8-1-2011

Power dynamics and questioning in elementary science lessons

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POWER DYNAMICS AND QUESTIONING IN ELEMENTARY SCIENCE LESSONS

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

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School of Psychological Sciences
Educational Psychology

August, 2011

This Dissertation by: Lori Ann Reinsvold

Entitled: *Power Dynamics and Questioning in Elementary Science Lessons*

has been approved as meeting the requirement for the Degree of Doctor of Philosophy in College of Education and Behavioral Sciences in School of Psychological Sciences, Program of Educational Psychology.

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ABSTRACT

Reinsvold, Lori Ann. *Power dynamics and questioning in elementary science lessons*. Published Doctor of Philosophy dissertation, University of Northern Colorado, 2011.

Discourse interactions between a teacher and students in an inquiry-based fourth-grade science classroom were analyzed to investigate how power dynamics and questioning strategies within elementary science lessons help support students in building their science understanding. Five inquiry-based classroom sessions were observed; verbal interactions were audio- and video-recorded. Research data consisted of observation transcripts, teacher interviews, student work, and instructional materials. Analyses were conducted on the frequencies of utterances, participation roles, power categories, and questioning categories. Results revealed that when students used more frequent power, (a) no significant differences were noted between frequencies of teacher and student talk, (b) the teacher posed more questions than did the students, and (c) students explained what they knew and asked questions to clarify their understanding. When the teacher used more frequent power, she asked questions to provide students opportunities to negotiate investigative processes and explain what they knew and how they knew it. Evidence of student understanding of the science concepts was found in how students used subject matter to discuss what they knew and how they knew it. Pre-service and in-service teachers should be encouraged to consider how their use of power and questioning strategies can engage students to reflect on how they build understanding of science concepts. Teachers can use Professional Learning Communities to reflect on

how their practice engages students. Future research should be employed to observe classrooms across an entire school year to determine how power and questioning dynamics flow among students and teachers and change over time. Research can also be used to understand the influence of gender and culture on power and questioning dynamics in classroom settings.

ACKNOWLEDGEMENTS

I would like to thank my advisor Kathy Cochran for her time and guidance during my journey. She provided me with a fellowship through the NSF funded Center for Learning and Teaching in the West (CLTW) project. The fellowship allowed me to attend informative regional and national science and mathematics education conferences, and provided funding for graduate course work. Also, Kathy joined my journey and became just as enthusiastic as I during the research aspect of my Ph.D.. I really enjoyed and appreciated the collaborations. We have other research questions to investigate so we can continue to build our understanding of power and questioning dynamics in classroom settings.

My committee, Teresa McDevitt, Kevin Pugh, Henry Heikkinen, and Elizabeth Franklin provided perspectives that allowed me to refine my research. Their guidance provided suggestion on how to improve my study and descriptions of my findings. I greatly appreciate their time and attention so that I could meet my goals.

I greatly appreciate the teacher and the students of this study. I was inspired by how the teacher engaged her students to learn science. The students seemed to love learning science. I am thankful for the teacher’s willingness to allow me to come into her world and talk about learning science.

I could not have completed my research without the financial support from the MAST Institute and the University of Northern Colorado. Because of the funds, I was able to receive assistance with transcriptions, and completion of my course work.

My family (Rob, Maggie, Eric & Nicole) has been a tremendous support. They remained confident that I would complete my graduate studies. They assisted me by being a sounding board for my research ideas, and reviewing my transcriptions and writings. I could not have accomplished this work without them.

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CHAPTER I

INTRODUCTION

To improve science teaching and learning, researchers are evaluating how science classroom interactions, specifically social relationships and discourse among teachers and students, provide opportunities to develop science reasoning and understanding (Candela, 2005; Chin, 2007; Erdogan & Campbell, 2008; Herrenkohl & Guerra, 1998; Moje, Collazo, Carillo, & Marx, 2001; Roth & Lucas, 1997; Scott, Mortimer, & Aguiar, 2006; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001; van Zee & Minstrell, 1997b). Some researchers are focused on *inquiry-based* science activities where students take responsibility to collaborate in open-ended investigations and talk with peers to solve problems (Cornelius & Herrenkohl, 2004; Kelly & Brown, 2003; Roychoudhury & Roth, 1996). Duschl, Schweingruber, and Shouse (2006) suggested that in order for elementary students to become successful in building their science knowledge, they must have opportunities to construct arguments and to organize and articulate evidence through reasoning. Students must be able to explain *how* and *why* they “know” something. For students to reach this high level of thinking, they need opportunities for interactions and engagement with content, peers, and teachers (Engle & Conant, 2002). Engle and Conant (2002) claim that research is needed to understand how students engage in disciplinary content within classrooms to develop new ideas and understanding.

Learning is a cognitive and social process (Bruer, 1994; Erickson & Shultz, 1992; Vygotsky, 1978). Lemke (1990) and Tobin (Tobin, Briscoe, & Holman, 1990) take a socio-cultural perspective regarding science learning; it is through social interactions that students test their understanding and their ideas during classroom discourse. Teachers shape students' ideas by how they engage and respond to students (Wertsch, 1998). Teachers direct students to complete established activities or to guide them to take responsibility to develop an investigation with their peers. There are opportunities for a teacher's questions to support students to ask each other questions about what they know and why they know it. As classroom tasks unfold, discourse emerges among the teacher and students, as do power relations between students and the teacher (Fairclough, 1989; van Dijk, 1996). These social and verbal interactions influence how elementary-age students think, talk, and act (Siegler, DeLoache, & Eisenberg, 2006). I designed and conducted this study to understand how an elementary teacher provided students with opportunities to interact and participate in discourse that allowed them to share what they knew about science concepts and why they knew what they did. I was specifically interested in power relationships and questioning strategies that occurred within the classroom setting.

Theoretical Framework

I employed social constructivism, situated cognition, Vygotsky's *Zone of Proximal Development*, and scientific inquiry perspectives to guide my research on how an elementary teacher and students in her classroom use discourse interactions to build science understanding. Social constructivism in the science classroom is characterized by a learning environment where students construct meaning through interactions within

their classroom community, which assists them in interpreting what science is (Tobin & Tippins, 1993; Vygotsky, 1978). Aligned with this view, Cazden (2001) makes this point in her review of classroom interactions and discourse:

> Speech unites the cognitive and the social. The actual (as opposed to the intended) curriculum consists in the meanings enacted or realized by a particular teacher and class. In order to learn, students must use what they already know so as to give meaning to what the teacher presents to them. Speech makes available to reflection the processes by which they relate new knowledge to old. But this possibility depends on the social relationships, the communication system, which the teacher sets up (Barnes, quoted in Cazden, 2001, p. 2).

Teachers create and students participate in socially organized activities where they use their knowledge, experiences, and discourse to build their understanding of science. Teachers make adjustments to planned activities based on what students ask and know and what teachers intend to accomplish. Science activities involve complex interactions of the teacher, students, instructional materials, and policies and the school's administrative expectations. Recognizing these complex interactions, I also employed a situated cognition perspective (Borko, 2004; Lave & Wenger, 1991) to understand how classroom power and questioning strategies are used by a teacher and her students to create opportunities to learn science. This perspective on learning participation "focuses attention on ways in which it is an evolving, continuously renewed set of relations . . . [among] persons, their actions, and the world" (Lave & Wenger, 1991, p. 50).

My view of participation and interaction between a student and teacher is described in Vygotsky's framework (Driscoll, 2005; Tudge, 1990), *Zone of Proximal Development*. Vygotsky described this zone as a learning opportunity where the student possesses ability to problem solve certain tasks, but needs support from the teacher to build understanding of more advanced tasks. The student's relationship with the teacher

is critical to the interactions in the zone. The teacher/student learning relationship is one of intersubjectivity (Wertsch, 1984). The teacher and student are social partners and "They must co-construct the solution to a problem [new tasks and knowledge] or share in joint decision making about the activities to be coordinated in solving the problem" (Driscoll, 2005, p. 258). For this type of interaction to result in learning, the teacher and student must share power and authority (Driscoll, 2005). The only cognitive difference between the teacher and student is their particular level of understanding. The teacher has a higher level of content knowledge and instructional strategies. The student comes into the learning opportunity with what she knows. The teacher supports and scaffolds the student's learning experiences. A more capable or knowledgeable student can also guide another student to build new knowledge.

National science education reform guidelines recommend the use of scientific inquiry when teaching and learning science (National Research Council, 2000). An inquiry-based science classroom depends on interactions among students and teacher to co-construct their understanding of science. Inquiry is characterized by three distinguishing features (National Research Council, 1996): (a) student and teacher abilities to do inquiry, (b) strategies employed by teachers to stimulate science learning, and (c) student understanding of the nature of science. The term "understanding" is broadly understood as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (National Research Council, 1996, p. 23). To acquire a deeper understanding of anything, individuals must be reflective in their thinking (Dewey, 1938). By using inquiry to build their understanding of science, students and teachers can observe, question, investigate,

analyze, draw conclusions, and evaluate what others come to understand. This requires (a) students to reflect on what they think they know and understand, as well as (b) teachers to probe students' understanding (Lamb & Tschillard, 2004; Windschitl, 2002).

Building a deep understanding of science through inquiry depends on language to exchange and negotiate meaning (Carlsen, 2007; Kelly & Green, 1998; Lemke, 1990; Moje, et al., 2001; Singer, Marx, Krajcik, & Chambers, 2000). For example, Metz (2004) recorded elementary students' conversations as they worked together to develop studies investigating animal behavior. She sought to determine how students dealt with uncertainty as they conducted their science investigations and reviewed their findings. Metz found that elementary students successfully engaged in complex scientific investigations when provided *scaffolded instruction* and *collaborative experiences*, such as opportunities for discussing experimental processes and findings with classmates. Students talked about uncertainties of what they observed and learned during the investigations. These findings support the claim that discourse, the interactive use of language, builds knowledge about science within inquiry classrooms.

Scope of Study

Discourse analysis. To understand how an elementary teacher and her students use power relationships and questioning strategies in an inquiry-based science classroom, I analyzed the discourse of the teacher and students' interactions. My approach to discourse analysis is based on the view that the teacher and students use language for certain social purposes (Halliday, 1978). Examples of these social purposes are the teacher directing students to work together in small groups, or a student asking the teacher for permission to share her rock collection. Social relationships exist as students

and teachers interact in science classrooms. Van Dijk (1996) described these classroom interactions as power relationships in that ". . . teachers usually control communicative events, distributing speaking turns, and otherwise have special access to, and control over, educational discourse" (p. 86). I used critical discourse analysis to understand how verbal exchanges create and influence these power relationships during classroom conversations (van Dijk, 1996, 2003). In this research, I refer to power relationships found in classroom interactions as power dynamics.

Relationships between power and questioning. Researchers have not investigated how power dynamics *and* questioning strategies influence how elementary students and teachers interact to understand science. For example, if a student's response does not support a traditional "school science" point of view, teachers may exercise power to reshape, reflect, or ignore the student's ideas. In Lemke's research (1990) on science dialogue, he states, "Teachers and students have grossly unequal power in the classroom. The teacher is the representative of adult authority and backed up, at least in theory, by the power of force as well as by the tradition of the schools. That difference in power extends to the control of dialog itself, both its form and its content, that is, both the activity structure and the thematic" (p. 44).

