

The Teacher Gives the Answer After No Measurable Wait-time I

The data demonstrated no apparent difference between the inquiry groups in teachers giving the answer without waiting for a measurable wait-time I. This behavior happened rarely, regardless of the level of inquiry of the lesson.

In summary, there is no evidence that the response strategies of teachers following no measurable wait-time I are related to inquiry-based science teaching. The response strategies analyzed include the teacher reasking or rewording a question and the teacher giving the answer, without waiting for a response.

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Can the Length of Wait-time II Be Used as an Indicator of Inquiry-based Science Teaching?

The length of Wait time II – the time following a student response before the teacher speaks again – is not supported as an indicator of inquiry teaching in science. Only one incident of measurable wait-time II was observed in the videotapes analyzed and therefore insufficient data were available to make any claims.

Can the Verbal Response Strategies of Teachers Following Student Response Be Used as an Indicator of Inquiry-based Science Teaching?

Teachers' Verbal Response Strategies Following an Incorrect Student Answer

Students in the three inquiry groups answered the teachers' questions incorrectly a similar number of times (Table 11). Teachers whose lessons ranked higher on the inquiry scale probed for the desired response more often than did teachers whose lessons ranked in the middle. However, teachers of lessons ranking in the middle level probed for the desired response less frequently than teachers whose lessons ranked lower on the inquiry scale. When the middle inquiry group of lessons is bunched with the lower inquiry group of lessons, there appears to be a relationship between level of inquiry and teacher's probing for the intended response to cognitive questions that students answer incorrectly.

In addition, while the number of divergent questions answered incorrectly by students in the higher-level inquiry lessons was slightly less than in the lower inquiry lessons, the teachers in the higher and middle-level inquiry lessons probed for the

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intended response to these higher-level cognitive questions more frequently than did teachers in the lower-level inquiry lessons. When the higher and middle inquiry groups are bunched together, there is a relationship between the level of inquiry of the lesson and the percentage of time teachers probe for intended response to divergent questions following an incorrect student answer. However, insufficient data are available to confidently conclude that either of these questioning/response strategies is related to the level of inquiry.

The opposite relationship is seen for teachers ultimately providing the answer to the question that students answered incorrectly. Teachers whose lessons ranked lower on the inquiry scale gave the desired response a greater percentage of the time than did teachers whose lessons ranked in the middle and these teachers gave the desired response less often than teachers whose lessons ranked higher on the inquiry scale. If the higher and middle-level inquiry groups of lessons are bunched together, there appears to be a trend between this response strategy and level of inquiry. However, insufficient data are available to conclude that this response strategy is related to inquiry teaching.

<u>Teachers Asking a Student to Explain his/her Answer to a Question</u>

Teachers whose lessons ranked higher on the inquiry scale more frequently followed a student response with a request for an explanation than did teachers whose lessons ranked in the middle or lower on the inquiry scale (Table 12). In addition, teachers of the higher-level inquiry lessons appeared to sanction the student explanations in a positive manner slightly more often than did the teachers of the

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middle and lower-level inquiry lessons. However, the frequency of these behaviors is so low that more data are needed to make and substantiate a claim.

Teachers Giving the Answer to a Question.

Teachers whose lessons ranked higher and in the middle on the inquiry scale provided the correct answer slightly less frequently than did the teachers whose lessons ranked lower (Table 13). When analyzing the types of questions teachers for which provide answers, the data indicate that there is no difference in the ratio of convergent to divergent questions where the teacher provides the answer between the various levels of lessons. Thus, the evidence is not strong enough to conclude that teachers' ultimately giving the answer to the question is related to level of inquiry.

Can the Length of Steps and Strands of a Teacher's Questioning Strategy Be Used as an Indicator of Inquiry-based Science Teaching?

The number of "questioning strands and steps" of the three inquiry groups of lessons were averaged and compared (Table 14). A step is defined as any distinct verbal action in the questioning of a particular concept. A strand is a set of steps associated with the questioning of a specific concept. Since a concept may be questioned using several different approaches in order to cover different aspects of the concept, there may be more than one strand associated with a concept.

The teachers whose lessons ranked higher on the inquiry scale had more steps, strands, and questions per concept during a lesson than teachers whose lessons ranked in the middle and teachers whose lessons ranked lower on the inquiry scale. Teachers

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whose lessons ranked higher on the inquiry scale asked the original question, repeated or rephrased the question, or asked a different question to lead to the desired response more frequently than did teachers whose lessons ranked in the middle and teachers whose lessons ranked lower on the inquiry scale. It follows that since they asked more questions, their transcripts demonstrated more steps per concept. These higher-level inquiry teachers also asked more strands of questions than the teachers of the middle and lower-level inquiry lessons. However, the teachers whose lessons ranked in the middle had fewer strands per concept than teachers whose lessons ranked lower on the inquiry scale. Thus the data are not convincing that the number of strands per concept is related to the level of inquiry.

The CQ:DQ ratio data were biased by a strong outlier in the middle group that may have skewed the average of this group of lessons. When Lesson 2-2 is removed from the analysis, the data indicate that the ratio of convergent questions to divergent questions does not differ between the groups and as a questioning strategy, is not related to inquiry teaching. The range of steps per strand and the range of questions per strand also demonstrated no difference between the three inquiry groups.

In summary, the use of multiple steps and questions by a teacher when discussing a concept appears to be related to level of inquiry. Thus, the data support the claim that probing by either repeating or rephrasing the question or asking a different question to lead to the desired response is related to inquiry teaching. In addition, the number of strands per concept indicates a possible relationship with the

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level of inquiry. However, insufficient data are available to conclude that this questioning strategy is related to inquiry teaching.

Can the Manner in Which Teachers Field Student Questions Be Used as an Indicator of Inquiry-based Science Teaching?

Several fielding techniques were analyzed, including: (a) the teacher answering the students' questions, (b) the teacher allowing another student to answer the question, (c) the teacher discussing the question or concept, (d) the teacher posing a new or different question to lead to the desired response, (e) the teacher returning the question to the questioner, (f) the teacher saying he or she does not know the answer, and (g) the teacher leaving the question unanswered (Table 12, Appendix F). Of these various fielding behaviors, only one appears to be useful as an indicator of inquiry while a second fielding behavior demonstrates a trend in that direction. The teachers in the lessons ranking higher on the inquiry scale ultimately provided the answer to the students' questions less frequently than did the teachers in the middle and lower-ranking inquiry groups (Table 15). Thus, the teachers' frequency of answering student questions stands out as the one fielding behavior of teachers related to level of inquiry.

The teachers in the higher and middle inquiry lessons returned the student's question, in some form, to the questioner or another student in order to lead to the desired response more often than did the teachers in the lower inquiry lessons. However teachers whose lessons ranked in the middle returned the student's question more frequently than did teachers whose lessons ranked higher on the inquiry scale.

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When the higher and middle-level inquiry groups are bunched together, this response strategy appears to be related to level of inquiry. However, the evidence is weak and not compelling.

Thus, the analysis of teachers' fielding strategies demonstrates that teachers' behavior of ultimately answering a student's question is related to level of inquiry. The higher the level of inquiry, the fewer student questions a teacher ultimately answers.

In summary, the specific claims of this study suggest that the following questioning and response strategies can be used as indicators of inquiry: (a) the number of questions asked by teachers; (b) the number of content-related questions asked by teachers; (c) the number of divergent questions asked by teachers; (d) the number of times teachers probe for the intended response when students do not answer a question; (e) the number of times teachers answer students' questions and (f) the number of steps and questions per concept. All except (e) are directly related – the higher the level of inquiry, the more frequently the strategy occurs. The exception is teachers answering students' questions. This strategy is inversely related to level of inquiry.

Discussion

Student Questions and Teachers' Fielding of Student Questions

The analysis of students' questioning demonstrates a trend where students in the higher-ranking lessons asked fewer content-related information and explanation

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questions than the students in the middle and lower-ranking lessons. While this comparison may be statistically insignificant, it may be useful to speculate what these data may imply. Perhaps the teachers in the lessons that ranked higher on the inquiry scale explained the concepts undertaken in the lesson well enough that students felt they understood the material and therefore had no further questions. Perhaps the students in the higher-level inquiry lessons sensed they grasped the concepts and thus did not have to ask information or explanation questions.

Students clearly do not ask many content-related information or explanation questions. The data from this study agree with Graesser and Person (1994) who also report that students ask only 1.3 to 4.0 questions per hour. Costa (2000) maintains "question-asking may not be as easy task for some students". The data from this study support the contention that question asking may indeed be difficult for many students.

Many authors have suggested reasons for this lack of student questioning: (a) students may lack experience in asking content-related science questions in the classroom environment (Cosgrove & Schaverien, 1996; Costa et al., 2000; Gall, 1970; Good et al., 1987; Graesser & Person, 1994; Orlich, 1980; Penick et al., 1996; and Roth, 1996); (b) the social and cultural environment of the classroom may not be conducive to students' asking questions (Good et al, 1987); (c) teachers dominate the classroom discourse and student questioning may be restricted by covert or overt behaviors of the teacher (Dillon, 1982; Hyman, 1980; Kelly et al., 2000; Roth, 1996;

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Sirotnik, 1983; and Taba, 1966; and (d) students may lack basic understanding about the nature of science (Marback-Ad and Sokolove, 2000).

Durham (1997) and Hyman (1980) believe that the deficiency of students' questions may be related to what teachers do when students ask questions, which Hyman refers to as the "fielding" of student questions. Durham suggests that science teachers should develop multiple strategies to respond to student cognitive questions because the type of responses employed by the teacher may have an impact on the effectiveness of inquiry-based learning activities. She also suggests that science teachers should encourage students to resolve their perplexities through the use of questions and responses, and that research is needed to identify those teacher response strategies that will encourage student questions.

Thus, this study analyzed not only the number and type of students' questions but also how teachers fielded student questions. Two fielding behaviors appear to be linked to inquiry teaching. The teachers of lessons ranking higher on the inquiry scale gave the answer to students' questions less frequently than did the teachers of middle and lower-level inquiry lessons; instead, the teachers of higher and middle-level inquiry lessons either discussed the student's question or probed the student or classroom for the intended response more frequently than the teachers of lower-level inquiry lessons. Therefore, there appears to be a relationship between fielding behaviors of teachers and level of inquiry observed in that lesson. It follows that while students in all classrooms are not asking many content-related questions, teachers whose lessons display more characteristics of inquiry are using strategies

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that do not simply give the answer, but allow the students to answer their own questions.

Hyman (1980) states that there is evidence that children ask more questions when they get answers. The data from this study supports that finding. Teachers in the lower-level inquiry lessons answered students' question more often and students in these lessons asked more questions than those in the middle and higher-level inquiry lessons. The data from this study may also demonstrate a possible relationship between teachers probing the students for the intended response and the number of questions students ask. Teachers in the higher-level inquiry lessons returned the question to the students and probed the students for the answer more frequently, yet the students in these lessons asked fewer questions than in the lower-level inquiry lessons, where teachers did not probe for answers and reasons as frequently. Nonetheless, regardless of these weak associations, it is clear that students are not asking many conceptual questions in the classroom, regardless of the teachers' fielding behavior.

As teachers, we may be so involved with asking questions that we ignore how we respond to student questions. How to encourage students to respond to personal perplexity though the use of questioning remains an unanswered question. More research is clearly needed to identify effective teacher response strategies.

Teachers' Questions

Teachers in the higher-level and middle-level inquiry lessons asked more total questions and more content-related questions than did teachers in the lessons scoring

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lower on the Inquiry Instrument. Teachers in the lessons that scored higher on the Inquiry Instrument asked a greater number of divergent questions than did teachers in the mid-level and lower-level inquiry lessons. The data also indicate that teachers in the lessons that ranked higher on the inquiry scale asked a greater number of cognitive questions than teachers in the middle or lower-level inquiry lessons; however, the data did not demonstrate a direct relationship between level of inquiry and number of cognitive questions.

The total number of questions asked by teachers in this study ranges from 105 to 247 per lesson; the number of content-related questions ranges from 63 to 218. This number includes a count of all statements ending with an implied question mark, and thus includes such questions as rhetorical, procedural, clarification, and confirmation questions as well as cognitive questions. The number of cognitive questions ranges from 22 to 145 per lesson, which agrees with Gall (1970) and Wilen and Clegg's (1986) results of between 30 and 120 cognitive questions per hour. A comparison of data with these studies in 1970 and in 1986 and the present study do not show any change in the number of cognitive questions asked by teachers.

The data from this study demonstrate that greater than 75% of all the teachers' classroom questions were related to the lesson content, leaving 25% or fewer of the teachers' questions related to managing the classroom. Only about 50% of all the teachers' content-related questions were cognitive questions – either convergent or divergent questions. The remainder of the content-related questions were rhetorical, procedural, confirmation, or clarification questions. Evaluation of the cognitive

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questions asked by teachers indicated that the ratio of convergent to divergent questions is 2 to 1. This analysis agrees with Otto (1991) who reports that 60 – 80 percent of teacher questioning requires a response at the lowest cognitive level of thinking. Barth & Shermis (1980), Dillon (1982), Gall (1970), Graesser & Person (1994), Roth (1996), and Vander Meij (1991) also contend that there is evidence that most teacher questions are based on recall of facts and do not engender critical thinking.

The teachers in this study asked twice as many lower-level cognitive questions (convergent) as higher-level questions (divergent). It appears as if teachers are more concerned about students' recall of facts than students' ability to manipulate and use the facts. Several classrooms were academically advanced, with supposedly very bright students, and yet, the teachers did not encourage the students to use or apply their knowledge in meaningful ways. While the teachers may, through the classroom activities, expect higher-level thinking from the students, the teachers did not ask many higher-level questions and thus did not present a good model of scientific questioning.

Why are teachers not asking higher-level questions? Barth and Shermis's (1980) conclusions following a study of social studies student teachers' effectiveness in applying inquiry questioning skills after questioning training provides plausible reasons as to why teachers may not be asking higher-level questions in the classroom. They hypothesized the following: (a) the student teachers may not have actually learned the skill of question asking but merely performed upon demand; (b) unless

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teachers have an understanding of inquiry, even with training they are not likely to learn questioning skills; (c) even if student teachers learn questioning skills, if the culture of the school does not support such behavior, the behavior is likely to wane; and (d) it may be impossible for teachers in a regular classroom to ask inquiry questions because preservice teachers are trained via "transmission" of information and see classrooms as places to transmit or instill certain values, attitudes, and assumptions.

Another interesting characteristic of teachers' questioning observed in this study is the complexity of the teachers' questioning strategies. The teachers whose lessons ranked higher on the inquiry scale had more steps and questions per concept during a lesson than both the teachers whose lessons ranked in the middle and the teachers whose lessons ranked lower on the inquiry scale. This indicates that teachers whose lessons ranked higher on the inquiry scale asked questions, repeated or rephrased questions, or asked a different question to lead to the desired response or the improvement of a response more frequently than did teachers whose lessons ranked in the middle and teachers whose lessons ranked lower on the inquiry scale. These teachers in the higher-level inquiry lessons also exhibited more complexity in their questioning about a particular concept; their transcripts demonstrated more strands of questions per concept – they approached a concept from several different perspectives – than teachers of the middle and lower-level inquiry lessons.

Orlich (1980) and Dillon (1982) agree that teachers should employ probing and prompting strategies, however Dillon's review of questioning research found

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only a few studies in education that directly address this issue. Probing by the teacher is an attempt to clarify the question or answer so the student can understand it better, thus causing the student to improve the overall response. Probing also includes eliciting additional responses from the respondent so the teacher can verify whether or not the student knows and more importantly understands the material (Orlich, 1990). Teachers must follow up a student's initial response with another question that "will take an initially weak response and improve its quality" (Dillon, 1982). Thus, by probing following the student's initial response, the teacher aids the student in a positive manner. The student is encouraged to revise an incorrect response or complete an incomplete one. Gall (1970) also advocates for probing by suggesting that "follow-up questioning of the student's initial response has substantial impact on student learning in classroom teaching situations".

Teachers' Response Strategies

The frequency with which the teacher continues questioning or probing for the intended response when a student does not offer an answer, following a measurable wait-time I is related to the level of inquiry. Two additional response strategies – the frequency the teacher probes for the intended response when a student answers a question incorrectly and the frequency the teacher ultimately gives the answer when a student answers incorrectly – indicate a possible relationship with the level of inquiry. However, the trend is not strong and thus no definitive claims are possible. In addition, the incidence of wait-time I and the frequency that students answer the

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teachers' questions, given a measurable wait-time I, show a weak relationship to the level of inquiry, however the data were skewed by Teacher 3 and, therefore, these potential indicators require more study.

Wait-time I is defined as that period of silence following a question and this period of silence purportedly provides students with an opportunity to consider what has been said and to assimilate new knowledge with previously learned knowledge. Carlsen (1991) questions whether there is evidence to suggest that wait time is an adequate measure of thinking time. Because teachers frequently take a while to ask a question, Carlsen maintains that the students may have had plenty of time to formulate a response prior to the final termination of the teacher's question. And, if a teacher typically asks questions in a topically related series, students may anticipate the teacher's next question before it is even asked. Carlsen continues to argue that the think-time explanation is built upon the "unlikely premise" that students process questions only during a period of silence.

The evidence provided by this study lends some support to Carlsen. The researcher observed students' hands in the air the moment they thought they knew the answer to a question – and sometimes they answered without raising their hands. This behavior was observed following both convergent and divergent questions. Therefore, the students were apparently formulating answers while the question was being vocalized, despite the level of question. There was rarely any wait-time I, regardless of the level of inquiry of the lesson, unless the students needed it to calculate a mathematical answer. While teachers may have wanted students to take

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their time to think through a concept before answering a question, it appeared as if the lack of wait-time I was not primarily due to teachers not allowing students time to formulate an answer, but was related to the fact that students' hands were up immediately after the question was voiced, and in many instances, students raised their hands before the teacher had completed the question. The fact that teachers called on or acknowledged students immediately or allowed students to answer without being called on may also be an issue here. In order to encourage students to answer questions in a thoughtful way, it may be wise for teachers to pause and provide a wait-time I even if hands are in the air. While the intent of this pause would be to allow all students the time to process the information and formulate an answer, it still may not insure that students are thinking; those who do not know the answer may not process the question at all if they believe that other students will answer.

At first glance, the data from this study suggest that students in the higher and middle-level inquiry lessons answer questions more frequently following measurable wait-time I than students in lower-level inquiry lessons. However, the use of wait-time I was seen most often in a classroom solving problems in physical sciences (Table 3, Appendix F). When those particular lessons were excluded, the data suggest that when asked questions that require an answer other than application of a mathematical formula, students are not likely to take time to think. Since higher-level questions are those whose answers are not available without synthesis and analysis, it follows that students should be taking time to think through the question and

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formulate a response. However, students who were prone to answer questions almost always raised their hands immediately, regardless of the level of the question. Wait-time I occurred so infrequently in lessons other than the physical science lessons that one cannot conclude that middle-school students take time to think through higher-level questions and formulate a response.

Wait-time II is defined as that period following a student answer before the teacher begins speaking again. In eighteen lessons, there was only a single incident of wait-time II observed. This pause following a student's response supposedly "provides the responder or other students with time to consider what has been said and to formulate a reaction, question, or alternative response" (Tobin, 1986). These data support Taba (1966), who speculates that teachers find it difficult to accept the slowness of the process of developing ideas, and thus do not "wait out the students". Taba explains that it is because teachers' expectations focus on the answer rather than the process that the pace feels so slow, and yet the slow pace is necessary for students to develop the cognitive skills required to process the information.

A questioning strategy that can be used as an indicator of inquiry is teachers probing for the intended response. Teachers in the higher-level inquiry lessons used questions to probe for the intended response or an elaboration on the original response more frequently than teachers in both the middle and lower level inquiry lessons. This probing strategy was observed more frequently in the higher-inquiry lessons in four separate analyses: (1) the analysis of steps and strands, (2) the analysis of teachers' response when students do not answer the initial question, (3) the

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analysis of teachers' response when students incorrectly answer a question, and (4) the analysis of teachers' response to student questions. These findings all support the hypothesis that probing is related to inquiry teaching. Teachers probing for a better, more complete, or more detailed response also provides a good example for students about the nature of science. Science is not simply a straightforward process of question – answer – question – answer. Sometimes the answer is unknown, incomplete, or incorrect and one must try repeatedly to approach an answer, many times not achieving a completely satisfactory solution. Question-asking in science is a complex and non-linear activity, consistent with those behaviors demonstrated by the teachers who probed for deeper student understanding and reflective thinking.

Overall, the general claims of this study are:

1. While teachers ask many questions per hour, few are higher-level, divergent questions. Thus, even in those lessons in which teachers demonstrate inquiry strategies, questioning is still not consistent with the role recommended by those who espouse inquiry teaching and learning in science.

2. Students do not ask scientifically valid questions in middle school classrooms. The lack of good student questions is apparently not related as much to teachers' fielding behaviors, but to a lack of good modeling of scientific questions by teachers.

3. Inquiry ranking, as determined by the Inquiry Instrument, appears to be dependent on the lesson as well as teacher behavior. A particular teacher might have one lesson ranked in the higher-level inquiry group as well as one lesson ranked in

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the middle-level inquiry group, depending upon the lesson. The data suggest that some teachers can and do use inquiry where applicable but not every lesson lends itself to inquiry strategies. However, some teachers, regardless of the lesson, do not use an inquiry approach. Therefore, within the limits of this study, the evidence indicates that the use of inquiry teaching strategies is dependent upon both the teacher and the particular lesson.

Limitations

Limitations of the Methodology

The first limitation noted in the protocol was that the inquiry scores of the lessons, provided by the Inquiry Instrument (Appendix C) did not indicate large differences in the range of teaching styles used by the teachers of classrooms selected for this study (Table 3). While there was a large difference between the highest and lowest scores, there is no clear demarcation between the higher and middle groups, although there is a larger difference between the middle and the lower inquiry groups.

This phenomenon may be due to the discriminatory ability of the Inquiry Instrument or due to the ability of the scorer to evaluate the various parameters of the lessons indicated on the Inquiry Instrument. It is worth noting that the Inquiry Instrument has not been analyzed for validity or reliability.

Assuming the rankings are valid, other questions remain: (a) Do all middle school science classrooms use a similar range of inquiry strategies, or is this only true for this study? (b) Would a larger sampling have yielded greater discrimination

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between high, middle, and lower-level inquiry lessons? (c) Is this phenomenon seen only in west Michigan, or are the inquiry characteristics of middle school science lessons similar in other geographic areas?

A second limitation to this study was the difficulty in classifying questions. Questions did not always match the definition categories. However, the analysis of the first transcript was compared with a similar analysis completed by Dr. William Waters (personal communication, June, 2001) a linguist, who helped define the types of question categories used in this study. The result of this analysis showed very similar results. This informal analysis supports the claim for face reliability of the classification protocol.

A third study limitation was the small number of lessons analyzed. Two significant problems resulted: (1) in several situations, a single teacher acted as a strong outlier and skewed the data; and (2) statistical significance was difficult to claim because of the small number of lessons that were analyzed. The analysis of fewer questioning parameters on a larger number of lessons may have allowed the researcher to make more definitive claims about the relationship between questioning strategy and the inquiry level.

Limitations of the Analysis

The variables used in this study were the inquiry-level of the lesson as measured by the Inquiry Instrument and the questioning strategies of teachers and students. Variables such as teachers' conceptual knowledge and teachers' experience

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were not controlled. Teachers' conceptual knowledge may be related to their questioning abilities and strategies. Carlsen's (1991) study demonstrated that "high-knowledge teachers planned to ask about material not covered in the textbook and required students to synthesize material. Low-knowledge teachers tended to use questions emphasizing recall of material found in the textbook". Since teachers' conceptual knowledge and experience may be prerequisites to inquiry teaching, these may be important variables that should be examined or controlled.

Another variable that was not considered in this study was the academic ability of the students. Anecdotal evidence from teachers indicated that several of the lessons ranking higher on the inquiry scale were from academically advanced classrooms, while several classrooms in the lower-level inquiry group had lower achieving students. Thus, intellectual ability of students may be related to the ability of the teacher to employ inquiry strategies.

Finally, student behavior is another factor not accounted for in this study. Anecdotal evidence from the researcher's observation of the lessons indicated that teachers with classroom management problems typically scored lower on the inquiry scale. Poor student behavior appeared to the researcher to interfere with some of the lesson plans and efforts of the teacher. These teachers seemed to spend more time managing the classroom than managing the learning. Because these lessons scored lower on the inquiry scale, a certain threshold level of student behavior and cooperation may be an important prerequisite for the use of inquiry teaching and learning strategies.

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Implications

Implications for Classroom Practice

First and foremost, teachers must ask more higher-level cognitive questions. The teachers observed in this study asked more than twice as many convergent questions as divergent questions. Science literacy cannot be attained by memorization and regurgitation of facts; science literacy involves the ability to use knowledge to apply, analyze, synthesize, and evaluate new problems or questions. Good et al. (1987) agree that teachers should commit more instructional time to thinking and problem solving so that students learn to organize and understand information.