Wang (2006) has shown that the nature of questions is related to power dynamics in adult discourse in non-school settings. She considered questioning strategies used both in institutional or formal discourse and in casual conversations. Some participants in institutional dialogue (doctor/patient; judge/lawyer; manager/cashier) have dominant roles, and they assign questions and control the overall structure of discourse. In casual conversations, a participant controls a temporary topic of the conversation by determining

the type and sequence of questions. A person who controls the conversation holds the central position in the conversation. Wang believed that those who used questions to control turn-taking and topics in informal and casual dialogs held power in the conversation. Like Lemke (1990), Wang recognized that there are unequal levels of power and status within discourse.

Researchers (Erdogan & Campbell, 2008; Redfield & Rousseau, 1981; Scott, et al., 2006; van Zee & Minstrell, 1997b) have shown that high-level reasoning and open-ended questioning allow students to engage with more than just facts and establish *how* and *why* they "know" something. A study by van Zee and Minstrell (1997b) found that the physics teacher, Minstrell, used a questioning strategy identified as a *reflective toss.* Minstrell used the reflective toss to invite a student into the conversation and capture what the student said. The student is asked to describe the thinking that underlies her statement. Minstrell believed that seeking clarification of the student's understanding within a respectful class discussion would remediate a student's misconception of a physics topic (Posner, Strike, Hewson, & Gerzog, 1982; Smith, diSessa, & Roschelle, 1993/1994; van Zee & Minstrell, 1997b).

Minstrell used the reflective toss to accomplish three outcomes: engage students in thinking about a science concept, refine the students' understanding of the concept, and, allow the students and teacher to discuss and evaluate their understanding. Minstrell's questioning strategy, reflective toss, engaged students in cognitive processes to build their understanding of science (Kelly, 2007). Van Zee and Minstrell's findings demonstrate that teachers exercise power through questioning strategies to encourage

students to evaluate, to provide evidence for their claims and ideas, to apply what they know to a novel topic, and, in general, to reason at a higher level regarding what they know about science.

Purpose

How do teachers and students actually use power and questioning strategies to build what they know about science? I investigated this by analyzing how elementary students and the teacher created discourse to build science knowledge in an inquiry-based classroom. I used discourse analysis to identify and describe classroom episodes and interactions where various power dynamics and questioning strategies were used both by the teacher and students. Specifically, I investigated the nature of questions asked by the teacher and students, and how these questions were associated with classroom power dynamics. I then traced the consequences of teacher and student use of power and questioning to students' understanding of science as a group.

Research Questions

To understand how power and questioning strategies are used to build science knowledge among students in an inquiry-based elementary classroom, the following main question and sub-questions were addressed:

Main Question:

Q1 How do power and questioning strategies in an elementary classroom support student understanding of science?

Sub-questions:

A How does a teacher use questioning strategies in classroom discourse to engage students to understand science?

B How does a teacher use power in classroom discourse to engage students to understand science?

C How do students use questions in classroom discourse to understand science?

D How do students use power in classroom discourse to understand science?

E How does the use of power relate to questions in classroom discourse?

Definition of Terms

Discourse: Discourse is described by three categories: (a) several sentences that are used to communicate understanding; (b) language use; and (c) a broad range of social interactions including nonlinguistic and general language use. These categories situate the exchange of words through conversation as a social interaction of language that is heard and observed (Jaworski & Coupland, 1999).

Discourse Analysis: Discourse analysis is the use of a group of research methods (Schiffrin, Tannen, & Hamilton, 2003) to evaluate discourse.

Inquiry: In an elementary science classroom, inquiry strategies are used by the teacher and students to build their understanding of science concepts, and to observe, question, investigate, analyze, draw conclusions, and evaluate what others come to understand (National Research Council, 1996).

Interaction: Interaction is the social structure where students and teachers discuss and investigate concepts and ideas together in order to build their understanding of the science.

Power: Power is defined as the state of having or exerting control over the actions and thoughts of others (Fairclough, 1989; van Dijk, 2003). Within social interactions, power is determined by the institutional roles, socio-economic status, gender, or

ethnicity of the participants. In this study, power is defined by five categories of classroom interactions: Conventional, Group, Individual Voice, Organizational, and Subject Matter (Cochran & Reinsvold, 2010; Gore, 2002).

Power Dynamics: The dynamics of power involves the creation, promotion, facilitation, resistance, and exchange of power in social interactions (van Dijk, 2003).

Student Engagement: Students actively develop, alter, discuss, and defend their ideas with others in the classroom (Engle & Conant, 2002; Herrenkohl & Guerra, 1998).

Questions: Utterances that are used to seek information (Dillion, 1988; van Zee & Minstrell, 1997b) that begin with *what*, *where*, *when*, *why*, *who*, or *how*. Statements are considered questions if they end with a particular intonation that signifies a query (Saha, 1984).

Questioning Strategies: A teacher uses questions to engage students to provide factual information or higher-level explanations about science. Students pose questions to understand and to seek clarity about science.

Limitations

Data for this qualitative study are collected from a single fourth-grade science classroom. The results may be different for younger or older students. One teacher and her students investigating one science unit are observed, so I have spent a limited length of time in the classroom to collect observation data. Because of my focused choice, I cannot generalize my findings to other science classrooms. The study does not include

data on student perspectives or attitudes towards the classroom use of power and questions, so it is not possible to know their perspectives on using these strategies to learn science.

I am the research instrument as I observed and collected data from the fourth-grade classroom. It is through my perspectives (Creswell, 2007) that I interpreted the collected data. Another researcher may have different perspectives, and thus may interpret these data differently. This is an important aspect of qualitative research, and I recognized this as I analyzed and presented my findings.

CHAPTER II

LITERATURE REVIEW

This literature review addresses three factors influencing the effectiveness of teaching and learning science: discourse, questioning strategies, and power dynamics. These factors served as the foundation for this research. I review related research pertaining to each factor and what researchers have reported about its impact on science teaching and learning.

Discourse

In *The Handbook of Discourse Analysis*, Schiffrin, Tannen, and Hamilton (2003) explain that discourse is a collection of several sentences used in conversations, arguments, and speeches. Jaworski and Coupland (1999) merged previous definitions of discourse into three categories: (a) several sentences used to communicate understanding; (b) language use; and (c) a broad range of social interactions including nonlinguistic and general language use. These categories situate the exchange of words through conversation as a social interaction of language that is heard and observed.

Discourse analysis is a group of methods researchers use to evaluate classroom discourse (Schiffrin, et al., 2003). The methods are used by researchers to understand what and how spoken language supports classroom learning (Adger, 2003; Carlsen, 2007; Kelly, 2007; Mehan, 1979). How these methods are designed and used is based on the researcher's viewpoint or theoretical framework (Creswell, 2007; Stake, 1995).

As I described in the *Theoretical Framework* section of the *Introduction* (p. 2), I recognize that meaning and understanding of language within a learning community, such as a science classroom, is developed through socially mediated interactions (Halliday, 1978; Vygotsky, 1978). Students and teacher use power through these interactions (Fairclough, 1989; Lemke, 1990; van Dijk, 1996). Critical Discourse Analysis (van Dijk, 2003) is the discourse analysis method that researchers use to understand how power is used in classroom conversations.

Critical discourse analysis. In this study, I am interested in how a teacher and students use power during social interactions to understand what is known (Rogers, Malancharuvil-Berkes, Mosley, Hui, & Joseph, 2005). Given this perspective, I will first review research associated with *Critical Discourse Analysis* (CDA). Linguist Norman Fairclough (Fairclough & Wodak, 1997) is credited with defining CDA (Hughes, 2001; van Dijk, 2003). Fairclough used the framework to analyze discourse at the micro- and macro-levels within social and political settings. Micro-analysis evaluates the use of language and interaction detail within the discourse. By contrast, macro-analysis identifies the power, dominance, and inequalities among social groups involved in the discourse.

Teun van Dijk (2003) described four categories for Fairclough's (1997) micro- and macro-levels: (a) *member-groups*, (b) *action-process*, (c) *context of social structure*, and (d) *personal and social cognition*. Member-groups identify the actors' affiliation with social organizations. Action-process refers to social actions or roles of actors and their groups. Context of social structure describes the situations of social interaction. Personal and social cognition categorize the understandings of actors and the group. The

actor's understanding depends on personal memories, prior knowledge, and experiences. Group understanding depends on social representations of what is collectively known and agreed upon.

Van Dijk (2003) extended the use of the critical discourse analysis (CDA) framework. Van Dijk believed researchers should use this method to study how discourse creates, facilitates, or resists dominance, inequality and abuse in social and political settings. Van Dijk explains, "CDA focuses on the ways discourse structures enact, confirm, legitimate, reproduce, or challenge relations of *power* and *dominance* in society" (p. 353). Researchers use this analysis approach to illuminate and explain social inequality within the conversation and setting.

Moje (1997) and Hughes (2001) used the CDA framework to guide their discourse analysis of science classroom conversations. Hughes (2001) was concerned with low enrollment of young women in high school physical science classes. Hughes believed that within physical science, a privileged male status is associated with science knowledge, activities, and learning opportunities. She called this the *dominant curriculum*. The curriculum has a predominance of abstractness in concepts and rigid practices regarding how physical science is understood. Hughes employed a CDA framework to conduct student interviews and to determine whether and how student gender and ethnicity influenced the display and support of scientist identities.

Hughes (2001) observed physical science and biology classes in a city school and college in the United Kingdom. The schools had diverse student populations both in terms of educational background and ethnicity. Classroom and staffroom observations and field notes were gathered for one year. In this study, she did not collect student

knowledge data. Hughes (2001) selected three mixed-gender student pairs as case studies; one pair was Caucasian; the other two pairs consisted of ethnic minorities. The members of each pair were selected based on the complexity of their science identity descriptions that were provided during a discussion with Hughes. She sought participants with different ethnicities; additionally, each pair was composed of a young male and a young female student.

In semi-structured interviews, the first student pair considered how young men and women discussed science in a male-dominated science classroom—physical science. To initiate the conversation with the first pair, Hughes (2001) asked them, "Do you know why there are more young men in physics classes than young women?" With the second pair, Hughes sought to know how ethnicity affects gender identities of scientists. The third pair discussed whether a reconfiguration of the dominant science curriculum (physical science) would encourage more students to develop science identities.

Analyzing the first pair's responses, Hughes (2001) found that the young woman did not identify with the male dominant discourse of the physical science classroom. Based on the student's experience in the physical science course, she could not identify herself as a woman scientist. The student believed that young women in general and smart ones specifically, would not study difficult and unpleasant courses, such as physical science. The young man identified with the physical science course and recognized the personal relevance of the science content to his future. He expressed willingness to work hard in physical science class to gain understanding because it would benefit him in the future.

In the analysis of the second pair, Hughes (2001) learned that the Vietnamese young woman was influenced by conversations with her parents. Her parents wanted her to take on a scientist identity; they wanted her to pursue science as a career. From conversations with her parents, the student learned that participation in challenging courses and academic success was important. This student was encouraged by her family to pursue strong academic science courses. Hughes (2001) did not expect her parents to exert this much influence. Hughes realized that she needed to include cultural interactions, such as family influence, to the analysis categories.