Second, teachers should model the effective use of questions as well as provide support and encouragement for students to ask questions in the classroom. It is clear from this study and also previous studies that students are not asking concept-related questions, either at a high or low-cognitive level. If a high-level question reflects the thoughts of the questioner (Dillon, 1982), then teachers must encourage and teach students how to ask scientific questions.

Third, it is important that teachers not only encourage students to formulate their own higher-level question but also stimulate students to carefully consider and answer teachers' higher-level questions. Research has still not answered the question of whether or not teachers' higher-level questions actually do stimulate higher-level thought in students (Dillon, 1982). Thus, it may not be the teacher's question but

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rather the formulation of an answer to a higher-level question that stimulates a student's higher-level thought processes.

Fourth, teachers should learn to wait for a few seconds after they ask a question, before they call on a student to answer the question, even though there will undoubtedly be hands in the air. As long as teachers are focused on the answer rather than the process (Taba, 1966), time for thinking and processing of answers requiring higher-level thinking will not exist. The teacher must therefore make a conscious effort to pause after asking questions and receiving answers.

Teachers must keep in mind that in inquiry teaching, teachers may cover less material in class because they are using more time to develop thinking processes and relying less on memorization (Orlich, 1981) and because students require more time to think and reflect upon higher-level questions. Thus, if teachers want to build higher-order thinking skills, they must reduce content in favor of process. Only then will they be providing important experiences to help students understand the structure of science (Orlich, 1981).

Finally, teachers may be communicating that scientists know all the answers. If this is so, teachers must change the manner in which science is taught, from a body of known facts to a process of inquiry where scientists are constantly asking questions of nature. "Good science demands two things: that you ask the right questions and that you get the right answers" (Orr, 1999). Although science education focuses almost exclusively on the second task, a good case can be made that asking good questions is both harder to instill in students and a more important skill.

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Implications for Teacher Training

Higher-level questions include synthesis and evaluation questions as well as analysis and application questions. However, there were no synthesis or evaluation questions asked by teachers in any of the eighteen transcripts analyzed. Thus teachers as well as students must be taught how to ask questions that require thinking beyond recall. As Barth and Shermis (1980) suggest, a lack of insight into inquiry theory and a prior teaching model that does not recognize inquiry behavior could explain why teachers are not asking higher-level cognitive questions. It follows that increasing both teachers' and students' questioning skills may thus require changes beyond pedagogical content knowledge to their beliefs about the nature of science.

The transcripts from this study support the finding of others that classroom discourse is very one-sided, with teachers dominating. There was very little verbal interaction between the teacher and the students. Teachers must therefore be taught how to draw students into conversations about science. Kelly et al. (2000), Tunnicliffe & Reiss (1999), and others agree that children's use of language and discourse with teachers is important in their construction of knowledge.

Implications for Future Research

This study did not control variables that often confound educational research, including the level of teachers' concept knowledge, teachers' teaching experience, perceived academic ability of students in the classroom, behavior of students in the classroom, and others. A further study to determine if there is a relationship between

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the level of inquiry employed by teachers and these variables would be worthwhile. If those factors that are closely related to inquiry teaching and deeper learning can be identified, that knowledge could be used to help overcome the obstacles blocking the use of inquiry strategies in the science classroom.

This study was complex in that it was a descriptive study of both questioning and inquiry and investigated a small sample of middle school science classrooms. Thus, analysis was limited to simple comparisons. It is recommended that those factors identified in this study that appear to be indicators of inquiry be examined further. A larger sample of lessons and narrowing the focus to fewer questioning strategies should provide more data from a larger range of classrooms.

This study suggests that interesting differences in teachers' questioning and probing strategies between inquiry levels may exist. Probing by teachers for the intended response appears to be related to level of inquiry; however, there was no readily apparent pattern in the type of cognitive questions asked by teachers as they probed for the intended response; some teachers asked convergent questions followed by divergent questions, some asked divergent followed by convergent. Even Gall et al. (1978) ask "should teachers start a discussion by asking recall questions to test students' knowledge of facts and then ask higher cognitive questions that require manipulation of the facts?" Thus future research to determine if the order of question types is related to students' processing information and higher-level thinking skills is recommended.

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In summary, teachers' probing and prompting strategies and the pattern of question types teachers use should be a part of their questioning repertoire. These strategies were observed in some of the transcripts of higher-level lessons analyzed in this study. Further studies about this complex teacher behavior as it relates to inquiry and higher-level thinking are recommended.

Finally, because the literature is inconclusive about whether teachers' use of higher-level questions is actually an effective teaching tool, the questioning strategies that are demonstrated to be indicators of inquiry must be compared to the ability of students to use scientific knowledge. As suggested by Gall (1970), "It is important that teachers' questions should not be viewed as an end in themselves. They are a means to an end – producing desired changes in student behavior". Therefore, researchers should give high priority to the tasks of delineating these desired outcomes and determining whether inquiry-based questioning strategies impact student learning and skill development.

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Appendix A

Protocol Clearance From the Human Subjects Institutional Review Board

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Human Subjects Institutional Review Board

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WESTERN MICHIGAN UNIVERSITY

Date: January 19, 2000

To: Robert Poel, Principal Investigator
Linda Goossen, Student Investigator for dissertation

From: Michael S. Pritchard, Interim Chair

Re: HSIRB Project Number 00-11-13

This letter will serve as confirmation that your research project entitled "Classroom Questioning Strategies as Indicators of Inquiry Based Science Instruction - Part I" has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: 19 January 2002

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Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-5162
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: January 19, 2000

To: Robert Poel, Principal Investigator
Linda Goossen, Student Investigator for dissertation

From: Michael S. Pritchard, Interim Chair

Re: HSIRB Project Number 00-11-14

This letter will serve as confirmation that your research project entitled "Classroom Questioning Strategies as Indicators of Inquiry Based Science Instruction - Part II" has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: 19 January 2002

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Western Michigan University
H. S. I. R. B.
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x [signature]
HSIRB Chair

CONSENT OF CLASSROOM TEACHER

Western Michigan University
Department of Science Studies
Principal Investigator: Robert Poel, PhD
Student Investigator: Linda Goossen

I have been invited to participate in a study of middle school science classrooms, entitled "Classroom Questioning Strategies as Indicators of Inquiry Based Science Instruction". The purpose of the study is to improve knowledge of effective science teaching and learning strategies. This project is Linda Goossen's dissertation project.

WHAT IS EXPECTED OF ME?

- Allow the researcher, Linda Goossen, to observe a lesson in my classroom for use in selecting classrooms for part II of the study.
- Help identify the best day and time for the observation.
- Conduct my lesson as usual; observation will be as unobtrusive as possible.

WHAT ELSE DO I NEED TO KNOW ABOUT THE STUDY?

- I can withdraw my consent or discontinue participation in the study at any time without prejudice or penalty.
- Confidentiality will be maintained. No person, school, or school district will be identified by name in the study. A code number will be used to identify my classroom. The researcher will destroy the master list of code numbers when it is no longer needed.
- All field notes will be secured in a locked cabinet in the principal investigator's office for three years following the study.
- As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to the subject except as otherwise stated in this consent form. Minor effects on the classroom caused by having an observer present and employment risks to me are possible. To protect me from these risks, the researcher will be as unobtrusive as possible while in the classroom and will divulge no information about me or my classroom to any school administrator.
- This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Subjects should not sign this document if the corner does not show a stamped date and signature.

My signature below indicates that I have read and/or had explained to me the purpose and requirements of the study and that I agree to participate.

I, ____

Printed Name **Signature** **Date**

agree to allow observation in my classroom as part of the study described above.

IF YOU HAVE QUESTIONS, please contact Linda Goossen, phone 616-866-2773. You may also contact Dr. Robert Poel, WMU, (616-287-3336); The Chair, Human Subjects Institutional Review Board (616-387-8293; or the Vice President for Research (616-387-8298) at WMU.

Person obtaining consent initials __________ Date ___________

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JAN 19 2001

x [signature]
HSIRB Chair

CONSENT OF CLASSROOM TEACHER

Western Michigan University
Department of Science Studies
Principal Investigator: Robert Poel, PhD
Student Investigator: Linda Goossen

I have been invited to participate in Part II of a study of middle school science classrooms, entitled "Classroom Questioning Strategies as Indicators of Inquiry Based Science Instruction". The purpose of the study is to improve knowledge of effective science teaching and learning strategies. This project is Linda Goossen's dissertation project.

WHAT IS EXPECTED OF ME?

- Allow the researcher, Linda Goossen, to videotape 3-4 lessons (45 – 75 minutes per lesson) in my middle school science classroom classroom.
- Help identify the best day and time for the videotaping (3-4 lessons @ 45 – 75 minutes per lesson).
- Conduct my science lesson as usual.

WHAT ELSE DO I NEED TO KNOW ABOUT THE STUDY?

- A digital video-camera and will be used to record the lessons. Two small microphones will be placed unobtrusively in the classroom to record the classroom discourse. The researcher and a technician will record the classroom discourse, thus the camera will focus on the speakers who have consented to participate. The researcher and technician will remain off to the side of the classroom or small group and will not intrude on any activity.
- I can withdraw my consent or discontinue participation in the study at any time without prejudice or penalty.
- Confidentiality will be maintained. No person, school, or school district will be identified by name in the study. A code number will be used to identify my classroom. The researcher will destroy the master list of code numbers when it is no longer needed.
- All videotapes and field notes will be secured in a locked cabinet in the principal investigator's office for three years following the study and will then be destroyed.
- As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken; however, no compensation or additional treatment will be made available to the subject except as otherwise stated in this consent form. Minor effects on the classroom caused by having an observer present and employment risks to me are possible. To protect me from these risks, the researcher will be as unobtrusive as possible while in the classroom and will divulge no information about me or my classroom to any school administrator.
- This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Subjects should not sign this document if the corner does not show a stamped date and signature.

My signature below indicates that I have read and/or had explained to me the purpose and requirements of the study and that I agree to participate.

I, ____

Printed Name **Signature** **Date**

agree to allow observation in my classroom as part of the study described above.

IF YOU HAVE QUESTIONS, please contact Linda Goossen, phone 616-866-2773. You may also contact Dr. Robert Poel, WMU, (616-287-3336); The Chair, Human Subjects Institutional Review Board (616-387-8293; or the Vice President for Research (616-397-8298) at WMU.

Person obtaining consent initials __________ Date ___________

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JAN 1 9 2001

x [signature]
. HSIRB Chair

Western Michigan University
Department of Science Studies
Principal Investigator: Robert Poel, PhD
Student Investigator: Linda Goossen

Your child has been invited to participate a study of middle school science classrooms, entitled "Classroom Questioning Strategies as Indicators of Inquiry Based Science Instruction". The purpose of the study is to improve knowledge of effective science teaching and learning. This project being conducted to fulfill Linda Goossen's dissertation requirement. Please read the following:

- My permission for my child to participate in this project means that my child may be videotaped as a part of this study. Three or four typical science lessons of 45 to 75 minutes each will be videotaped by the researcher and a technician.
- My child will be free at any time - even during the videotaping - to choose not to participate. If my child refuses or quits, there will be no negative effects on him/her.
- A small video-camera and will be used to record the lessons. Videotaping will be as unobtrusive as possible. The researcher and technician will remain off to the side of the classroom or small group and will not intrude in any activity. The researcher will record the classroom conversation, thus the camera will focus on the speakers who have consented to participate. Two small microphones will be placed unobtrusively in the classroom to record the classroom conversation.
- If you or your child do not give permission, the researcher guarantees that your child will not videotaped at any time during these sessions.
- Confidentiality will be maintained. No student, teacher, school, or school district will be identified by name in the study. A code number will be used to identify the classroom. The researcher will destroy the master list of code numbers when it is no longer needed.
- All videotapes and notes will be secured in a locked cabinet in the principal investigator's office for three years following the study and will then be destroyed.
- The only risks anticipated are minor effects on the classroom caused by having an observer and video-camera present. To protect my child from these risks, the researcher and technician will be as unobtrusive as possible while in the classroom.
- I can withdraw my child from this project at any time without any negative effects on my child.
- This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. You should not sign this document if the corner does not show a stamped date and signature.

My signature below indicates that I, as a parent or guardian, can and do give permission for ________________________ (child's name) to be videotaped as a part of the study of science teaching.

Printed Name	Signature	Date

IF YOU HAVE QUESTIONS, please contact Linda Goossen, phone 616-866-2773. You may also contact Dr. Robert Poel, WMU, (616-287-3336); The Chair, Human Subjects Institutional Review Board (616-387-8293); or the Vice President for Research (616-397-8298) at WMU.