Hughes (2001) discovered that the third pair believed the dominant discourse of science consisted of certainty and authority. The pair did not participate in the physical science curriculum, but preferred the life science curriculum, which was designed around constructivist pedagogy. The young woman expressed discomfort with the dominant science discourse and curriculum. She preferred the life science curriculum because she felt confident and independent, and comfortable with unexpected results in lab activities. She did not identify with clever, correct, or smart science students, but was secure with her own knowledge and ability. On the other hand, the young man preferred the dominant science because he did not feel comfortable developing his own investigations and wanted to be told what to do and know.

Hughes (2001) concluded that as a researcher, she could not focus on gender alone when analyzing the discourse and determining individual scientist identities. From her discourse analysis she recognized that the development of scientist identities is influenced by home, cultural conversations, and experiences in non-dominant curriculum classrooms where students build their understanding. Hughes' use of the critical

discourse analysis of the interviews revealed the complexities of how students develop scientist identities from different learning strategies and experiences outside the classroom.

Elizabeth Moje (1997) also used the critical discourse analysis (CDA) framework to guide her analysis of conversations. Moje believed that through discourse analysis, researchers can look beyond students' understanding of science. She realized that use of the CDA framework would enable her to illuminate how teacher and student utterances and writings develop rules, knowledge, and opportunities for students to become successful.

Moje (1997) sought to understand how knowledge was constructed within a high school chemistry class, and to evaluate how students and teachers used discourse to build types of positions and authority relationships. She developed a classroom ethnography of a first-year chemistry class. Moje selected a teacher who emphasized literacy and the language of chemistry, and was experienced and highly regarded as a chemistry teacher. The students were from working- and middle-class families. Data regarding 22 sophomore and junior chemistry students were collected over two and a half years. Classroom observations, field notes of classroom interactions, audio-recordings of interviews with the teacher and students, and classroom documents constituted data sources for this study.

Moje (1997) analyzed four aspects of classroom conversations. First, she analyzed the text of the classroom discourse and was particularly interested in how responses were linked to others in the conversation. Analysis of word use was the second area of the study. Moje determined how terms were used to elicit meaning, and what

words were connected to particular classroom activities. The third area of analysis was identifying who was listening and who was speaking. The students chose speaking and listening roles, but at times the teacher asked students to assume one particular role. The fourth area of analysis combined the first three aspects (who responded to whom, word usage and meaning, who was talking) to determine how discourse shaped students attitudes towards science authority.

Through interviews, Moje (1997) learned that the teacher focused on strategies to ensure students were accurate and organized as they communicated their understanding of chemistry. The teacher reasoned that since scientists must communicate effectively, students should also do so. The teacher played multiple roles in the classroom: classroom teacher, scientist, mother, and student advocate. When these roles were invoked, the teacher expected students to demonstrate certain behaviors. The teacher believed her role was to evaluate student knowledge. The students needed to be accurate, precise, objective, mindful of their work abilities, and organized. She often used the authority of science as the rationale for why students should be precise and organized. The students accepted this authority of science.

Moje (1997) reported that the teacher asked students to assume the role of evaluator of each other, but they did not do this; they were not critical of their classmates. Rather, they assumed roles as helpers and colleagues. The students viewed the teacher as the evaluator and member of a larger science community. Because of the teacher’s actions and conversations, they recognized that science has order, accuracy, and

precision. Moje noted that the teacher did not realize that her expressions of institutional definitions and categories affected students' perceptions of what science is and how it is conducted.

Moje used critical discourse analysis to illuminate student and teacher assumptions embedded in chemistry classroom discursive practices. The teacher expected and assumed that students would adopt the language and role of scientists. For example, the teacher asked a student for his definition of "mixture". She asked the student to repeat the definition three times and then write it on the board. As he wrote the definition on the board, she explained that the use of one word can change the definition's meaning. In this case, the student used the word "element" and she wanted him to use the word "matter". The teacher went to great lengths to indicate that students must be like scientists: be careful and precise when describing a concept of science. The students accepted their teacher's request, and used the language of science as demonstrated by the teacher. Moje's discourse analysis found that the teacher exerted control and influence over how the students spoke about science. She employed CDA to identify issues of power as teacher and students interacted.

From this review, researchers have employed the critical discourse analysis framework to evaluate discourse and determine how power in social settings, such as a classroom, influences the teaching and learning of science. Hughes (2001) used CDA to evaluate the discourse she conducted with students about their learning environments and how it affected their identity with science. She did not assess student understanding of science concepts. Moje (1997) gathered more data (classroom observations and interviews) than did Hughes (2001) for her analysis. She completed a micro- and macro-

analysis (Fairclough & Wodak, 1997; van Dijk, 2003) of the utterances to evaluate the exchanges and word usage in a high school science classroom. These data provided her a richer base from which to build a understanding of classroom interactions. She was able to determine the roles of the teacher and students, and how the science learning community (teacher and students) perceived themselves and others relative to the science content. Hughes did not assess students' chemistry understanding.

I designed my research to identify many sources of classroom interactions to understand how power and questioning strategies influence how students understand science concepts. I collected the conversations for each activity, the activity's learning objectives, and the student assessment from the activity. Like Moje (1997), I examined exchanges among classroom participants and how they use science words. This allowed me to analyze discourse and student work within the context of the objectives, and determine what patterns of interactions influence student learning.

Questioning Strategies

As I described in the *Theoretical Framework* section of the *Introduction* (p. 2), building a deep understanding of science concepts through inquiry depends on the use of language to exchange and negotiate meaning (Kelly & Green, 1998; Moje, et al., 2001; Singer, et al., 2000). Metz (2004) noted that results of a long-term study of teachers and students in elementary classrooms suggested elementary students successfully engaged in complex scientific investigations when provided *scaffolded instruction* and *collaborative experiences*. The strategies included questioning and discussing experimental processes

and findings by classmates and teachers. These results indicate *discourse* in general and *facilitated questioning* specifically about science is important for instructional success in elementary science classrooms.

Duschl, Schweingruber, and Shouse, editors of the National Research Council report, *Taking science to school: Learning and teaching science in grades K-8* (2006), recommended that elementary students should be encouraged to engage in productive classroom science discourse. The editors suggested to become successful in building their understanding of science, elementary students must be able to respond to questions with organized arguments and articulate evidence through reasoning. In other words, students must be able to explain *how* and *why* they "know" something. Krajcik, Blumenfeld, Marx, Bass, Fedricks, and Soloay (1998) observed middle-school students as they presented reports, including data analysis and their interpretations or conclusions from project-based lessons. The researchers admitted they were unable to infer students' thought processes from their presentations. The researchers needed to supplement their observations with questions to students to ascertain *why* students arrived at their presented conclusions. Questioning helps students organize *what* they know and explain *why* they know what they know. By using questioning strategies, teachers can learn *why* students arrive at their conclusions for their science investigations in inquiry-oriented classrooms (Duschl et al., 2006).

It has been suggested that in an inquiry-based science classroom, teacher questioning strategies should be used to facilitate and develop student use of questions to investigate and understand their world. The National Science Education Standards states that "inquiry into authentic questions generated from student experiences is the central

strategy for teaching science" (National Research Council, 1996, p. 31). With this perspective, there are opportunities for teacher questions to support students to ask each other about what they know and why they know it. The inquiry-based science classroom focuses on student-centered or teacher-centered investigations (Chin, 2007; King, 1994; Roth, 1996; van Zee, et al., 2001; van Zee & Minstrell, 1997b). With this perspective of questioning by students and teachers, what types of questions are posed in a classroom and how do they influence learning?

Meredith Gall (1970) reviewed educational studies of spoken questions prior to 1970. He found researchers such as Bloom and Carner developed general categories to classify questions independent of the teaching context. Most categories were based on cognitive processes. Bloom's cognitive domain categories (1956) are well known, consisting of *knowledge, analysis, synthesis, evaluation,* and *application*. Carner's categories, as noted by Gall (1970), consist of *concrete, abstract*, and *creative*. Gall provided an overall classification system for types of questions found in literature. He proposed five classifications: *recall, analytic thinking, creative thinking,* and *evaluative thinking*.

In his review of the literature, Gall (1970) found teachers ask more factual questions of students than they do high-level reasoning questions. He believed questioning strategies are used to change student behavior, and future research should explore which type of questions impact student behavior. He advocated something sought today in science education (National Research Council, 1996): teacher assistance in developing strategies to support students' questioning skills. With this understanding, teachers can support a student's ability to ask questions about relationships and

applications of topics studied in the classroom and experienced in the natural world. Overall, this questioning process would deepen students' understanding of content being studied.

Eleven years after Gall's work, Redfield and Rousseau (1981) conducted a meta-analysis of 14 studies that examined teachers' questioning behavior. The researchers claimed that teacher questioning of students improves student achievement. Redfield and Rousseau used Bloom's categories of cognitive processes (application, analysis, synthesis, and evaluation) to identify questions that would be considered higher cognitive questions. They claimed that the ability to identify or recall information characterized lower cognitive questions.

Redfield and Rousseau (1981) specifically explored the effect of teacher questioning strategies on student achievement. They compared studies where teachers were trained to use questioning strategies and were free to employ those questioning skills in their classroom to studies where researchers requested teachers to use either high- or low-level cognitive questioning strategies in their classrooms. The researchers of these 14 studies used achievement tests to determine student learning gains after exposure to their teachers' questioning strategies. Redfield and Rousseau used Glass's (1978) statistic to calculate effect size. They obtained an average effect size value of +0.73 for the 14 studies. Redfield and Rousseau hypothesized that an average control student group would achieve at the 50^{th} percentile, and, following an intervention, would achieve at the 77^{th} percentile. The researchers concluded, based on their data, that increases in student achievement occur when teachers use higher cognitive questions.

Redfield and Rousseau's findings support Gall's (1970) review of question types classified according to Bloom's Taxonomy, and support the idea that deeper student understanding depends on teacher's use of higher cognitive questions.

Roberts and Zody (1989) developed an observation instrument, *Measure of Effective Questioning Techniques* (MEQT), to assess teacher questioning. The instrument was designed for supervisors of classroom teachers. Five elements of instructional practices were evaluated by a supervisor using this tool: *interactive teaching style*, *appropriate cognitive level of type of question, wait time, modeling the mental process of answer formulation*, and *transfer*. Interactive teaching describes the extent to which teacher and students are involved in discussions about the class material. Interactive teaching includes more teacher and student questioning than lecture-style teaching. The authors believed more interaction stimulates more feedback and learning. Appropriate cognitive levels of questions include use of rapid recall up to applied comprehension questions. The authors noted that the types of questions teachers used depend on the lesson goals. Roberts and Zody recognized Mary Budd Rowe's (1986) research on wait time. Rowe found when a teacher waits at least three seconds after asking a question, giving students time to think and answer, the quality of student responses and classroom discussion improves. As teachers ask more questions about why students know what they know, students become more reflective regarding what they know and why they know it. The teacher models questioning practice, which helps students understand how to formulate an answer in a similar setting. The last element, transfer, refers to a teacher's ability to ask students about their prior knowledge of a topic. It also is used to evaluate how the teacher's question provides students the

opportunity to apply their knowledge to similar or different scenarios. This encourages students to elaborate and extend what they know to something new or similar. The MEQT was an observational tool for teacher supervisors, but it effectively linked the types of questions to positive learning opportunities for students. The researchers did not evaluate student understanding relative to the observation tool.