Permission obtained by __________(researcher's initials) Date ___________

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WESTERN MICHIGAN UNIVERSITY
H. S. I. R. B.
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x ____________
HSIRB Chair

STUDENT ASSENT

Western Michigan University
Department of Science Studies
Principal Investigator: Robert Poel, Ph.D.
Student Investigator: Linda Goossen

My classroom has been invited to be videotaped as a part of a study. The goal of the study is to help improve science teaching and learning.

The classroom will be videotaped four times.

My name will not be used in the study.

The videotapes will be locked in a cabinet for at least three years after the study, and then destroyed.

I understand that I can refuse to be videotaped at any time during the study, even if my parents or guardians gave permission for me to be videotaped.

Check one of the following:

_____ I agree to be videotaped.

_____ I do not want to be videotaped.

______________________________ ______________
NAME DATE

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SAMPLE RECRUITMENT LETTER – PART I

Western Michigan University
School of Science Studies
Kalamazoo, MI 49008

Date

Name
Address

Dear (teacher's name):

You have been recommended to me by a colleague as an excellent teacher of science. I am writing to you to ask if you would be interested in being involved in a study that I am currently implementing for my dissertation. This study has been developed to collect information from middle school classrooms that may be used to improve our knowledge of effective teaching and learning of science.

The first part of the study involves my observation of one of your typical teaching sessions of middle school science. I would come to your classroom at the designated time and observe your classroom, taking notes while present. I would be as unobtrusive as possible, so as not to interfere with the lesson. Confidentiality is assured; no person, school, or school district will be identified in the study. All field notes taken in your classroom will be stored for three years in a locked cabinet and then destroyed.

Following this first part of the study, approximately half of the originally observed classrooms will be invited to participate in the second part of the study, which will involve videotaping several lessons. The videotapes and notes will be used to determine effective science teaching strategies. At the completion of the study, all videotapes and notes will be stored for three years and then destroyed.

I understand that this is major request, but believe that the results or the study will help teachers increase the effectiveness of their science teaching. Your school's requirements for participation in research will be followed. I will contact you to make specific arrangements.

I look forward to hearing from you and welcome and appreciate your participation. If you have any questions, please call me at 616-895-3733 (days) or 616-866-2773 (evenings). I will be following this letter with a phone call to discuss your possible participation.

Sincerely,

Linda Goossen

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SAMPLE RECRUITMENT LETTER – PART II

Western Michigan University
School of Science Studies
Kalamazoo, MI 49008

Date
Name
Address

Dear (teacher's name):

I am writing to you to ask if you would be interested in participating in Part II of the study in which you were originally involved, which I am undertaking for my dissertation. As you may recall, in part I of the study, I observed a group of middle school science classrooms so that I could select six schools for part II of the study. In part II, three or four of your classroom sessions will be videotaped so that I can collect more specific information about effective science teaching techniques. Your classroom has been selected for this part of the study and I invite you to participate.

I will come to your classroom at the designated times and videotape your classroom, taking notes while present. The equipment will consist of a videotape recorder and several small microphones set up around the classroom. We will be as unobtrusive as possible, so as not to interfere with the lesson. Confidentiality is insured; no person, school, or school district will be identified in the study. At the completion of the study, all field notes and videotapes taken in your classroom will be stored for three years in a locked cabinet and then destroyed.

This study has been developed to collect information from middle school classrooms that may be used to improve our knowledge of effective teaching and learning of science.
I understand that this is a major request, but believe that the results of the study will help teachers increase the effectiveness of their science teaching. If you agree to participate, I will need your written permission, as well as acknowledgement from your principal. Your school's requirements for participation in research will be followed. I will contact you to make specific arrangements.

I look forward to hearing from you and welcome and appreciate your participation. If you have any questions, please call me at 616-895-3733 (days) or 616-866-2773 (evenings). I will be following this letter with a phone call to discuss your participation.

Sincerely,

Linda Goossen

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SCRIPT OF PHONE CALL TO SCHOOL ADMINISTRATOR TO ASK FOR APPROVAL TO INVITE TEACHERS TO PARTICIPATE IN THE STUDY.

Hello, is this (name of school administrator)?

"This is Linda Goossen. I am a student at Western Michigan University, working on my Ph.D. in science education. My research project is entitled "Classroom Questioning Strategies as Indicators of Inquiry Based Science Instruction". The study has been designed to improve our knowledge of effective teaching and learning of science. I am calling to see if you would give me permission to invite your middle school science teacher(s) to participate in the study."

"The study actually has two parts. The first part entails my visiting and observing 10 – 15 middle school science teachers during a typical class lesson to determine where those teachers fit on a continuum from traditional to inquiry-based the teaching strategy is. After this phase of the study, I will select six classrooms – two traditional, two middle-of-the continuum, and two high level inquiry – from those observed in part I, and invite those six teachers to participate in part II of the study. Part II entails my videotaping three to four typical classroom teaching sessions of each of the six teachers. The teachers do not have to "do" anything other than their usual teaching. The videotaping will be as unobtrusive as possible. The videotapes will ultimately be analyzed for questioning strategies along the continuum of teaching style. This study in no way evaluates the teachers or the classroom."

"Confidentiality is assured - at no time will school districts, principals, teachers or students be identified in the study. Code numbers will be used to identify the classrooms observed in both phases of the study. I will destroy the code lists when they are no longer needed. In addition, the interaction between the teachers and myself is confidential. To protect the teachers and students, I am not allowed to discuss my interactions with the teachers or my observations in the classrooms with you or anyone else."

"I will be following Western Michigan University's Human Subject s Institutional Review Board's protocol for signed consent as well as your school district's policies for participation in research. In part I of the study, all teachers who agree to participate will be required to sign a consent form. In part II of the study, teachers and parents/guardians will be required to sign a consent form, and students will be given an assent form to sign. At any time before or during the study, the teachers, guardians, and students may withdraw their permission to participate."

"Do you have any questions?"

(If so, I answer the questions, unless they ask which teachers I will invite. Then I tell the principal that in order to protect the teacher, I am not allowed to divulge that information. The principal's site approval letter allows me to invite the science

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teachers from that school. The teacher will then be free to turn down the invitation, and at no time will they feel any obligation to participate in the study, and at any time, the teacher may change his or her mind and refuse any further participation.

"If you have no further questions, would you give me approval to invite your teacher(s) to participate in the study?"

If they say no, I say "Thank you for your time".

If they say yes, I then say " I need to get documentation of your approval. I have written a form letter that you may use with your school's letterhead, or you may write your own letter of approval. I will give you copies of the letter of invitation I will be sending to your teacher(s) and a copy of the consent form that your teacher(s) will be required to sign if they agree to participate. I will also give you copies of the letters of invitation and teacher and parent consent forms that will be applicable if your teacher(s) is invited to participate in Part II of the study.

At this point I make an appointment to meet the principal, review all the appropriate documents, answer any additional questions, and get a signed site official approval letter.

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SCRIPT OF PHONE CALL FOLLOWING TEACHER RECRUITMENT LETTER TO SEE IF THE TEACHER IS WILLING TO PARTICIPATE IN THE STUDY

"Hello, is this (the teacher's name)?"

"This is Linda Goossen. I sent a letter to you last week to inform you of my study for my dissertation in science education from Western Michigan University. This call is a follow-up to answer any questions you might have, to describe the study more explicitly, and to see if you agree to participate in the study."

"The study actually has two parts. The first part entails my visiting and observing 10 – 15 middle school science teachers during a typical class lesson to determine where those teachers fit on a continuum from traditional to inquiry-based the teaching strategy is. After this phase of the study, I will select six classrooms – two traditional, two middle-of-the continuum, and two high level inquiry – from those observed in part I, and invite those six teachers to participate in part II of the study. Part II entails my videotaping three to four typical classroom teaching sessions of each of the six teachers. The teachers do not have to "do" anything other than their usual teaching. The videotaping will be as unobtrusive as possible. The videotapes will ultimately be analyzed for questioning strategies along the continuum of teaching style. This study in no way evaluates the teachers or the classroom."

"Confidentiality is assured - at no time will school districts, principals, teachers or students be identified in the study. Code numbers will be used to identify the classrooms observed in both phases of the study. I will destroy the code lists when they are no longer needed. In addition, the interaction between the teachers and myself is confidential. To protect both you and your students, I will not discuss my interactions or my observations in the classrooms with your principal or anyone outside of your room.

"I will be following Western Michigan University's Human Subject s Institutional Review Board's protocol for signed consent as well as your school district's policies for participation in research. First, I have obtained your principal's written approval to invite teachers from this school to participate in the study. All teachers who agree to participate in part I of the study will be required to sign a consent form before the study can begin. For part II, teachers and parents/guardians will be required to sign a consent form), and all the students will be given an assent form to sign. The consent forms for the parents/guardians will be sent home with the students to be signed before the study can begins. If any parent/guardian or student does not agree to participate, the videotaping will not include that particular student. At any time before or during the study, you, the parent or guardian of your students, or the students may withdraw permission to participate."

"Do you have any questions about the study?"

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If the teacher has any questions, I will answer them.

"Would you like to participate?"

If the teacher says no, I will say " Thank you for your time."

If the teacher says yes, I will then reply, "Thank you. Could I make an appointment to come in before the study to meet you and get your signed permission?"

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SCRIPT FOR GETTING CONSENT WHEN I MEET WITH THE TEACHER FOR PART I OF THE STUDY

"This permission form is called an informed consent form. Informed consent is the process by which you will receive written information about the study that will enable you to voluntarily decide whether or not to participate in the study."

At this point, I will read through the informed consent document with the teacher.

"Do you have any questions?"

If so, I will answer them.

"Are you interested in participating in the study?"

If the teacher says yes, I will say "Would you please sign and date the informed consent document?"

At this point, I will schedule a date to observe the classroom.

If the teacher says no, I will say "Thank you for your time. It was nice to meet you." Then I will leave.

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SCRIPT OF PHONE CALL FOLLOWING TEACHER RECRUITMENT LETTER TO ASK IF THE TEACHER IS WILLING TO PARTICIPATE IN PART II OF THE STUDY

"Hello, is this (the teacher's name)?"

"This is Linda Goossen. I sent a letter to you last week to ask if you are interested in participating in part II of the study for my dissertation in which you were involved a few weeks ago. This call is a follow-up to answer any questions you might have, to describe the study more explicitly, and to see if you agree to participate in the study."

"The study actually has two parts. The first part entailed my visiting and observing 10 – 15 middle school science teachers during a typical class lesson to determine where the teaching strategies in those classrooms fit on a continuum from traditional to inquiry-based. Having completed part I, I have selected your classroom as a participant in part II, if you agree. Part II entails my videotaping three to four of your typical classroom teaching sessions. You do not have to "do" anything other than their usual teaching. The videotaping will be as unobtrusive as possible. The videotapes will ultimately be analyzed for questioning strategies along the continuum of teaching style. This study in no way evaluates the teachers or the classroom."

"Confidentiality is assured - at no time will school districts, principals, teachers or students be identified in the study. Code numbers will be used to identify the classrooms observed in both phases of the study. I will destroy the code lists when they are no longer needed. In addition, the interaction between the teachers and myself is confidential. To protect both you and your students, I will not discuss my interactions or my observations in the classrooms with your principal or anyone outside of your room. The videotapes and any field notes will be kept in a locked cabinet in the primary investigator's office for a minimum of three years following the study.

"I will be following Western Michigan University's Human Subject s Institutional Review Board's protocol for signed consent as well as your school district's policies for participation in research. I have obtained your principal's written approval to invite teachers from your school to participate in part II of the study. For part II, you and the parents/guardians of your students will be required to sign a consent form, and all the students will be given an assent form to sign. Informed consent is the process by which you, the parents or guardians, and the students will receive written information about the study that will enable you to voluntarily decide whether or not to participate in the study. The consent forms for the parents/guardians will be sent home with the students to be signed before the study can begins. If any parent/guardian or student does not agree to participate, the videotaping will not include that particular student. At any time before or during the study, you, the parent or guardian of your students, or the students may withdraw permission to participate."

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"Do you have any questions about the study?"

If the teacher has any questions, I will answer them.

"Would you like to participate?"

If the teacher says no, I will say " Thank you for your time."

If the teacher says yes, I will then reply, "Thank you. Could I make an appointment to come in before the study to get your signed permission, give you permission forms to send home with your students, and to schedule the videotaping sessions?"