Science education researcher Wolff-Michael Roth (1996) claimed teacher questions should not be evaluated by their type or impact on student achievement, but by “. . . their situational adequacy” (Roth, 1996, p. 710). Based on his research, Roth claimed that because student-centered learning environments contain complex interactions, it is difficult to categorize types of questions that teachers use. Roth believed qualitative research on teacher questioning practices is needed. To address this, Roth developed a case-study of one teacher using “highly effective questioning strategies” in a Grade 4/5 science classroom. Roth sought to understand the teacher’s questioning practices. Roth’s data consisted of transcripts of observations and field notes, and the teacher’s personal notes about the teaching. Roth ensured credibility of his research findings by using research design techniques of persistent and prolonged observations for seven months and debriefing observers and the teacher after each lesson.

Roth (1996) used Carlsen’s (1991) framework to organize the nature of teacher questions. This framework consisted of three features: *context of questions, content of questions, student’s response and reactions to questions*. Roth used these categories to analyze the teacher’s questioning practices. The category, context of question, describes the teacher’s interactions with the classroom setting, the students with various backgrounds (social, historical, and physical characteristics), and the structure of the

curriculum. Roth investigated how questions are used to support and understand these interactions in a student-centered engineering curriculum. The second category, content of the questions, describes the teacher's content knowledge and its applications. Roth sought to investigate how questions supported student understanding of engineering concepts. With the third feature, the student's response and reactions to questions, Roth investigated how the teacher facilitates and encourages responses and reactions to questions. These categories illustrate the complexity of questions and responses within an inquiry-based science classroom.

Roth (1996) identified features present in teacher questions; interactions among the three categories provided a complex view of teacher questioning strategies. For example, the teacher adjusted the content of questions when it appeared that students became emotional about improving aspects of a bridge's structure. Interactions between the context and reaction/response features were noted when the teacher sought control of behavior during the student activities. Roth concluded questioning practices depend on lesson goals, but support student learning and are as complex as the unfolding interactions among teacher, students, and instructional materials. Roth did not explicitly evaluate the effects of questioning on student understanding of science.

Emily van Zee (van Zee, et al., 2001; van Zee & Minstrell, 1997b) also studied teacher questioning strategies. Van Zee collaborated with K-12 teachers and co-researchers to investigate questioning strategies teachers used within their classrooms. Van Zee used case studies to investigate how questions assisted students in understanding science.

Van Zee collaborated with Minstrell (1997b), a highly regarded science teacher, to study how he used questioning to guide physics students' understanding of measurement concepts. The researchers recorded one classroom discussion and then held numerous conversations with Minstrell to explore his perspectives of questioning strategies and interactions that occurred during the discussion. These debriefing conversations were audio-recorded. They spent many sessions determining which utterances were questions, creating a visual model of the questioning sequence, and identifying interactions to analyze. Through this analysis, evidence of Minstrell's questioning strategies and beliefs emerged.

To identify which utterances were questions, van Zee and Minstrell (1997b) recognized that questions often seek information (Dillion, 1988). They identified questions that began with *what*, *where*, *when*, *why*, *who*, and *how*. They also used the Saha (1984) questioning taxonomy for questions: begin with a verb, end with an intonation, end with a request for judgment (e.g., Don't you think?), or convey an either/or request (e.g., Is it this value or that value?). Van Zee and Minstrell also identified statements that implied questions (I am trying to think which . . ."). Using this scheme, the researchers identified questions within the classroom discussion.

The interaction that van Zee and Minstrell (1997b) specifically analyzed was a situation where a female student suggested an alternative method to determine the average value of a measurement from a set of repeated measures. Minstrell did not expect this method to be suggested by a student. Minstrell asked the student to explain

how she came to develop this method and how she used the method to calculate an average. Minstrell guided her to share and elaborate her thinking about the method within a non-judgmental learning environment.

After analyzing the transcripts of classroom discussions and debriefing sessions, van Zee and Minstrell (1997b) recognized that Minstrell employed a questioning strategy that they identified as *reflective toss.*

> An example of a reflective toss that helped students clarify their meanings would be "Now what do you mean by 'average' here?" An example of a reflective toss that helped students to consider a variety of views in neutral manner would be "What about this other method that was mentioned, of saying, let's just add up the number that are different?" An example of a reflective toss that helped students to monitor the discussion and their own thinking would be "Does that make sense?" (van Zee & Minstrell, 1997b, p. 259).

Minstrell acknowledged a student's statement by inviting the student into a conversation with a reflective toss; this toss captures what the student said and asks the student to describe thinking that underlies the statement. Minstrell believed that seeking clarification of the student's understanding within a respectful class discussion would correct the alternative method of calculating the average (Smith, et al., 1993/1994; van Zee & Minstrell, 1997b). Minstrell used the reflective toss to accomplish three outcomes: (a) engage students in thinking about a proposed method, (b) refine the students' understanding of the method, and, (c) allow students and teacher to discuss and evaluate the proposed method. Minstrell's questioning strategy engaged students in cognitive processes to build their understanding of science (Kelly, 2007). van Zee and Minstrell (1997b) did not evaluate whether the teacher questioning strategies affected student understanding of the science concepts.

van Zee, Iwasyk, Kurose, Simpson, and Wild (2001) developed a multi-case study regarding K-20 how teachers and students use questions during conversations about science. The science lessons were inquiry-based and consisted of guided discussions, student-generated inquiry discussions, and small group interactions. The researchers used audio- and video-recordings of instruction, audio-recordings of researchers' conversations and meetings, student interviews, student work, and field notes as data sources. The researchers reviewed the data and developed common themes and experiences. They summarized their analysis as a set of claims about student and teacher questioning. The researchers asked anonymous reviewers to provide feedback on their analysis and summaries. The analysis allowed the researchers to form explanations of cultural practices and ways of speaking in classrooms. The researchers found that the majority of examples they analyzed were from guided discussions. The researchers noted that the validity of their case studies was limited due to the subjective nature of their research methodology. However, they believed that because of the numerous researchers and use of reviewers, their collective interpretations represented a credible view of practicing teachers' thoughts.

During guided discussion, the researchers found that teachers used many types of questions to deepen student understanding of science. The teachers asked questions to develop conceptual understanding, to clarify student understanding, to seek student experiences, to evaluate and refine student ideas, and to seek evidence of their ideas. Teachers used student responses to develop and pose questions for others to reflect upon. Teachers recognized that due to the social interactions and the more open discussions to cultivate understanding, they had to use questions to initiate discussions. They found

discussions could follow a different topic if not controlled by teacher questions. As they used guided discussions, the teachers found it challenging to meet the lesson goals within the allocated time. These findings are similar to Roth's conclusions (1996); teachers develop and use specific questions based on the classroom context and lesson goals. Van Zee et al., (2001) did not evaluate whether the teacher questioning strategies affected student understanding of the science concepts.

Chin (2007) conducted a qualitative study on science teacher questioning practices in Singapore. She investigated how teachers' questions during classroom discussions supported student's development of scientific knowledge. She observed six lessons from six science teachers who taught seventh-grade students. The teachers used a variety of instructional strategies, from discussions to lectures and laboratory activities. The lessons were audio- and video-recorded. Chin collected lesson handouts, samples of student work, and field notes from meetings with teachers. Chin focused on grammatical forms of questions in the audio-recordings transcripts. She determined whether questions affected or altered the direction of the conversation. She also considered the cognitive level of teacher questions. Student responses to all teacher questions were analyzed, as well. She devoted particular attention to whether student responses demonstrated any change in their thinking, or if new ideas and understanding were shared. Like Roth (1996), Chin employed Carlsen's (1991) framework, based on the content of questions (growth of student knowledge), context of questions (questioning related to classroom situations), and responses and reactions to questions (control student turn-taking) when developing themes from her analysis.

From Chin's (2007) data analysis, she identified four distinct questioning strategies that engaged students in deeper thinking about science content. Those strategies were *Socratic questioning, verbal jigsaw, semantic tapestry,* and *framing*. Socratic questioning is when teachers stimulate and guide student thinking; it is used to ask the student to articulate what they are thinking. For example, "How do we find the density of an object?" Verbal jigsaw questioning is used to help students form propositional statements with scientific terminology. An example of a verbal jigsaw question is, "These chromosomes in metaphase are . . .?" Semantic tapestry is a questioning strategy allowing students to link challenging concepts to a conceptual framework they understand and can build upon. A semantic tapestry question is, "If we see wood floating in water, what does this tell us about the density of wood?" Framing is a questioning strategy that engages students in new topics, in the main conceptual idea of a lesson, and in the lesson summary. An example of a framing question is, "What happens to an oxygen molecule in a cell?" Although Chin identified these four broad categories of questioning strategies, she did not provide evidence on how valid or reliable her results were. She also did not evaluate whether the teacher's questioning strategies improved student understanding of the science concepts.

Gall (1970) and Roberts and Zody (1989) recognized that different cognitive level questions will elicit different student cognitive responses. When teachers ask factual questions, they seek little cognitive work from students. Higher cognitive questions (e.g., evaluate and analyze) require students to organize what they know and explain their understanding. Redfield and Rousseau's (1981) meta-analysis work explicitly documents that teachers' use of higher cognitive questions improves student achievement. Roth

(1996), van Zee (van Zee, et al., 2001; van Zee & Minstrell, 1997a, 1997b), and Chin (2007) used qualitative research to understand and describe complex interactions among students and teachers as they ask and respond to questions. These researchers concluded that teachers in their studies used questioning strategies based on how teachers and students approached and interacted with science concepts. Strategies were described, but Roth (1996), van Zee (van Zee, et al., 2001; van Zee & Minstrell, 1997a, 1997b), and Chin (2007) fail to indicate whether students gained a better understanding from these interactions. I will use the type of questions that van Zee (van Zee, et al., 2001; van Zee & Minstrell, 1997a, 1997b) (e.g., ends with an intonation or request for judgment, or conveys an either/or request), and Chin (2007) (e.g., Socratic questioning, verbal jigsaw, semantic tapestry, and framing), identifying my classroom observations and data analysis. For my research, I investigated questioning strategies and how these interactions influence student understanding of science in a fourth-grade classroom.

Power Dynamics

Fairclough (1989) and van Dijk (2003) define power in the context of discourse. Within verbal interactions, power is determined by institutional roles, socio-economic status, gender, or ethnicity of the participants. Fairclough claims that discourse participants possessing power in conversations exert control on how others contribute. Van Dijk defines those with social power within groups as those who control the actions and thoughts of others. Cornelius & Herrenkohl (2004) determined that power is not a fixed attribute of an individual, but shifts due to the context and interactions of the learning experience. It is based on relationships among participants, subject matter, and cultural tools used in those interactions (Candela, 1999, 2005; Cornelius & Herrenkohl, 2004; Herrenkohl & Guerra, 1998; Wertsch, 1998). In this section of the literature

review, I describe how researchers have investigated students and teachers use of power to influence social relationships and to build understanding in science classrooms.

To understand the role and influence of power in interactions for learning, the participant structure (Phillips, 1972) of the classroom must be addressed. The social roles, rights, and responsibilities of students and teachers define the participant structure. These social relationships determine each speaker's relationship with other participants and the subject matter (Cornelius & Herrenkohl, 2004). Wertsch (1998) viewed participant structure as a cultural tool that teachers use to transform relationships of power between and among students, between students and teachers, and among those relationships and the instructional materials. From these perspectives, I believe that educational psychologists can begin to understand how shifts in power among participants in a classroom affect student understanding. I will provide a rich description of qualitative research that Cornelius and Herrenkohl (2004) conducted, since the researchers examined the influence of cultural tools and participant structure on power relationships in a science classroom. This understanding and evaluation helped guide my research on power and questioning in an elementary science classroom.