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SCRIPT FOR GETTING CONSENT WHEN I MEET WITH THE TEACHER FOR PART II OF THE STUDY

"This permission form is called an informed consent form. Informed consent is the process by which you will receive written information about the study that will enable you to voluntarily decide whether or not to participate in the study."

At this point, I will read through the informed consent document with the teacher.

"Do you have any questions?"

If so, I will answer them.

"Are you interested in participating in the study?"

If the teacher says no, I will say "Thank you for your time. It was nice to meet you." Then I will leave.

If the teacher says yes, I will say "Would you please sign and date the informed consent document?"

If the teacher agrees to participate in the study, I will then say, "I also need informed consent from the parents or guardians of your students. Will you please send these forms home with your students to get the appropriate signatures. I will hand him /her the appropriate number of forms and say "Thank you." How long can I expect to wait before all the forms are signed and returned?"

"When I return to your class to begin the videotaping sessions, I will bring forms for each of the students to sign, giving his or her assent to be videotaped. If either the parents or the students do not give permission to be videotaped, that the child will not be videotaped at any time during the sessions. Always keep in mind that you, the parents, or the students can withdraw permission to participate in the study at any time during the study."

At that point, I will schedule the dates to begin videotaping.

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Appendix B

**Observing Teaching Practices in K-12 Classrooms:
Instruments and Methods
Focused on Science
Version B**

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OBSERVING TEACHING PRACTICES IN K-12 CLASSROOMS:

INSTRUMENTS AND METHODS

focused on Science

Version B:

for multiple classroom observations to improve programming

Mark Jenness, Ed.D
Zoe A. Barley, Ph.D

For use only by those who have received certified training

Science and Mathematics Program Improvement (SAMPI)
Western Michigan University

1999

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OBSERVING TEACHING PRACTICES IN K-12 CLASSROOMS:
INSTRUMENTS AND METHODS
focused on Investigative Science
Version B: for multiple classroom observations to improve programming

Why observe teaching practices?

Most school reform efforts are focused on improving student achievement and well being. Accomplishment of these goals is directly affected by the quality of instruction and classroom management. Improving teaching practices that lead to increased student learning must be an important objective for school reform.

To help improve instructional practices, there must be a way to determine their current nature and quality based on state and national goals for science education. The best way to gather credible information (although not necessarily the most efficient or cost-effective) is to observe actual teaching in classrooms. If observation data are used effectively and appropriately, it can help teachers improve their instructional practices, and thereby improve student learning.

What is the orientation of the instruments and methods in this package?

These classroom observation materials are grounded in the Michigan and national standards in science content and pedagogy. The standards emphasize science education that is inquiry-oriented, investigative, and engaging for all students. The teacher is seen as a facilitator of learning rather than a dispenser of information.

The focus of these observation materials is on lessons, gathering information about the design, implementation, and content of a lesson and the classroom culture in which that lesson is conducted. These instruments are not intended to evaluate teachers, but only to assess teaching practices in the context of the lesson being observed.

For science, there are two versions of the instrument. Version B, presented in this document, is designed to be used when multiple observations are being conducted in a particular school, school district, or service area. The data is compiled (anonymously) and used to determine what kinds of professional development or technical assistance is needed. This version also provides data to assess the overall status of science or mathematics classroom practice. Version A, available in a separate document, is for use one-on-one with a teacher. Following an observation, the observer shares their findings as a way to diagnose the strengths and limitations of the lesson and to suggest strategies for improvement.

The instruments are designed for observing science lessons in kindergarten through 12th grade classrooms.

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Where can I get more information?

These materials were produced with support from a Michigan Goals 2000 grant from the Michigan Department of Education by Science and Mathematics Program Improvement (SAMPI) at Western Michigan University. Ideas have been drawn from a variety of sources to create this set of materials.

Some elements of the observation instruments have been adapted from the National Science Foundation Local Systemic Change Initiative Classroom Observation Protocol developed by Horizon Research, Inc. of Chapel Hill, North Carolina. Special thanks go to Horizon Research for the fine work they have done in the field of classroom observation instrumentation.

In addition, Michigan educators from various institutions—local school districts, Mathematics and Science Centers, Michigan Department of Education, intermediate school districts, and colleges and universities—have provided ideas and reviewed the materials. Their advice has been invaluable in making modifications to the instrument to make it more "user-friendly."

Various versions of the instruments have been field tested in more than 200 classrooms between 1996 and 1999. This final version is the result of that work.

Specific classroom observation instruments are often difficult to obtain, since most are developed and used within a particular institution or across a set of projects. For more information about this set of materials or sources of other materials, contact SAMPI at 616-387-3791.

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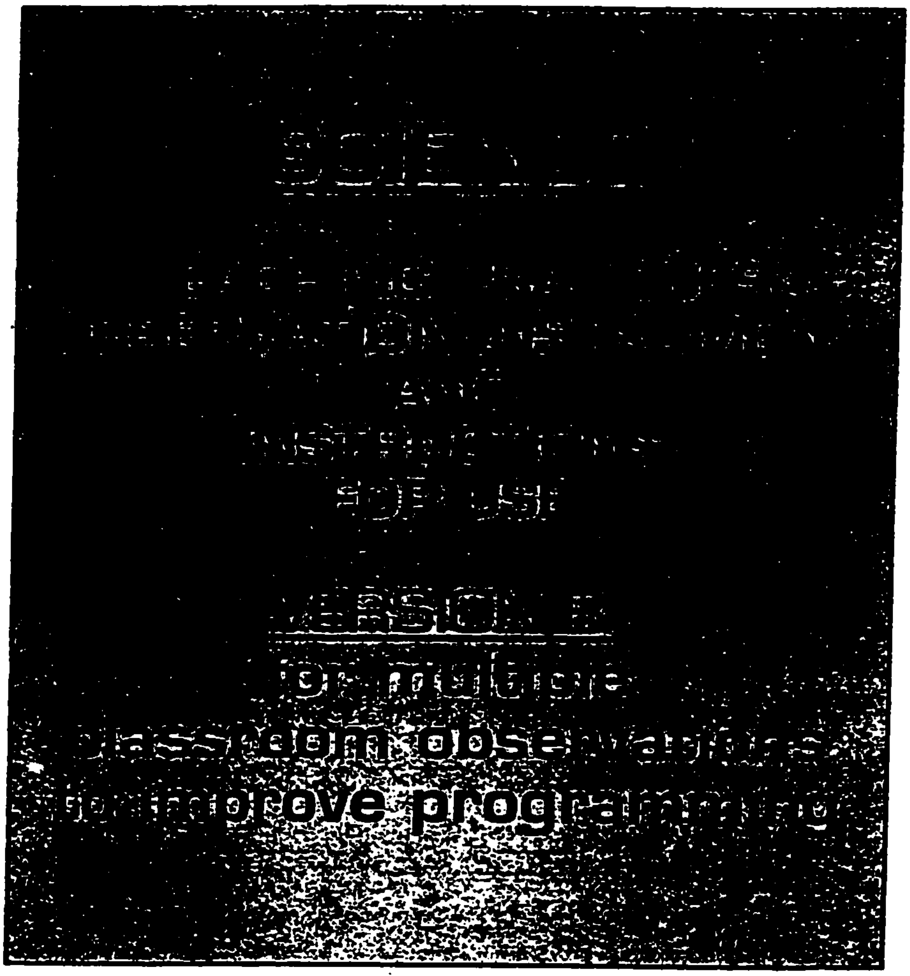

VERSION B
for multiple
classroom observations
to improve programming

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K-12 SCIENCE TEACHING PRACTICES OBSERVATION INSTRUMENT AND PROCEDURES VERSION B: To Improve Programming and Other Support for Teachers

INSTRUCTIONS FOR USE

What is the sequence of events in using this instrument?

1. Arranging the observation session
2. Checking in on the day of the observation
3. Conducting a pre-observation interview (2-5 minutes)
4. Observing the science lesson
5. Conducting a post-observation interview (2-5 minutes)
6. Completing the observation form
7. Compiling and interpreting the data
8. Sharing the information
9. Using the information to help improve professional development and other teacher support efforts

1 Arranging the observation session

Arrangements for the observation will vary depending on the context in which the observation is conducted (as part of a special project or program, for all teachers in a school or district, or for a particular group of teachers). However, the observation session should not be a surprise for the teacher. The teacher should know the purpose of the observation, understand how the information will be used, know who will conduct it, and help select the time for the visit. Obviously, the observation should be done when a "typical" science lesson is being conducted. The observation instrument is not very useful on a test day.

Whether the instrument or set of indicators is shared with the teacher beforehand will depend on circumstances. For strictly diagnostic purposes (to give immediate feedback to the teacher), being familiar with the indicators is probably useful for the teacher. If the purpose is to gather information to determine strengths and weaknesses (for deciding about how to help teachers improve), it may not be useful for teachers to know the indicators beforehand, since the teacher then might "teach to the observer." See sections 8 and 9 below for more information on using the data.

Teachers involved in specific projects (i.e., a professional development program in inquiry-based science) should know at the time of enrollment in the project that a classroom observation is an expectation and what the general parameters are for it.

The observation and resulting use of the information will be most successful if both teacher and observer are comfortable with the arrangements for the observation.

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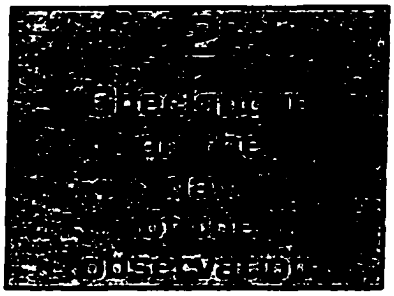
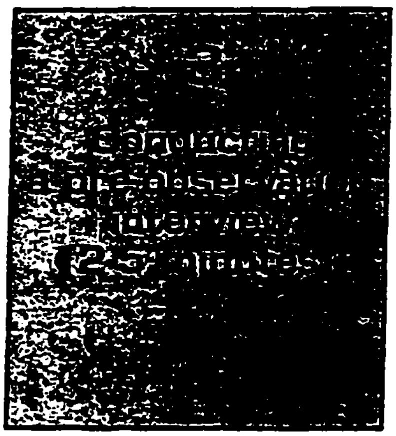


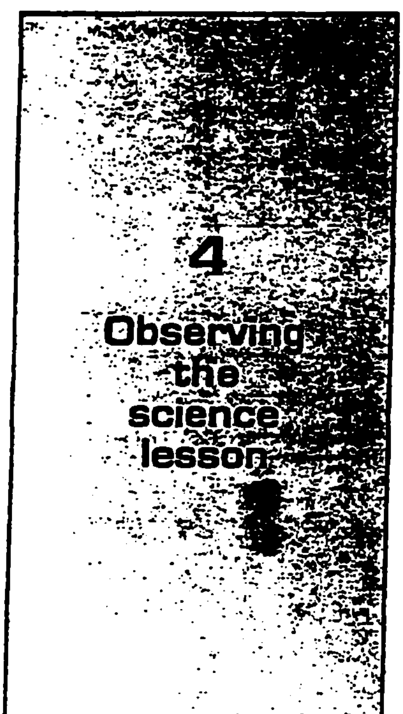
Be sure to check in at the office before going to the classroom, unless other arrangements have been made. Arrive a few minutes early so there is time to conduct the pre-observation interview (see #3 below). Introduce yourself to the teacher and ask them where you can sit to be "out of the way" but still see what is going on in the classroom.

The teacher may want to introduce you to the students and let them know why you are visiting their classroom or the teacher may want you to introduce yourself to the students.



When you arrive, it will be important to ask the questions on the pre-observation interview. This will be quite informal, taking just a few minutes. Working this interview in can sometimes be a challenge, depending on the situation. Often there is little time between one lesson and the next. Or the teacher may need to give attention to particular students. The observer must find a way to ask the questions without being intrusive.

Some pre-observation interview questions are more fully answered by the teacher as they begin the lesson, reminding students what they will be doing during that lesson and what they have done previously. If a text or other printed curriculum materials are being used, the observer can glean information about the lesson from those sources. If possible, be sure to have a copy of materials being used by the students to review as you observe the lesson.



You should already be trained on the use of the observation instrument and be familiar with the indicators and how they are characterized for this instrument.

During the observation, station yourself somewhere in the room where they can easily see what is going on in all parts of the room. Sometimes it may be necessary to move to other locations during a lesson, depend-ng on how the session is conducted. It may also be appropriate to walk around the room when students are working individually or in small groups, as long as it does not intrude on the lesson. It may also be appropriate to ask questions of students while in their small groups (be cautious, however, not to make judgments based on a few interactions with a few students). It might be better to "listen-in" on conversations. Be sure it is OK with the teacher to do this.

Take notes during the lesson with enough detail so that you can complete the observation instrument after the session. As the lesson begins, write the date, time the lesson begins, name of the teacher and school, and the nature of the lesson and where it fits in the unit (from pre-observation interview). Also note how many students are in the class, how the classroom is arranged, the kinds of science-related equipment or supplies evident, and other information about the classroom setting. Note the kinds of materials being used (e.g. text, kits, etc.).

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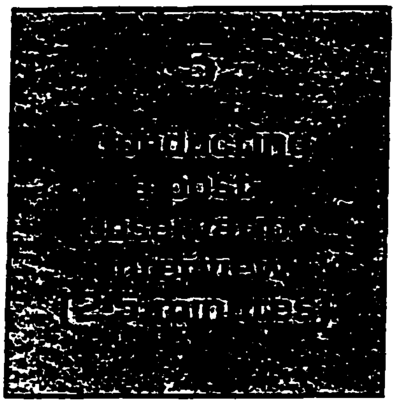
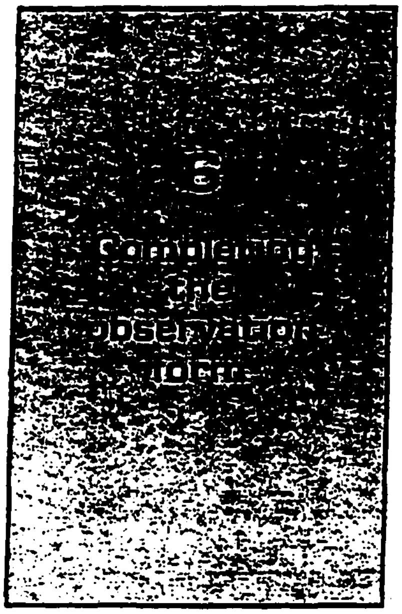


Conducting this brief and informal interview can also be a challenge, depending on circumstances. This information will be useful, however, as you complete the observation instrument. Occasionally, there is time during the lesson to ask the teacher additional questions, depending on how the lesson is conducted. Use those opportunities when they present themselves.

If the observation is being conducted for the purpose of providing direct feedback to the teacher, some questions can be left until the observer meets with the teacher following the lesson.



COMPLETE THE OBSERVATION FORM AS SOON AFTER THE OBSERVATION AS POSSIBLE.

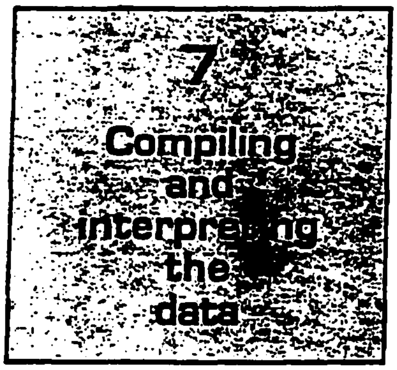
A code number can be assigned to the observation so the observer can keep track of multiple observations. The teacher's name should not appear on the observation form.

Use the notes from the observation and pre- and post-interviews to 1) complete the section about the lesson and classroom and 2) assess each indicator and provide evidence for the judgment.

Assessments should be deliberate and thoughtful. It is important to provide a rationale by giving evidence for the rating. If there is not enough evidence for a particular indicator, check the "don't know" box.

Space is provided for additional comments or discussion of other important indicators identified during the observation.

Once the form is completed, it is suggested that the observer dispose of the observation notes.



Interpreting observer findings from the observation can be challenging. When doing multiple observations, data can be compiled when all observations are complete. Data can be compiled by hand or by using a computer database program at least capable of providing frequencies. See separate Data Analysis section in this packet following the Guide to the Indicators section.

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It is important to share with teachers what has been learned from the observation(s). If the observation has been done to provide direct feedback to a teacher, that can be done as a one-on-one discussion. The observer can supply the teacher with a copy of the completed observation form at the time of the debriefing meeting. DO NOT JUST SEND THE TEACHER THE RESULTS WITHOUT HAVING A ONE-ON-ONE DISCUSSION. The teacher and observer must be able to discuss the findings if these are to be useful. Prior to sharing the results with the teacher, the observer should review the purpose of the observation and how the indicators help elucidate the nature and effectiveness of teaching practices. THE EMPHASIS OF THIS DISCUSSION SHOULD BE ON HOW TO IMPROVE TEACHING PRACTICES. Refer to the Suggestions for Improvement section following the Guide to the Indicators in this packet of materials.

Data from multiple observations can be compiled and interpreted as indicated in #7. These data can be shared with people who identify instructional needs, provide professional development, or track progress toward school improvement goals. No names should be associated with any data provided, nor should any demographic information be provided that might identify a particular teacher. Information from multiple observations should only be reported as group data.

9 Using the information to improve professional development and otherwise support teachers

An important use for data from multiple observations is to make decisions about the nature and extent of professional development for teachers. As observation data are analyzed (see Data Analysis), the data can be used to identify strong and weak teaching practices. They can identify gaps that can then be prioritized. Using this information, a professional development plan can be devised, appropriate professional development sessions organized, and suitable professional development providers recruited.

Observation information can be used to identify the kinds of professional development that will meet specific needs of an individual teacher or educators in a building or district school. With this information, professional development does not have to be generic. It can be tailored to specific curriculum implementation efforts and associated instructional strategies.

Professional development providers can be more creative and effective in meeting needs of teachers.

The challenge for those making decisions about professional development is to recruit competent and effective providers and conduct the professional development in a format that works for participants. One promising format is a learning community, in which teachers work with facilitation help from specialists to address gaps identified by the observations.

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K-12 SCIENCE TEACHING PRACTICES LESSON OBSERVATION

PRE-OBSERVATION INTERVIEW

After introducing yourself to the teacher and expressing appreciation for allowing you to observe the science lesson, ask the following:

1. What are you doing in science today? Tell me about your plans for today's lesson.

2. What science unit are you working on? Where does today's lesson fit in this unit? What did you do yesterday in science? What are your plans for tomorrow?

3. What instructional materials are you using? What science program (text, kit, etc.) are you using?

4. Is there anything in particular that I should know about this class?

POST-OBSERVATION INTERVIEW

Thank the teacher for allowing you to observe the class. If time and circumstances permit, ask the following:

1. Were there ways in which the lesson was different from what you had planned? Did you accomplish everything you intended?

2. What is your assessment of how well students understood science ideas in today's lesson?

3. What are the challenges you face in encouraging students to be actively engaged in learning science?

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CODE NUMBER:

K-12 SCIENCE TEACHING PRACTICES OBSERVATION FORM–Version B: To improve programming

This form should be completed using the observer's notes and information from the pre- and post-observation interviews. Complete this form as soon after the observation session as possible, while thoughts are fresh.

DATE OF OBSERVATION ____________________ OBSERVER ____________________

TIME OF OBSERVATION: Start ____________ End ____________ GRADE LEVEL ____________

INFORMATION ABOUT THE LESSON AND CLASSROOM

1. In a few sentences, describe the lesson observed. Include where this lesson fits in the overall unit of study.

2. Indicate the primary intended purpose(s) of this lesson based on the pre- and post-observation interviews.

   - O Identify prior student knowledge
   - O Introduce new science concepts
   - O Develop conceptual understanding
   - O Review science concepts
   - O Demonstrate how a science concept applies in a real world context
   - O Develop awareness of contributions of scientists from diverse background
   - O Other. Describe: ______________________________
   - O Learn science process and skills
   - O Learn science vocabulary/specific science facts
   - O Develop appreciation for core science ideas
   - O Assess student understanding of science concepts

3. Briefly describe the instructional materials used in the lesson (e.g., textbooks, science kits, science equipment/supplies, audio-visuals). Give specific names of materials being used.

4. Indicate major ways that student activities were conducted.

   O Whole group activity O Small group activity O Pairs of students O As individuals

5. Rate the adequacy of classroom resources to support the science lesson.

   |1 |2 |3 |4 |5 |6 |7 |
   Few resources — Many Resources

6. Rate the arrangement of the room relative to how well it facilitates student interactions.

   |1 |2 |3 |4 |5 |6 |7 |
   Inhibits interactions — Facilitates interactions

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LEVELS OF ACCOMPLISHMENT

In this section, rate each of the indicators or answer the questions in four areas: planning/organization, implementation, content, and classroom culture. Note that any single lesson may not provide enough evidence for every indicator or question. In that case, check the DON'T KNOW box. Note any other indicators you consider important in understanding the lesson. Refer to the "Guide to the Indicators" for clarification of indicators.

PLANNING/ORGANIZATION OF THE SCIENCE LESSON

1. **Does the lesson come directly from a pre-packaged science program (i.e., AIMS, DASH, district kit) with very few teacher modifications?**

Yes	No	Don't Know

If yes, name of program and specific lesson.

2. **Were supplies and equipment available to adequately conduct the lesson?**

Yes	No	Don't Know

If no, what major things were missing or deficient.

3. **Was the lesson organized to provide substantive student-student interactions?**

Yes	No	Don't Know

If yes, what is the evidence?

4. **Was the lesson organized to provide substantive teacher-student interactions?**

Yes	No	Don't Know

If yes, what is the evidence?

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PLANNING/ORGANIZATION CONTINUED...

5. Were investigative science tasks essential elements of the lesson plan (e.g., manipulation of information to help make sense of content, elements of problems-solving situations, connections to real world experiences)?

Yes	No	Don't Know

If yes, what is the evidence?

6. Was the lesson organized so that it appropriately addressed students' experiences, developmental levels, preparedness, and/or learning styles?

Yes	No	Don't Know

If yes, what is the evidence?

7. Was the lesson organized so that it appropriately addressed issues of access, equity, and diversity?

Yes	No	Don't Know

If yes, what is the evidence?

8. Was the lesson organized so there was adequate time for students and/or the teacher to reflect on the lesson and its content?

Yes	No	Don't Know

If yes, what is the evidence?

9. Was the lesson organized so there was adequate time for wrap-up and closure of the lesson?

Yes	No	Don't Know

If yes, what is the evidence?

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PLANNING/ORGANIZATION CONTINUED...

10. Did the lesson incorporate student and/or teacher use of technology (i.e., computers, science monitoring equipment, calculators)?

Yes	No	Don't Know

Note: If incorporation of technology was a major part of the lesson, complete the technology support section of this form.

11. Other comments about lesson planning/organization.

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IMPLEMENTATION OF THE SCIENCE LESSON

1. Teacher appeared confident in his/her ability to teach this science lesson.

1	2	3	4	5	6	7
Limited Confidence						Great Confidence

Supporting evidence for rating:

☐ Don't Know

2. Periods of student-teacher interaction were probing and substantive (questioning and dialog emphasized higher-order thinking and deep understanding and exposed students' prior knowledge).

1	2	3	4	5	6	7
Weak Student-Teacher Interaction						Strong Student-Teacher Interaction

Supporting evidence for rating:

☐ Don't Know

3. The teacher's classroom management style was effective in engaging students in lthe lesson.

1	2	3	4	5	6	7
Limited Effectiveness						Very Effective

Supporting evidence for rating:

☐ Don't Know

4. The pace of the lesson was appropriate for the developmental levels of the students.

1	2	3	4	5	6	7
Poorly Paced						Well Paced

Supporting evidence for rating:

☐ Don't Know

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IMPLEMENTATION CONTINUED . . .

5. **Periods of student-student interaction were productive and enhanced individual understanding of the lesson's content.**

1	2	3	4	5	6	7
Interaction Not Productive						Interaction Very Productive

Supporting evidence for rating:

☐ Don't Know

6. **Other comments about lesson implementation or other indicators of importance.**

OVERALL RATING FOR IMPLEMENTATION OF THE SCIENCE LESSON

The overall rating represents the observers best summary judgment of the appropriateness and quality of the lesson IMPLEMENTATION. Overall ratings are not necessarily intended to be the numerical average of the ratings of the indicators for Implementation of the Lesson. There may be other factors that influence an overall rating.

1	2	3	4	5	6	7
Implementation of the lesson not at all consistent with best practice in investigative science teaching and learning						Implementation of the lesson very consistent with best practice in investigative science teaching and learning

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CONTENT OF THE SCIENCE LESSON

1. The science content of the lesson was important and worthwhile.

1	2	3	4	5	6	7
Trivial Content						Important Content

Supporting evidence for rating:

☐ Don't Know

2. Students were intellectually engaged with important ideas related to the focus of the lesson.

1	2	3	4	5	6	7
Limited Engagement						Significant Engagement

Supporting evidence for rating:

☐ Don't Know

3. Science was portrayed as a dynamic body of knowledge continually enriched by conjecture, investigation, analysis, and/or proof/justification.