Cornelius and Herrenkohl (2004) identified three characteristics of power related to dynamic relationships and interactions within a classroom's participant structure: (a) *ownership of ideas*, (b) *partisanship*, and (c) *persuasive discourse*. Ownership of ideas refers to the relationship of power between the individual and a unit of knowledge. A group of people or an individual can hold onto and promote an idea or a body of

knowledge (Sharrock, 1974). Engle and Conant (2002) and Goodnow (1990) described this power relationship in education: teachers, peers, textbooks, and students themselves influence how a student relate to a body of knowledge.

Cornelius and Herrenkohl (2004) used Hatano and Inagaki (1991) research to describe partisanship. Partisanship is a power relationship among students due to their interactions and their science understanding. Hatano and Inagaki (1991) reported that in classroom discussions, science students argued in favor of certain views of the topic and criticized other sides of the argument. Students aligned themselves with particular sides of each argument. The researchers found that students taking sides appeared to be more influenced by their relationship with each other than by what they knew about the topic.

The final aspect of power is persuasive discourse (Cornelius & Herrenkohl, 2004); it is defined as the manner in which students communicate with each other to affect their power relationships. In describing this aspect of power, Cornelius and Herrenkohl used Bakhtin's (1981) work regarding the notion of internally persuasive speech. In internally persuasive speech, the recipient of a speaker's message compares this information to what he or she knows and evaluates the message. The recipient has the power to decide whether to accept the message. The social position of the recipient is compared to whether or not the messenger holds authority. Those who have power through authoritative discourse do not permit recipients to compare the message to what they know, but rather expects learners to accept passively what is said. Authoritative discourse is practiced by teachers who ask questions to which they know the answers and

thus subsequently evaluate student responses. Cazden (2001) and Mehan (1979) found teachers who view themselves as possessing power use authoritative discourse with their students.

Corneilius and Herrenkohl (2004) conducted a qualitative study to understand how these aspects of power (ownership of ideas, partisanship, and persuasive discourse) emerge within the complex interactions of participant structure in a science classroom. The researchers used data from a larger study by Stevens, Wineburg, Herrenkohl, and Bell (2005), *Promoting Argumentation in the Teaching of History and Science* (PATHS*).* In the larger study, researchers investigated students' epistemological understanding of history and science, and identified teachers' pedagogical practices for science and history instruction. Specifically, they sought to provide curricula that would encourage students to understand how to think like historians and scientists. In small groups, students conducted science investigations, and examined documents in science and history to identify information that would assist them in building their own theories about the science and history concepts. As students conducted these activities, Steven et al., (2005) provide students with five cultural tools supporting their science and history thinking and development of theories. In science classrooms, these cultural tools were a large white board, a poster "Thinking like a scientist", audience roles, a questioning chart, and a forum-style presentation format. The students presented and defended their theories before the entire class. During the small group and large group presentations and discussions, the teacher expected students to use argumentation when introducing and defending their theories.

Cornelius and Herrenkohl (2004) studied how these cultural tools affected power relationships within a sixth-grade science PATHS classroom. The sixth-grade science unit was *Sinking and Floating*. Students formed small groups and completed several laboratory activities to build their understanding of density and ways of thinking and doing science. Students used the experiments to (a) predict whether objects would float or sink, (b) determine whether the objects floated in buckets of water, (c) record data and determine results, and (d) develop and modify theories based their investigations. Before the entire class, each group presented their theories and reasons for why certain objects float or sink.

The students employed a large whiteboard (Stevens, et al., 2005) to present their thinking and form their scientific arguments. Specifically, students used the whiteboard to organize observation concerning floating and sinking objects, and to record their predictions, results, and theories for the Floating and Sinking investigations. Students used the whiteboard to present a poster of their findings to the class.

The teacher displayed the poster, "Thinking like a scientist" (Stevens, et al., 2005) in the classroom and used it to introduce students to processes that scientists employ to develop theories. The teacher and students discussed and examined these processes before students began the investigations and whole-class presentations. The poster was adopted from Herrenkohl and Guerra's work (1998), and ". . . included (a) predicting and theorizing, (b) summarizing results, and (c) relating predictions and theories to results" (Cornelius & Herrenkohl, 2004, p. 474).

Students were assigned audience roles (Stevens, et al., 2005) for the whole-class presentations and discussions. Audience roles were developed and studied by Herrenkohl and Guerra (1998) and Herrenkohl, Palinscar, DeWater, and Kawasaki (1999), as they studied elementary student use audience roles during scientific discourse. Herrenkohl and Guerra (1998) gave fourth-grade students explicit audience roles and guidelines to evaluate and question other students' science findings during whole-class presentations. The roles corresponded to the three strategies outlined in the "Thinking like a scientist" poster. The researchers found that teachers did not need to ask as many questions of students when non-presenting students were given audience roles. Students assuming audience roles probed presenters for clarification and explanations. Herrenkohl and Guerra (1998) found that audience roles transformed student participation by giving them responsibilities and strategies for evaluating and seeking understanding of peer presentations.

The teacher used the questioning chart (Stevens, et al., 2005) to guide student questioning during classroom activities. Together, the teacher and students developed questions to include in the chart. Questions related to the "Thinking like a scientist" poster. They focused on *predicting and theorizing*, *summarizing results*, and *relating predictions and theories to results*. The chart was displayed so students in the audience would have a classroom aid to support their participation in discussions.

The teacher used the presentation and discussion format (Stevens, et al., 2005) to provide students an opportunity to present their theories, and provide audience members with opportunities to ask clarifying and challenging questions. The presentation and questioning opportunities had to be completed within certain time limits. This forum

style format and audience roles allowed the students to become active participants in developing their understanding of the content as well as the process of doing and thinking like a scientist.

The sixth-grade classroom that Cornelius and Herrenkohl (2004) studied was in a school in an urban setting that served a diverse population of students. The science teacher, Mrs. Garrett, taught for four years; her teaching style was one of “balancing inquiry and exploratory based [instruction] with the scaffolding [students] need to have the skills to be able to do that” (Cornelius & Herrenkohl, 2004, p. 475). She believed that the PATHS curriculum aligned with her own teaching philosophy -- students work together to develop and discuss answers to classroom challenges.

Cornelius and Herrenkohl (2004) analyzed videos of sixth-grade classroom activities and interviewed two students to seek to understand more deeply how students related to aspects of power and cultural tools in the PATHS classroom environment. One interviewee was Alicia, a Euro-American girl whose family had lived in the school district for the previous ten years. The second student, Alex, was a Korean boy whose family immigrated to the United States three years prior. Alicia and Alex were not from the same small-group. Based on their classroom observations, the researchers (Cornelius & Herrenkohl, 2004) chose Alicia and Alex because: (a) they provided reflective responses regarding how relationships and their understanding influenced their learning, (b) they verbalized what they were thinking as they shared what they understood about Sinking and Floating activities, (c) they were friends and they admitted that they liked to argue with each other, and (d) they appeared powerful in classroom discussions because they contributed a great deal and defended their theories.

Cornelius and Herrenkohl (2004) recognized the teacher's role in providing learning experiences for students. Mrs. Garrett influenced the power structure of students and the content by shaping participant structure with cultural tools of the class so students had opportunities to build their understanding. Cornelius and Herrenkohl referred to work by Engle and Conant (2002) to describe how teachers such as Mrs. Garrett facilitate meaningful student participation. Engle and Conant proposed four principles of *productive disciplinary engagement:* (a) problematizing content encourages students to question, propose, and challenge ideas and the teacher seeks clarification and provides support for those expressions, rather than simply validating them, (b) students become stakeholders in their own learning as teachers gave them authority to conduct investigations and share their findings, (c) teachers require disciplinary standards of inquiry by students, such as supporting a theory with evidence, which students must follow when interacting and learning from each other, and (d) teachers and students have time to investigate, share, and ask questions so that they can interact and build their understanding.

Cornelius and Herrenkohl (2004) used their understanding of the three aspects of power (ownership of ideas, partisanship, and persuasive discourse), participant structures, cultural tools from the PATH study, and productive disciplinary engagement to organize their interview to learn how Alicia and Alex participated and viewed power relationships in their sixth-grade science classroom. The researchers analyzed the interview transcripts alongside their classroom observations and video-recordings.

Regarding the ownership of ideas aspect of power, both students demonstrated ownership of ideas about sinking and floating. They explained their theories based on what they observed, but Alicia indicated that she obtained conflicting results from her different laboratory activities. She sought outside information (from books and parents) to help build her understanding. She used this information to conduct additional investigations to verify what she understood. Alex also used his observations during the investigations to evaluate his theory. Both students considered their understanding of sinking and floating to come from their investigations and observations, not from what others had determined for them.

Cornelius and Herrenkohl (2004) observed the power aspect of partisanship through students' ownership of ideas as they shared and defended their theories. Certain students shared their ideas more strongly than did others. Forum-style presentations, where students were given audience roles and a question chart, effectively supported students' questioning each other's thinking. Herrenkohl and Guerra (1998) recognized that students were given the *right* and *responsibility* to participate in whole-class discussions. Alicia and Alex noted that many disagreements arose about group theories during these whole-class discussions, and they justified this by commenting that everyone had their ideas. Alicia noted the power aspect of partisanship by naming friends who disagreed and agreed. Alex recognized that it was difficult to convince other students to agree upon a theory. Cornelius and Herrenkohl (2004) noted that Alicia, Alex, and other students argued and defended their sides due to their direct experience and knowledge about sinking and floating, not because they sought praise from their teacher for being right.

The students' use of a forum-style format provided opportunities to display the persuasive discourse aspect of power (Cornelius & Herrenkohl, 2004). The presenters held the power to share, defend, and convince the audience of their theories, and, as Alicia and Alex noted, audience members had power to question the theories, and, at times not agree with presented ideas. Alicia and Alex recognized the challenge of persuading the audience through discourse and with evidence. It was difficult, but they realized that they and other students could engage in discourse and convince others about science ideas. The cultural tools in the classroom that the researchers provided (forum-style presentation, audience roles, question charts, a participant structure for Alex, Alicia, other students, and the teacher) allowed students to develop and participate in persuasive discourse and power dynamics in order to share and defend their science knowledge.

Cornelius and Herrenkohl's (2004) research provides an example of how power shifted among classroom participants and across interactions about the science content. The question and answer opportunity among audience members and presenters of theories is an example of shifts in power. Students took the opportunity and responsibility to seek understanding and clarify what they knew through these interactions. The teacher, with the researchers' support, provided students with cultural tools and participant structures to encourage productive science engagement (Engle & Conant, 2002) so that students were provided opportunities to discuss their understanding of sinking, floating, and the ways of doing and knowing science. The researchers' findings about power, social, and disciplinary engagement are limited to a whole-class observation and interviews with two students. The rich description of this research

provided a perspective for me of how the instructional support (cultural tools and participant structure) assisted two students who became actively engaged in sharing and defending their science knowledge. I used these findings to guide my observations of how power dynamics many shift among students and the teacher within the fourth-grade classroom.

Cornelius and Herrenkohl's (2004) did not determine if students' understanding improved through their use of power and interactions. The researchers assumed the two students in this qualitative study understood sinking, floating, and ways of doing and knowing science. The researchers based this assumption on what teacher and students talked about, and how they interacted with the cultural tools, their peers, and teacher.

Candela (1999, 2005) studied how teachers and students used power in discourse to learn science in elementary school classrooms. Candela (1999) conducted qualitative research in fifth-grade elementary science classrooms in Mexico City. Candela set out to investigate students' contributions to classroom discourse. She sought to determine if students followed their teacher's requests, or if they used opportunities during conversations to assume power and to construct their own understanding. Like other educational researchers (Cazden, 2001; Cochran & Reinsvold, 2010; Erickson, 1986; Lemke, 1990; Mehan, 1979; Scott, et al., 2006; Wang, 2006) Candela recognized teachers' power in classroom conversations, possessing power and control of educational discourse. As teachers interact with students, they may use power to reshape or ignore student ideas (Cazden, 2001; Cochran & Reinsvold, 2010; A. D. Edwards & Furlong, 1978; D. Edwards & Mercer, 1987; Lemke, 1990; Mehan, 1979; Scott, et al., 2006).

When identifying the participant structure of classrooms, Candela realized students are often subordinate to the teacher's position in the participant structure. For example, the teacher's use of power reduced the students' abilities to ask questions or give explanations; teachers expected students to give correct answers to their teacher's questions (Holt, 1969).

Candela (1999) used conversational analysis tools, also termed ethnomethodological analysis (Schiffrin, et al., 2003; Wieder, 1999), to determine how students' discourse participation was influenced by what was said. Candela gathered observation notes and transcripts of fifth-grade elementary science classroom discussions to analyze shifts of power dynamics among teachers and students. The science topics addressed by the class were gravity, density, carbon dioxide production, and combustion. Candela was particularly interested in interactions among the students and teacher: she sought to investigate how students voiced their agreement or disagreement to what was said and how their teacher responded.

Candela (1999) found dynamic shifts in power during science discussions among students and teachers. Candela concluded that students influenced their teacher's discussion structure either by (a) not participating in the discussion, (b) defending their explanations, (c) evaluating teacher and student explanations, (d) questioning the teacher's or other students' explanations, or (e) initiating topics for discussion. Teachers maintained classroom control by sustaining the activity task structure, initiating the discussion, and asking questions, but did not control how students responded. Both teacher and students asked questions of each other; the teacher asked questions for which he/she knew the answer, whereas students did not know the answers to their questions.

The conversations focused on agreeing, supporting, or questioning what each other knew and said about the science topic. There was considerable give and take among students and between teachers and students.

Overall, Candela (1999) found that students communicated competently in sharing and defending their explanations. It appeared to Candela through conversations that students gained an understanding of the science topic; however, Candela did not report evidence to demonstrate improved student understanding of the science content. The power structure that emerged depended on the perceived relevance of the content to the participants. Students confronted the teacher's authority, and they were able to alter the roles and responsibilities to engage in sharing and defending what they knew. As in Cornelius and Herrenkohl's research (2004), Candela found conversations in the fifth-grade classroom did not represent a competition for power to disrupt learning, but conversations in which shifts in the power structure were observed to share, defend, or agree with science explanations.

In another study, Candela (2005) investigated how institutional practices are affected by interactions of students and teachers as they negotiate power relationships. Institutional practices are school norms established from cultural practices (Anderson-Levitt, 2003; Candela, Rockwell, & Coll, 2004; Duranti, 1997). Teachers implement school norms in the classroom (D. Edwards & Mercer, 1987; Mehan, 1979; Mercer, 1995; Sinclair & Coulthard, 1976). Students influence these norms through their personalities, personal histories and cultures, and prior knowledge. Students are also

influenced by the interactions with their teachers and peers (Candela, 1999; Cole, 1996; Lambert & McCombs, 1998). Institutional practices determined participant structure noted in Candela's fifth-grade classroom study (1999).

As in her earlier study (1999), Candela (2005) focused on turn-by-turn communication of classroom conversations between students and teacher. Candela recognized speaking among participants as a social and cognitive event (Duranti, 1997). As teacher and students participated in academic conversations, they needed to ascertain roles and responsibilities of others and cognitively manage their understanding based on what others said or may say. Candela focused specifically on how statements are collaboratively developed and interpreted within academic activities in a science classroom. She referred to this dynamic conversation as "authorship" (Candela, 1999, p. 325), and sought to understand how student authorship influenced institutional practices in the classroom.

Candela (2005) conducted this ethnographic study in three elementary classrooms in Mexico City. Two classrooms contained children of recent immigrant families from rural towns; one classroom contained children of working-class families. She observed and video-recorded two fifth-grade classrooms and a third-grade classroom. She observed seven fifth-grade lessons and four third-grade lessons. The fifth graders studied properties of gravity and combustion, and the third graders studied properties of light.

Candela's (2005) first example of student authorship of instructional practices was found in the third-grade classroom. The third-grade teacher in this classroom asked students to form small groups and share what each wrote about different uses of light, and then to create a text that combined all the information. Candela analyzed the transcribed

conversation and her observations of one group to discover that students organized their information about light and formed a participant structure that followed their teacher's directions. One boy organized group work and guided the small group to read what they had written about light. He assigned roles on what needed to be done. He guided them separately to read their work aloud and interrupted them to read loud enough so all could hear:

Extract 1:

B 1 [Boy 1]: as loud as you can (he is telling B3 how to read)
B3: light travels really fast, that is why you see lightning first
and then you hear the thunder, light helps us see
B1: ok, let's continue, ok, now write, it says . . .
G1[Girl 1]: light, light helps us to see in the night, it also helps to see
what we write, it shines on us
B1: ok, now get to work, start writing
G1: ye::s
B3: be careful
G1: start a new paragraph
B1: right, let's start a new paragraph then
B2: should I read too?
B1: ok
(Candela, 2005, pp. 327-328)

Through these interactions, the student provided instructions and forms of participation; he organized the group's work. Other students shared in task responsibilities: (a) a boy asked that they be careful as they write, and (b) a girl suggested that they begin a new paragraph when describing a new idea about light. Together, students completed their academic task by authoring institutional practices through their words and actions. Candela recognized that small-group work occurs frequently in science classrooms,

where investigations and hands-on manipulation of objects occur, and that children can interact through conversation to develop instructional practices to complete an academic task successfully.

To determine whether elementary students can interact with their teacher and co-author institutional practices, Candela (2005) analyzed interactions of a fifth-grade class studying combustion. The teacher first provided a demonstration for the class. As the teacher shared what he was doing, the students were attentive. They freely commented on what was or was not being demonstrated by the teacher. The children told the teacher how the demonstration should be conducted; they shared what they thought should be added to the apparatus to allow combustion to start. Another student criticized the teacher for not having enough matches to complete the demonstration. The teacher acknowledged these students' comments, which placed students in social positions where they could criticize and seek changes in what was being done. The teacher also justified why he did what he did and encouraged students to assume responsibilities for how they conducted their activities. This example illustrates how students shared in the responsibility to complete the activity successfully. With the teacher, the students used words and actions to complete the work appropriately. Candela concluded that discourse interactions documented that the responsibility for academic success was distributed among all participants.

Candela (2005) found that when third-grade students interacted in small groups to complete an academic task, they became authors of instructional practices. They assumed responsibility through their words and actions to organize the participant structure to complete the task at hand successfully. Likewise, fifth-grade students were

willing and able to influence a teacher-led demonstration by providing criticism and suggestions. The teacher recognized and encouraged their contributions and placed students in social positions as knowledgeable and responsible participants. The students influenced how their teacher conducted the activity. From observations and transcripts, Candela believed that these elementary students took control of the interaction when they recognized they held the responsibility to contribute to the topic under study or to the norms of social participation. In this study, Candela knew from cultural and institutional practices of the schools that teachers in the study possessed classroom authority. However, teachers also encouraged their students to assume responsibility for influencing the academic and social practices of classroom activities. Candela believed her study illustrated when students are given opportunities to contribute to institutional practices in the context of academic activities, they actively participate in the discipline's knowledge construction.

To understand shifts in power and participant structures, Candela analyzed social changes and conversations where students and teachers facilitate active involvement so all voices are heard (Cornelius & Herrenkohl, 2004). In Candela's work (1999, 2005), she described how elementary students influence classroom discussions and teacher-led demonstrations. These illustrated power structure shifts within classroom interactions. In both studies, power dynamics among students and between teacher and students changed as they focused on contributing and shaping an academic task. *Implicit* in these studies was the realization students were building their science knowledge from such experiences. Like Cornelius and Herrenkohl's (2004) research, Candela (1999, 2005) found that when students are given roles and responsibilities to interact in science

activities, they use power to influence interactions among each other, with the teacher, and with the subject matter. Similar to Cornelius and Herrenkohl's (2004) research, Candela (1999, 2005) simply assumed that student interactions and engagement were indicators of knowledge gains. I believe that *explicit* indicators of student knowledge gains need to be gathered to support such inferences. Data on student knowledge are gathered in my research to verify whether interactions and power shifts within classroom interactions actually influence student understanding of the content.

Bianchini (1997) and Shepardson and Britsch (2006) also studied power dynamics within classroom interactions as students learn science. Bianchini (1997) studied how small group work in sixth-grade life science classes influenced student access to science materials and discourse. The teacher and students used the *Program for Complex Instruction* framework (E. G. Cohen, 1994) and *Human Biology* (Lotan, Bianchini, & Holthuis, 1996) instructional units to build understanding of life science topics.

The Complex Instruction framework (Bianchini, 1997) was designed to provide teachers and students with support to work together in collaborative teams to understand science topics. The Human Biology curriculum was structured around big ideas and central questions that provided many open-ended activities for students to build their understanding. The sixth-grade teacher was given strategies by Bianchini (1997) to assist in developing cooperative norms within small groups; these norms allowed each student to acquire authority and take responsibilities for participation and learning. These norms (Bianchini, 1997) were similar to cultural tools found in Cornelius and Herrenkohl's (2004) study. Each small group was given procedural roles that enabled them to become

active participants in the learning activity. Those roles "include facilitator, material manager, recorder, safety officer, and harmonizer" (Bianchini, 1997, p. 1041). Students used these roles to manage group tasks.

Another component of the Program for Complex Instruction framework (E. G. Cohen, 1994; Lotan, et al., 1996) was status support strategies that the teacher used to build student self-esteem regarding their popularity and academic ability. Status features were based on gender, popularity, academic ability, ethnicity, and social class. These status building strategies were based on previous research (E. G. Cohen, Kepner, & Swanson, 1995; E. G. Cohen & Lotan, 1995); they found that student access to conversations during science group-work was affected by the student's status. A status strategy used by the teacher included reminding students that each individually did not possess a complete set of skills and abilities (observing, organizing, visualizing relationships, recording, explaining) to be a successful learner. Each student had at least one essential skill, so students were encouraged to work together to complete the activity successfully. A second strategy was for the teacher to recognize publicly individual contributions to group activities. The teacher's use of such status strategies encouraged and supported participation by all students.

When investigating the sixth-grade classroom, Bianchini (1997) focused on two status features, academic ability and popularity, because she believed these features influenced productive collaborative work among students. There were levels with these status features. A high-status student in a small group was one who was expected to

possess the skills to succeed, tended to participate more in conversations, and had access to learning materials. The other levels (low- and middle-status) reflected lesser degrees of high-status attributes.