1	2	3	4	5	6	7
Limited Portrayal						Strong Portrayal

Supporting evidence for rating:

☐ Don't Know

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CONTENT CONTINUED . . .

4. The teacher showed an understanding of the science concepts and content that were the focus of the lesson and the topical/conceptual area being addressed by the lesson.

1	2	3	4	5	6	7
Limited Understanding						Strong Understanding

Supporting evidence for rating:

[ ] Don't Know

5. The teacher made connections between concepts/content in this lesson and previous and future lessons in the overall unit or topic being addressed.

1	2	3	4	5	6	7
Weak Showing						Strong Showing

Supporting evidence for rating:

[ ] Don't Know

6. The teacher made connections between this lesson and other areas of science or other s:.bjects.

1	2	3	4	5	6	7
Limited Connnections						Strong Connections

Supporting evidence for rating:

[ ] Don't Know

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CONTENT CONTINUED . . .

7. The lesson incorporated applications of the science content/concepts to real-world situations.

1	2	3	4	5	6	7
Limited Applications						Strong Applications

Supporting evidence for rating:

☐ Don't Know

8. The teacher incorporated abstractions (scientific theories and models) as appropriate.

1	2	3	4	5	6	7
No Abstractions						Many Abstractions

Supporting evidence for rating:

☐ Don't Know

9. Other comments about lesson content or other indicators of importance.

OVERALL RATING FOR CONTENT OF THE SCIENCE LESSON

The overall rating represents the observers best summary judgment of the appropriateness and quality of the lesson CONTENT Overall ratings are not necessarily intended to be the numerical average of the ratings of the indicators for Content of the Lesson. There may be other factors that influence an overall rating.

1	2	3	4	5	6	7
Insignificant or trivial science content addressed in lesson						Significant science content consistent with science standards addressed in lesson

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CLASSROOM CULTURE IN WHICH THE SCIENCE LESSON WAS CONDUCTED

1. Active participation of all students was encouraged and valued.

1	2	3	4	5	6	7
Participation Not Encouraged/ Not Valued						Participation Strongly Encouraged/Valued

Supporting evidence for rating:

☐ Don't Know

2. The teacher showed respect for and valued students' ideas, questions, and contributions to the lesson.

1	2	3	4	5	6	7
Limited Respect/Value						Great Respect/Value

Supporting evidence for rating:

☐ Don't Know

3. Students showed respect for and valued each others' ideas, questions, and contributions to the lesson.

1	2	3	4	5	6	7
Limited Respect/Value						Great Respect/Value

Supporting evidence for rating:

☐ Don't Know

4. The classroom climate for the lesson encouraged all students to generate ideas, questions, conjectures, and/or propositions.

1	2	3	4	5	6	7
Climate Discouraged Students						Climate Encouraged Students

Supporting evidence for rating:

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CLASSROOM CULTURE CONTINUED . . .

5. Student-student interactions reflected collaborative working relationships.

1	2	3	4	5	6	7
Limited Collaborative Relationships						Strong Collaborative Relationships

Supporting evidence for rating: ☐ Don't Know

6. Teacher-student interactions reflected collaborative working relationships.

1	2	3	4	5	6	7
Limited Collaborative Relationships						Strong Collaborative Relationships

Supporting evidence for rating: ☐ Don't Know

7. The teacher's language and behavior showed sensitivity to issues of gender, race/ethnicity, special needs, and/or socio-economic status.

1	2	3	4	5	6	7
Little Sensitivity						Strong Sensitivity

Supporting evidence for rating: ☐ Don't Know

8. Other comments about classroom culture or other indicators of importance.

OVERALL RATING FOR CLASSROOM CULTURE

The overall rating represents the observers best summary judgment of the appropriateness and quality of the CLASSROOM CULTURE. Overall ratings are not necessarily intended to be the numerical average of the ratings of the indicators for the Classroom Culture in Which the Lesson was Conducted. There may be other factors that influence an overall rating.

1	2	3	4	5	6	7
Classroom culture not supportive of student learning						Classroom culture very supportive of student learning

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OPTIONAL SUMMARY RATING OF THE LESSON

Depending on how the data from the observation of multiple lessons is going to be used, the observer may want to do a summary rating of the entire lesson, based on the ratings of the four major elements (five elements, if the technology support material is used). If the purpose of the set of observations is to get an overview of the nature and quality of science lessons being conducted, the summary rating can be useful. However, unless the number of the set of lessons is fairly large (an adequate proportion of the population of teachers being sampled and selected randomly) generalizing from the summary ratings of the sample to the entire population is problematic. The summary rating is useful at looking at change over time among a population of teachers, as long as the sampling is credible.

The summary rating represents the observers best judgment of the quality of the lesson. The summary rating is not necessarily intended to be the numerical average of the ratings of the indicators for the four elements: planning/organization, implementation, content, and classroom culture. There may be other factors that influence the summary rating.

SUMMARY RATING OF THE LESSON

1	2	3	4	5	6	7
Overall, the lesson was not at all reflective of a high quality investigative science lesson.						Overall, the lesson was an excellent example of a high quality investigative science lesson

SUPPORTING EVIDENCE FOR THE SUMMARY RATING:

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Appendix C

Inquiry Instrument

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Indicators of Inquiry

1. Periods of student–teacher interaction were probing and substantive (discourse emphasized higher-order thinking and deep understanding and exposed students' prior knowledge).

1	2	3	4	5
weak S- T interaction				strong S-T interaction

2. The students were intellectually engaged with important ideas related to the focus of the lesson.

1	2	3	4	5
limited engagement				significant engagement

3. The teacher showed respect for and valued students' ideas, questions, and contributions to the lesson

1	2	3	4	5
limited respect				great respect

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4. The classroom climate for the lesson encouraged **all** students to generate ideas, questions, conjectures, and/or propositions.

1	2	3	4	5
limited encouragement				strong encouragement

5. The teacher encouraged students to predict, hypothesize, and make inferences.

1	2	3	4	5
limited encouragement				strong encouragement

6. The teacher encouraged students to gather, record, analyze, and interpret data.

1	2	3	4	5
limited encouragement				strong encouragement

#1-4 from Observing Teaching Practices in K-12 Classrooms.

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Appendix D

Student and Teacher Question Types

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CLASSIFICATION OF STUDENT AND TEACHER QUESTIONS

I. Student to teacher questions

S - learning - reask same question
S - learning - clarification
S - learning - confirmation
S - learning - explanation
S - learning - information
S - learning - procedural
S - learning - procedural clarification
S - learning - procedural confirmation
S - learning - procedural information
S - learning - rhetorical
S - learning - solving

S - other
S - other - clarification
S - other - confirmation
S - other - procedural
S - other - rhetorical
S - reask same question

II. Student to student questions

S - S - learning - clarification
S - S - learning – confirmation
S - S - learning - explanation
S - S - learning - information
S - S - learning - memory
S - S - learning - rhetorical
S - S - learning - solving

S - S - other
S - S - other - clarification
S - S - other - confirmation
S - S - other - information
S - S - other - rhetorical

S - S - procedural
S - S - procedural clarification
S - S - procedural confirmation
S - S - procedural information

S - S - worksheet - analysis
S - S - worksheet - repeat question
S - S - worksheet - solving
S - S - worksheet - understanding

III. Teacher to student(s) questions

T - learning - analysis
T - learning - analysis – probe 1
T - learning - analysis - probe 2
T - learning - analysis - probe 3
T - learning - analysis - probe 4
T - learning - analysis - probe 5
T - learning - analysis - probe 6
T - learning - analysis - probe 7
T - learning - analysis - probe 8
T - learning - clarification
T - learning - comprehension
T - learning - comprehension – probe 1
T - learning - comprehension - probe 2
T - learning - comprehension - probe 3
T - learning - comprehension - probe 4
T - learning - comprehension - probe 5

T - classroom - clarification
T - classroom - confirmation
T - classroom - other
T - classroom - procedural
T - classroom - rhetorical

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T - learning - comprehension - probe 6
T - learning - comprehension - probe 7
T - learning - comprehension - probe 8
T - learning - comprehension - probe 9
T - learning - confirmation
T - learning - confirmation – probe 1
T - learning - memory/comprehension
T - learning - mem/ comp – probe 1
T - learning - mem/ comp - probe 2
T - learning - mem/ comp - probe 3
T - learning - mem/ comp - probe 4
T - learning - mem/ comp - probe 5
T - learning - mem/ comp - probe 6
T - learning - memory
T - learning - memory - probe 1
T - learning - memory - probe 2
T - learning - memory - probe 3
T - learning - memory - probe 4
T - learning - memory - probe 5
T - learning - memory - probe 6
T - learning – procedural analysis
T - learning - procedural analysis - probe
T - learning - procedural analysis - probe 2
T - learning - procedural clarification
T - learning - procedural conf - probe
T - learning - procedural conf - probe 2
T - learning - procedural conf - probe 3
T - learning - procedural conf - probe 4
T - learning - procedural conf - probe 5
T - learning - procedural confirmation
T - learning - procedural solving
T - learning - procedural solving – probe 1
T - learning - procedural solving - probe 2
T - learning - procedural solving - probe 3
T - learning - procedural comprehension
T - learning - procedural comprehension – probe 1
T - learning - procedural comprehension - probe 2
T - learning - procedural comprehension - probe 3
T - learning - procedural
T - learning - returns student-question
T - learning - rhetorical
T - learning - solving
T - learning - solving – probe 1
T - learning - solving - probe 2
T - learning - solving - probe 3
T - learning - solving - probe 4

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Appendix E

Questioning Strategy Coding Scheme

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CODING OF QUESTIONING STRATEGY

DQ teacher initiated solving & analysis questions **DQ_P** probes
CQ teacher initiated memory and comprehension questions **CQ_P** probes

A student answer - correct or partially correct
A_I student answer - incorrect
A_M multiple student answers - **A_{MM}** **A_{MC}** **A_{MI}** (multiple multiple, multiple correct, multiple incorrect)
A_{OT} student answer off topic or not to the question asked – not necessarily wrong
$A_?$ students says s/he doesn't know answer

(a) the length of wait-time

(b) the verbal response strategies of teachers following wait-time I, if <u>no student response is forthcoming</u>. The teacher may:

- (i) ask the same question again
- (ii) rephrase the question in order to clarify
- (iii) ask a different question or launch into a different topic in order to lead to the desired response
- (iv) (continued) discussion about concept/question
- (v) answer the question
- (vi) criticize the student(s) for not responding
- (vii) designate next speaker
- (viii) walks off/ignores lack of answer/goes on to another concept or question
- (ix) tells student to collect data to answer question

(c) the length of wait-time II

(d) the types of verbal response strategies of teachers following student response.
The teacher may:

- (i) request elaboration or the answer
- (ii) request explanation of the answer
- (iii) designate the next speaker
- (iv) challenge/refute the student's answer
- (v) solicit ideas of alternative solutions to the question
- (vi) affirm/accept (sanction) the student's answer
  - **p**= positive sanction (includes "right")
  - **n** = neutral sanction (includes repeating answer or a neutral O.K.)
- (vii) solicit additional ideas
  1. ask the same question again
  2. rephrase the question in order to clarify
  3. ask a different question in order to lead to the desired response
  4. ask a different question to get more explicit information

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(viii) (continue the) discussion about the concept/question
(ix) reask or rephrase question in order to confirm or emphasize student answer
(x) answer the question him/her self
(xi) clarify/confirm student answer
(xii) cuts off student answer
(xiii) tells student(s) to collect the data to answer the question
// terminates discourse regarding the question/concept

(e) the types of verbal response strategies of the student who answered the question following wait time II or following teacher response to student response. The answering student may:
(i) adds to his/her answer
(ii) changes his/her answer

(f) the types of verbal response strategies of <u>a different student</u> following wait-time II, <u>after a student has answered the question</u>. Another student may:
(i) request elaboration of the answer
(ii) request explanation of the answer
(iii) challenge the student's answer
(iv) accept the student's answer (iv_I = incorrect)
(v) answer the question him/her self (v_I – incorrect)
(vi) add to original student's answer

(g) how teachers field student questions; these fielding behaviors will be classified according to whether the student question is:
(1) related to a teacher question or statement
(2) related to a student question or statement
(3) not apparently related to other discourse

The teacher may:
(i) answer the question
(ii) ignore the question
(iii) allow another student to answer the question
(iv) reword the question in order to clarify
(v) discuss the question/concept
(vi) dismiss or reject the question
(vii) postpone the question
(viii) pose a new or different question back to the student to lead to the desired response or to get more explicit information
(ix) return the question to the questioner
(x) relay the question to the class or a classmate
(xi) praise the question
(xii) wait for the questioner or another student to respond to the question
(xiii) seek clarification of the question
(xiv) call for further research
(xv) say he/she does not know the answer

(h) teacher cuts off student answer

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Appendix F

Student and Teacher Questioning Data

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Table 1

Student Questions Grouped by Inquiry Level of the Lesson

Lesson	No. Student questions	No. Content-related Student Questions
1-2	22	4
6-1	23	4
2-4	21	1
3-2	24	1
4-2	11	5
3-4	33	5
4-1	24	2
1-3	35	6
2-2	17	4
3-1	32	2
6-4	34	8
6-2	35	9
2-3	47	2
1-1	35	1
4-3	27	7
5-4	47	3
5-2	21	4
5-3	39	7

Note. In this and the following tables, each lesson is identified by the teacher identification number followed by the lesson number, e.g. lesson 1-2 is Teacher 1, lesson two out of four that were videotaped of that teacher. The data are grouped into three sections – lessons scoring higher on the inquiry instrument (the top group of lessons), lessons scoring in the middle on the inquiry instrument (the middle group of lessons), and lessons scoring lower on the inquiry instrument (the bottom group of lessons).