Prior to this study by Bianchini (1997), the sixth-grade teacher completed university-supported workshops to understand the Complex Instruction framework and the Human Biology curriculum. She taught in an urban classroom; students were ethnically diverse. Bianchini (1997) gathered qualitative data, and audio- and video-recordings, from these classrooms, which contained eighty students. She analyzed these data to understand how students of different status contribute to science conversations within their small groups. She sought to determine how students shared and defended their understanding, and connected their new knowledge to real-world applications. She used a questionnaire developed for the Complex Instruction framework (E. G. Cohen, 1994) with students at the study's start to determine students' classroom. Bianchini used Cohen's (1994) *Whole-Class Instrument* to observe student behavior documenting number of students on task at specific times during each activity. She used this instrument to determine the quality of group-work. She used the *Rate of Talk* instrument (Cossey, 1997) to identify the frequency of on-task talk of each student during the activity. To document the growth in understanding of science facts, concepts, and real-world applications, each student completed a paper-and-pencil test before and after each unit. She studied two Human Biology units. To probe students' understanding and participation in group activities, Bianchini (1997) interviewed 16 students after completion of each unit. The audio-recordings of small-group conversations and student interviews were transcribed.

After analyzing transcripts of observations and interviews, Bianchini (1997) found that group discussions focused on activity procedures rather than on conceptual understanding and connections to real-world applications. She also found that high-status students had greater access to materials and more discourse opportunities. Through quantitative analysis, Bianchini (1997) found that, on average, the rate of on-task talk was statistically different among high-status, middle-status, and low-status student groups. She also found that student status was highly correlated with on-task talk ($r = .60$, $p < .001$). The t-test results showed that high-status students talked more frequently than did middle- or low-status students, and middle–status students talked at a higher rate than did low-status students.

When analyzing pre- and post-tests of student knowledge, Bianchini (1997) found students had made small gains in their science understanding. She believed this was explained by what she found in the qualitative results: students focused more on procedural aspects of their activities rather than on building their conceptual understanding. She also found that the average rate of on-task talk was significantly and positively correlated with students' post-test scores. Bianchini states ". . . students who talked more during group-work learned more as well" (1997, p. 1057).

When analyzing data on student on-task behavior from the Whole Class Instrument, Bianchini (1997) found that the teacher ensured that students were engaged in conversations and using the materials. Bianchini also found that the teacher failed to use all status strategies effectively that supported equal student participation, and did not publicly recognize low-status students' intellectual contributions. From her findings, Bianchini (1997) concluded that teachers must diligently support student roles and

responsibilities in group work, so that they have equal access to conversations and materials. Teachers must be cognizant of student status and provide opportunities, using cultural tools and participant structures (Candela, 1999, 2005; E. G. Cohen & Lotan, 1995; Cornelius & Herrenkohl, 2004), so that all students can engage in activities and discourse to build their understanding.

Shepardson and Britsch (2006) studied teacher-student interactions within a fourth-grade science classroom. They based their study on Vygotsky's Zones of Proximal Development (Tudge, 1990; Vygotsky, 1978), where a student's ability to understand and solve problems depends on support of an older individual, such as a teacher. The sociocultural character of classroom interactions (and, specifically, teacher-student collaboration) was also a guiding perspective in Shepardson and Britsch's study. These researchers recognized how language use among participants in classroom discourse influenced participant access to learning resources and conversations. The researchers also based their work on van Dijk's (1996) work that showed teachers control what was said and turns of talk in the classroom.

Shepardson and Britsch used critical discourse analysis to investigate the social power of fourth-grade science conversations. They sought to determine whether all students participating in science activities in this fourth-grade classroom had opportunities to speak and share their understanding. The researchers intended to understand how a teacher's interactions with small groups of students influenced students' verbal conversations within small groups, and how these interactions can provide student access to procedural and conceptual understanding about the subject matter of the group activity.

For one year, Shepardson and Britsch (2006) observed a teacher and students in a fourth-grade science classroom in a public elementary school. The teacher and most students were Anglo-American. Students were from middle- and upper-class economic families. The researchers observed many interactions of small groups and students participating in investigations. The researchers also conducted informal interviews with the teacher after science instruction to understand (a) how the teacher planned the activities, (b) the teacher's thoughts about her interactions with students in small groups, and (c) the teacher's judgment of students' replies. Based on the researchers' initial classroom observations, they chose to observe six students working within their small group. The researchers asked the teacher for assistance in this selection because they wished to observe students developmentally on track as fourth-graders, active users of their science journals, and socially engaged with their peers. During four science units, the researchers collected audio- and video–recordings of the small group's activities. The researchers also interviewed the six students to obtain their views of the small group interactions. The students' science journals were collected and copied to allow comparisons of what students wrote to what they said.

Shepardson and Britsch (2006) transcribed the audio-recordings and noted each turn or utterance by the students and teacher. The participant turns were coded in terms of one of three grammatical functions: query, statement, or imperative. Participant turns were also coded for their social function: *informative, managerial, directive*, *evaluative*, *procedural, understanding*, and *reformulation* (expands or repeats a statement or query). The researchers also used encounter codes to describe the pedagogical and/or the social

function of each turn. The encounter codes were procedural, conceptual, and managerial. They analyzed the language of these coded segments to identify any patterns of social and individual power.

From the analysis of turns and encounters, Shepardson and Britsch (2006) identified three patterns, labeled as *Zones of Interaction*. The three zones were labeled (a) *Individual Zone of Interaction*, (b) *Multiple Zones of Interaction*, and (c) *Collective Zone of Interaction*. Each zone defines the boundary of the learning context where discourse turns and encounters occur. The boundary is dynamic; some students were invited to participate in the zones of interaction, and others may join the interaction later in the conversation. The researchers noted that the teacher controls all zones of interaction, and student participation characterizes each zones. Consistent with Cornelius and Herrenkohl (2004), Candela (1999, 2005), and Bianchini (1997), these zones are characterized by shifts in power dynamics within classroom interactions.

Shepardson and Britsch (2006) defined an Individual Zone of Interaction as the situation where the teacher talks to only one student. During this interaction, the student has access to different procedural and conceptual learning opportunities. Students were either included or excluded from these interactions. One conversation that researchers classified as within the Individual Zone of Interaction, was the teacher asking a student to list measurable characteristics of a rubber band. At the end of this interaction, another student asked the teacher about the procedure for measuring the rubber band, and the teacher rephrased the second student’s question and turned her attention to that student. The first student and other students in the small group were not included in that second Individual Zone of Interaction.

Multiple Zones of Interaction were used by Shepardson and Britsch (2006) to describe a complex situation containing more than one zone. In such an interaction, the teacher attempts to involve a small group of students in a discussion based on what the teacher seeks to accomplish. However, not all students were willing to accept the teacher's directive, and they formed their own zone of interaction. The researchers shared an example where the teacher sought to understand how students drew the rubber band in their science journals. She posed a procedural question to the small group; she did not get the answer she expected. She rephrased the question and then provided options for how the rubber band should be drawn. The responding students did not use words the teacher expected to hear. The teacher stated what she expected them to say about the rubber band, "flat on the table" (Shepardson & Britsch, 2006, p. 457). The researchers believed that students were not in the same zone of interaction as the teacher. The students did not follow what their teacher wanted them to understand and say. The researchers identified multiple zones of interaction in this encounter.

In a Collective Zone of Interaction, the teacher and students share the same social and content objectives. In this interaction zone, the teacher was observed to manage individual or group behavior, not to facilitate understanding of the science content or procedure. The example the researchers provided was of a teacher asking a group what they planned to do. The student response was generalized not specific, so the teacher asked them pointedly what they were to do. The researchers believed that the type of questioning the teacher used did not help students to think through what they had to do. The teacher was regarded as the manager of students' behavior in this zone of interaction.

Shepardson and Britsch (2006) used the Zones of Interactions framework to assist them in determining how teachers and students access social and content power to interact and understand the content. The researchers found that the teacher controlled all zones of interaction. In this study, the teacher expected the student to follow her procedures and descriptions to complete the activity tasks. The teacher regulated students' behavior as they accessed materials. She expected students to follow prescribed steps to complete the tasks, but did not provide them with interactions to reflect on why they were following those procedures and what they were learning from the interactions. Students did not possess social and content power to deepen their procedural or content knowledge. Bianchini (1997) also reported that the teacher and students focused more on procedural tasks than on their understanding of science content. Teachers studied by Bianchini (1997) and Shepardson and Britsch (2006) did not provide adequate support and power to enable students to interact through conversation to build their understanding.

Researchers of Power Dynamics in science classrooms (Bianchini, 1997; Candela, 1999, 2005; Cornelius & Herrenkohl, 2004; Shepardson & Britsch, 2006) document that shifts in power dynamics among students, teachers, and science content influence science learning interactions. Power is shared, denied, or negotiated by teachers. Teachers controlled how students interact and build science ideas and knowledge through verbal interactions. As teacher and students participated in science conversations, they ascertain the roles and responsibilities of others and cognitively manage their understanding based on what others have said or may say. Teachers should develop and implement participant structures (roles and responsibilities) (Bianchini, 1997; Candela, 1999, 2005; Cornelius &

Herrenkohl, 2004; Herrenkohl, et al., 1999) for classroom participants to encourage reflective discourse. Participant structures described by Cornelius and Herrenkohl (2004), and Candela (1999, 2005) provided teachers and students with power and questioning opportunities. Scientific dialogue is stimulated by questioning opportunities among classroom participants; teachers and students shared and defended their ideas, procedures, and findings. Power dynamics in science classrooms should allow such engagement for learning; such activities mirror what scientists do (Rutherford & Ahlgren, 1990).

From this review of research (Bianchini, 1997; Candela, 1999, 2005; Cornelius & Herrenkohl, 2004; Shepardson & Britsch, 2006), it is clear that teachers can shape power dynamics within science classroom interactions. However, this research fails to demonstrate whether student science knowledge improved within the power dynamics. Redfield and Rousseau's research (1981) explicitly documented that the teacher's use of higher cognitive questions improved student achievement. Roth (1997), van Zee (1997, 2001), and Chin (2007) found that teachers use complex questioning strategies within their science classrooms, but student knowledge gains from these interactions were not investigated. How do teachers and students use questioning strategies within classroom power dynamics to learn science? I conducted this study to address this question.

CHAPTER III

METHODOLOGY

From the literature review (Chapter 2), I found that social interactions among classroom participants are influenced by power and questioning strategies employed by teachers and students. To understand how these influences build science knowledge among students in an inquiry-based elementary classroom, I proposed the following research questions.

Main Question:

Q1 How do power and questioning strategies in an elementary classroom support student understanding of science?

Specific questions:

A How does a teacher use questioning strategies in classroom discourse to engage students to understand science?

B How does a teacher use power in classroom discourse to engage students to understand science?

C How do students use questions in classroom discourse to understand science?

D How do students use power in classroom discourse to understand science?

E How does the use of power relate to questions in classroom discourse?

Design

I used a primarily qualitative approach to examine the teacher's interactions with fourth-grade students who are learning science. To understand how the teacher facilitated and monitored students' science understanding, a case study of the inquiry-based elementary science classroom was employed (Merriam, 1998; Stake, 1995). Data sources included teacher interviews, audio- and video-taped classroom observations, classroom instructional materials, and student work from the elementary science lessons. These data enabled me to develop rich descriptions and explanations of interactions where the teacher supports students learning.