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Table 2

Teacher Questions Grouped by Inquiry Level of the Lesson

Lesson	TQ[a]	LQ[b]	CQ[c]	DQ[d]	CQ:DQ[e]
1-2	161	148	52	30	1.7
6-1	253	184	88	37	2.4
2-4	179	145	21	22	1.0
3-2	169	156	76	34	3.4
4-2	164	152	76	31	2.5
3-4	157	146	39	38	1.0
4-1	165	137	39	25	1.6
1-3	105	63	17	5	3.4
2-2	198	153	25	17	1.5
3-1	141	123	51	30	1.7
6-4	268	218	91	54	1.7
6-2	142	83	13	15	1.1
2-3	247	168	20	12	1.4
1-1	135	111	57	15	3.8
4-3	236	173	61	19	3.2
5-4	182	134	35	22	1.6
5-2	108	95	44	8	5.5
5-3	121	84	24	19	1.3

Note. [a]T = the total number of teacher questions posed during that lesson. [b]LQ = the number of content or lesson-related teacher questions. [c]CQ = the number of convergent questions. [d]DQ = the number of divergent questions. [e]CQ:DQ = the ratio of convergent questions to divergent questions.

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Table 3

Wait-time I as Measured in Seconds

Lesson	Each Wait-time I listed by the seconds of duration
1-2	4, 3
6-1	2, 2, 3, 2, 2, 5
3-2	6, 2, 4, 3, 3, 3, 2, 4, 4, 2, 5, 3, 4, 10, 3, 2.5
3-4	5, 6, 2, 3.5, 2, 5, 4, 7.5, 4, 10, 2.5, 3, 2, 6.5, 4, 3, 5.5,10, 2, 4.5, 4
2-2	9, 5.5, 2
3-1	4, 2, 2, 2, 2.5, 3, 3, 2, 2, 2.5,15, 2, 4, 4, 7, 4, 2,12, 3.5, 3.5, 3, 2.5, 6
6-4	5, 2, 3, 3, 4, 2, 3
6-2	4
4-3	2, 4.5, 2
5-4	5, 5, 4
5-2	2.5, 2
5-3	2

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Table 4

Wait-time I Equal to or Greater than two Seconds After Which a Student Answers the Question

Lesson	No.[a]	%[b]	CQ[c]	DQ[d]
1-2	2	100	0	2
6-1	0	0		
3-2	7	43.7	3	4
3-4	11	52.3	5	6
2-2	0	0		
3-1	14	60.9	12	2
6-4	3	42.9	3	0
6-2	0	0		
4-3	0	0		
5-4	0	0		
5-2	0	0		
5-3	1	50	0	1

Note. [a]No. = the number of times a student answers a question following a wait-time I of two seconds or more. [b]% = the percent this number is of the total number of wait-time I of two seconds or more. [c]CQ = the number of times the question answered is a convergent question. [d]DQ = the number of times the question answered is a divergent question.

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Table 5

Wait-time I of Two Seconds or More After Which the Teacher Continues Questioning

Lesson	No.[a]	%[b]	CQ-CQ[c]	DQ-DQ[d]	CQ-DQ[e]	DQ-CQ[f]
1-2 0	100					
6-1 6	100	2	4	0	0	
3-2 9	100	5	2	1	1	
3-4 10	100	3	6	0	1	
2-2 2	66.7	1	1	0	0	
3-1 9	100	1	7	0	1	
6-4 4	100	1	2	0	2	
6-2 1	100	1	0	0	0	
4-3 3	100	3	0	0	0	
5-4 3	100	0	3	0	0	
5-2 1	50	1	0	0	0	
5-3 1	100	0	1	0	0	

Note. [a]No. = the number of times the teacher continues questioning after wait-time I when a student does not answer the question. [b]% = the percent of questions not answered by a student this number represents. [c]CQ-CQ = the number of times an unanswered convergent question is followed by a convergent question. [d]DQ-DQ = the number of times an unanswered divergent question is followed by a divergent question. [e]CQ-DQ = the number of times an unanswered convergent question is followed by a divergent question. [f]DQ-CQ = the number of times an unanswered divergent question is followed by a convergent question.

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Table 6

Teachers Giving the Answer to an Unanswered Question Following a Wait-time I of 2 Seconds or More

Lesson	No.[a]	CQ[b]	DQ[c]	Time[d]
1-2	1	0	1	4
6-1	0			
3-2	0			
3-4	1	0	1	4
2-2	1	0	1	2
3-1	0			
6-4	0			
6-2	0			
4-3	0			
5-4	1	1	0	4
5-2	0			
5-3	0			

Note. [a]No. = the number of times the teacher gives the answer to an unanswered question following a wait-time I. [b]CQ = the number of times the unanswered question is a convergent question. [c]DQ = the number of times the unanswered question is a divergent question. [d]Time = the time in seconds of the wait-time I followed by no student answer, after which the teacher gives the answer to the unanswered question.

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Table 7

Teacher Reasks the Question After Wait-time I of
Less Than Two Seconds

Lesson	No.[a]	CQ-CQ[b]	DQ-DQ[c]
1-2	0		
6-1	5	1	4
3-2	3	3	0
3-4	0		
2-2	0		
3-1	0		
6-4	9	3	6
6-2	2		2
4-3	0		
5-4	4	2	2
5-2	1	1	0
5-3	3	1	2

Note. [a]No. = the number of times the teacher probes after no measurable wait-time I. [b]CQ-CQ = the number of times a convergent question is followed by a convergent question. [c]DQ-DQ = the number of times a divergent question is followed by a divergent question.

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Table 8

Teacher's Verbal Response Following an Incorrect Student Answer

Lesson	No.[a]	CQ[b]	DQ[c]	%dis/pro[d]	%DQdis/pro[e]	% t-ans[f]
1-2	6	2	4	67	75	33
6-1	6	5	1	92	0	17
3-4	4	1	3	75	100	0
3-2	13	12	1	29	100	15
2-2	3	1	2	33	50	33
3-1	8	4	4	63	75	0
6-4	11	7	4	73	75	9
6-2	1	0	1	100	100	0
4-3	10	6	4	60	50	20
5-4	11	5	6	36	50	45
5-2	3	1	2	67	50	67
5-3	7	4	3	29	67	43

Note. [a]No. = the number of questions per lesson a student answers incorrectly. [b]CQ = the number of convergent questions answered incorrectly. [c]DQ = the number of divergent questions answered incorrectly. [d]% dis/pro = the percent of incorrectly answered questions following which the teacher discusses further or probes for the desired response. [e]%DQdis/pro = the percentage of incorrectly answered divergent questions the teacher discusses further or probes for the desired response. [f]% t-ans = the percent questions answered incorrectly following which the teacher ultimately gives the answer.

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Table 9

Teachers Asking Students to Explain Their Answer

Lesson	No.[a]	CQ[b]	DQ[c]	S_P[d]	S_N[e]	T-ans[f]
1-2	6	2	4	2	1	1
6-1	10	8	2	3	0	0
3-2	2	0	2	0	0	0
3-4	0					
2-2	0					
3-1	6	2	4	1	3	0
6-4	5	1	4	2	1	0
6-2	0					
4-3	6	1	5	2	0	0
5-4	4	0	4	1	0	2
5-2	0					
5-3	3	0	3	0	1	1

Note. [a]No. = the number of times a teacher asks a student to explain his or her answer. [b]CQ = the number of times the original question is a convergent question.
[c]DQ = the number of times the original question is a divergent question. [d]S_P is the number of times the teacher sanctions the student explanation in a positive manner. [e]S_N = the number of times the teacher sanctions the student explanation in a neutral manner. [f]t-ans = the number of times the teacher ultimately gives the explanation following a request for a student to explain his or her answer.

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Table 10

Frequency of Teachers Giving the Answer to a Question

Lesson	A+B[a]	CQ[b]	DQ[c]
1-2	4+1	2	3
6-1	2	0	2
3-2	4+2	4	2
3-4	2+1	0	3
2-2	2+2	3	1
3-1	2	1	1
6-4	5+1	3	3
6-2	3	2	1
4-3	6	3	3
5-4	6+1	4	3
5-2	3	2	1
5-3	7	1	6

Note. [a]A+B = the number of times per lesson that a teacher gives the answer to a question after a student has attempted to answer it (A) and/or before the student has attempted to answer it (B). [b]CQ = the number of times the original question is a convergent question. [c]DQ = the number of times the original question is a divergent question.

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Table 11

The Length of Teachers' Questioning Strands and Steps

Lesson	A[a]	B[b]	C[c]	D[d]	E[e]	F[f]	G[g]	H[h]	I[i]
1-2	5	43	16	2.1	4.7	9	3.3	3-36	1-11
6-1	5	69.8	20.6	3.2	5.2	13.4	3.4	2-43	1-13
3-2	8	38.8	11.8	2.8	2.4	16.3	4.9	3-36	1-12
3-4	2	28	23.5	1.0	7	8	3.4	3-21	1-9
2-2	2	35.5	9.5	18	3.5	10.1	2.7	4-15	1-6
3-1	8	35.8	11.1	2.0	3.4	10.6	3.3	3-33	1-16
6-4	16	25.8	7.6	1.9	2.3	11.4	3.4	7-42	2-13
6-2	2	23.5	7.5	1.5	1.5	15.7	5	2-34	1-10
4-3	2	41.3	11.5		2.5	14.2	4.6	6-34	2-12
5-4	6	8.5	3	4	4	9.6	3	3-28	1-7
5-2	5	18	5	3.2	2.4	7.5	2.1	2-16	1-6
5-3	3	48	13.7	.9	5.7	8.5	2.4	2-22	1-6

Note. Lesson 5-4 was primarily a laboratory session, and the questions asked were about procedure, following directions, and results. It did not appear as if any major concepts were the focus of that particular lesson; however, the questions were grouped in a similar fashion to those in other lessons, and the teacher was accorded six concepts, because he had six major groups of questions about procedure, results, etc. Thus, saying that he discussed six concepts is actually a misrepresentation of the activity in the room that day.
[a]A = average number of major concepts. [b]B = average number of steps per concept. [c]C = average number of questions per concept. [d]D = average ratio of convergent questions to divergent questions per concept. [e]E = average number of strands per concept. [f]F = average number of steps per strand. [g]G = average number of questions per strand. [h]H = range of steps per strand. [i]I = range of questions per strand.

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Table 12

How Teachers Field Student Information or Explanation Questions

Lesson	No.[a]	A[b]	B[c]	C[d]	D[e]	E[f]	F[g]	G[h]
1-2	4	3	0	0	0	0	0	1
6-1	4	2	0	1	0	0	0	1
3-2	1	0	0	0	0	1	0	0
3-4	5	0	2	0	3	0	0	0
2-2	4	2	0	0	0	0	2	0
3-1	2	1	0	0	1	0	0	0
6-4	8	6	0	0	1	0	0	1
6-2	9	3	1	0	0	5	0	0
4-3	7	7	0	0	0	0	0	0
5-4	3	1	0	0	1	0	0	1
5-2	4	2	0	0	0	0	0	2
5-3	7	4	0	0	1	0	0	2

Note. [a]No. = the number of student information /explanation questions.
The teacher may: [b]A = answer the question. [c]B = allow another student to answer the question. [d]C = discuss the question or concept. [e]D = pose a new or different question back to the student to obtain more explicit information or lead to the desired response. [f]E = return the question to the questioner. [g]F = say he/she does not know the answer. [h]G = leave the question unanswered.

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