A case study is defined by a bounded system (Merriam, 1998), and is characterized by a limited number of participants conducted over a period time. Based on this methodology, the researcher must specifically define the participants and duration of the study. Other educational researchers (Cornelius & Herrenkohl, 2004; Hughes, 2001; Roth & Lucas, 1997) have used the case study design to study interactions within a science classroom.

I sought to understand complex social interactions, particularly questioning and power dynamics, which build elementary students' understanding within a specific science classroom. Therefore, in this study, the bounded system was a fourth-grade classroom containing interactions among students, a teacher, and instructional materials. The study occurred as the teacher and students investigated features of Colorado vertebrates, and took place over 28 days.

Participants and Setting

Teacher and students. Purposeful sampling (Creswell, 2007) was used to select the teacher and students. A fourth-grade teacher and students in a U.S. Rocky Mountain region classroom served as the participants and setting for this case study. A fourth-grade classroom was used because these students had received science instruction in third grade; thus they had previous experience in science learning. Also fourth-grade students in the region of this study were not required to complete a standardized science achievement test, so instruction and learning in this classroom was not directly affected by such a high-stakes event. Table 1 provides a list of criteria used to select and describe the teacher and students of this study.

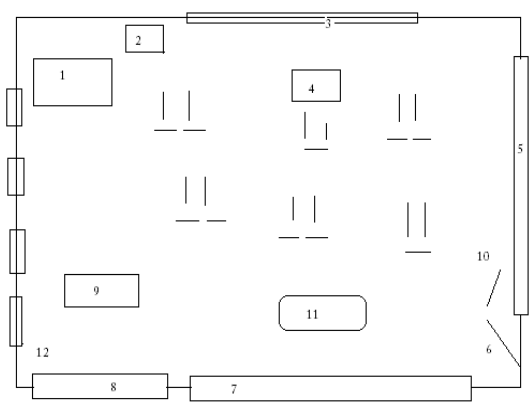
Table 1

Selection Criteria and Description of the Teacher and Students

Selection Criteria	Teacher Description	Students Description
The teacher must agree to volunteer for participation in this study.	Two fourth-grade teachers, both females, were considered for this study. One teacher was on maternity leave and the other volunteered.	
The teacher must teach science in a fourth-grade classroom.	The fourth-grade teacher taught elementary school for seven years, and taught science for six years.	
The teacher must use inquiry-based instructional materials and actively seek strategies to teach science well.	The teacher taught the school district's science unit, *Colorado Wildlife*. She used her own materials, as well as *Colorado Wildlife* (Block-Gandy, 2001), and materials from the Colorado Division of Wildlife (Armstrong, 1993; Becker, et al., 1997a, 1997b; Colorado Division of Wildlife, 1994). Block-Gandy designed investigations so the teacher could use guided-inquiry strategies when assisting the students to understand the vertebrates and life zones of Colorado. The authors of the Colorado Division of Wildlife materials (Becker, et al, 1997a, 1997b) designed lessons so students had opportunities to observe, collect, and analyze information about animals. By participating in these activities, students would engage in scientific inquiry.	
The teacher must teach science to all classroom fourth-grade students at least three to four days weekly	When this study was proposed, the identified elementary school was the only district elementary school where all students at the fourth-grade level learned science. Science was taught half of the academic year, and social studies was taught the other half of the year. During weeks when science was taught, it was taught daily.	There were 23 students in the teacher's fourth-grade class. Seventeen of the students and their parents granted consent to participate in the study. All students participated in the science lessons.
The teacher must teach a group of students that represent the diversity of the school district.	The school district's student population was 58.3% Hispanic, 37.2% White, 1.3% African-American, 1.4% Asian, and 0.2% Native Americans (Colorado Department of Education, 2010a).	Forty-one percent of students in the teacher's class were Hispanic, 55% White, and 0.5% Asian.
The teacher must teach all fourth-grade students science, irrespective of their literacy needs.		All students in the teacher's class remained in the classroom to learn science. There were two students with special needs and required an Individualized Education Program (IEP).

The teacher possessed an elementary education degree, and had participated in over 12 hours of science and science education professional development. The teacher met monthly with other elementary teachers to discuss use of the school district's science instructional materials and how well students were learning science.

Classroom setting. The school in which this study was conducted was new, compared to other elementary schools in the region. Classroom layout was typical of many elementary classrooms (Figure 1). I sat in the back of the classroom, positioned so my presence as an observer did not disturb classroom activities. For all observations, I sat in front of the bookcase, labeled 8 in Figure 1, and the video-camera was at location marked 12. The windows were along the left side of the room. The video-camera captured the entire classroom, but did not disturb classroom activities.



Key
1. Teacher desk with computer
2. TV suspended from ceiling
3. White board
4. Overhead projector and Elmo
5. Storage cabinets with counter and sink
6. Door to hallway
7. Open cabinets for student coats and backpacks
8. Bookcase
9. Short bookcase
10. Easel
11. Teacher desk for small-group discussions
12. Video-camera

| __ Student desks

Figure 1

Diagram of the 4th Grade Classroom

Method

Five data sources were used to address the research questions. Data sources were:

- A highly structured teacher interview (Merriam, 1998), initially conducted prior to classroom observations.
- Observations of the teacher and students for 28 classroom sessions. Each classroom session lasted from 25-45 min. Sessions were audio- and video-recorded, and field notes were collected.
- Weekly interviews with the teacher, which were intended to learn what the teacher was thinking and deciding as the science lessons unfolded. Seven interviews were conducted.
- Teacher's science instructional materials were collected and reviewed.
- Student's science notebooks and quizzes were collected and photocopied.

I collected data continuously as the teacher and students completed a unit on the scientific method and a unit on vertebrates, *Colorado Wildlife* (Block-Gandy, 2001). I recognized that each data collection opportunity would influence the next. My observations and interview questions evolved as I learned more about teacher-student interactions, use of instructional materials, and student work in the science notebooks and their quiz results. These data collection processes provided me with more confident descriptions and interpretations of observed interactions (Merriam, 1998).

Initial structured teacher interview. Through my introductory research letter to and initial interview with the teacher, I explained that I sought examples of inquiry-focused teaching and learning in an elementary science classroom. I said that wanted to learn how teachers provide students with opportunities to talk about and describe what

they know about science. For the initial interview, I set an iPod recorder on the table where we sat and talked. Table 2 describes the interview topics. Appendix A provides a list of all teacher interviews, dates, and times.

Table 2

Categories of Data Sought from Structured Teacher Interview

Ethnicity of teacher
Total years taught
Highest earned college degree
Approximate total science professional-development hours and types of professional development experienced over career
Instructional goals and content area of the science lessons to be observed
Teacher's science-teaching philosophy
Teacher's preferred instructional strategies and interaction styles
Classroom student ethnicities
Students' prior science learning experiences

Classroom observations. For each classroom session observation, the iPod recorder was attached to the teacher's waist to capture teacher-student verbal interactions as she moved through the classroom. The video camera was placed in the back of room (Figure 1) to capture verbal and non-verbal interactions. I used a field notebook to write my thoughts as I observed.

I used findings from *2005-06 Local Systemic Change Classroom Observation Protocol* (Horizon Research Inc., 2005), and previous research (Cazden, 2001; Cochran & Reinsvold, 2010; Cornelius & Herrenkohl, 2004; Lemke, 1990) to inform and guide my classroom observations. Horizon researchers used the 2005-06 Local Systemic

Change Classroom Observation Protocol to assess ways teachers and students arrived at sense-making of science content through interactions, and to identify questions that teachers and students processed to build meaning. Researchers (Cazden, 2001; Cochran & Reinsvold, 2010; Cornelius & Herrenkohl, 2004; Lemke, 1990; van Zee, et al., 2001; van Zee & Minstrell, 1997b) who observed classroom interactions suggest that researchers should attend to strategies teachers employ to engage students in conversations as they build science understanding. These researchers also recognized that researchers should determine the extent to which students are provided opportunities to pose their own questions about what they are learning. I used the Horizon tool and research recommendations to guide my observations and to consider how the teacher and students control interactions, and the type and cognitive-level questions used by the teacher and the students. With this understanding, I developed guiding questions (see Appendix B) to focus my classroom observations. Other questions arose as I observed the classroom. I assumed the role of observer-participant (Merriam, 1998), because I recognized that the teacher and students controlled all activities that I observed. Also, at times, I was invited into the classroom conversations.

Teacher interviews. Weekly teacher interviews (Appendix A) helped me to build an understanding of the context within which classroom interactions occurred. From these interviews, I learned about the teacher's teaching and learning perspectives and how she viewed and supports student learning. The interviews also allowed me to understand the teacher's interpretation of what occurred as the lessons unfolded and how she decided to interact with students. The interviews occurred weekly, either during the teacher's lunch hour or after school. I used an open-ended structure for these interviews

(Merriam, 1998) and audio-recorded the conversations with the iPod. I explored the teacher's interpretation of what occurred during science lessons and concurrent student-teacher and student-student interactions. Sample questions for these interviews are listed Appendix C. I developed these questions during my classroom observations and teacher interviews, and I used them to understand the data that I collected and interpreted.

Instructional resources. I also reviewed the fourth-grade elementary curriculum guide (Greeley-Evans School District 6, 2008) and instructional materials (Armstrong, 1993; Becker, et al., 1997a, 1997b; Block-Gandy, 2001; Colorado Division of Wildlife, 1994) used by the teacher. According to my interview with the teacher, the Inquiry-based science materials were required by the school district's administration. A team of teachers from different grade levels in the school district collectively developed scope and sequence structures for each elementary science unit, including investigation and instructional materials used in my observations. The district administration approved this curriculum guide and established a calendar defining when each unit should be taught. All district elementary teachers were required to follow the guide and calendar in order to complete the science units within a specific time. From the teacher interview, I learned that teachers had to begin the Colorado Wildlife unit by August 27th, 2010 and end the unit by November 12th, 2010.

During my 28 observations (Appendix D) the teacher engaged her students in the following two major science units: 1) the Scientific Method (Observations 1 - 4), and 2) the Colorado Wildlife (Block-Gandy, 2001) (Observations 5 - 28). The scientific method unit was not found in the school district's curriculum guide, but was developed by the teacher. The main purpose of the scientific method unit was for students to understand

and use scientific method in an investigation. During an interview, the teacher explained that she added this unit to support the district administration's request to provide students with more opportunities to learn and use scientific methods. The main purpose of the Colorado Wildlife unit was for students to identify the five types of vertebrates by physical and behavioral characteristics. The teacher also supplemented the Colorado Wildlife materials (Block-Gandy, 2001) with instructional materials developed by the Colorado Division of Wildlife (Armstrong, 1993; Becker, et al., 1997a, 1997b; Colorado Division of Wildlife, 1994).

For this study, I chose to use three lessons within the teacher's Colorado Wildlife unit. These lessons allowed students to investigate animal pelts, tracks, and scat. The science lessons took place over five classroom observations (Observations 12 – 16; see Appendix D). The teacher used the Colorado Division of Wildlife (1994) materials for these three lessons. The authors (Becker, et al, 1997a, 1997b) designed these lessons so students had opportunities to observe, collect, and analyze information about animals. By participating in these activities, students would be engaged in scientific inquiry. I choose these lessons for this study because students explored animal parts to understand the features and behaviors of vertebrate, and the interactions among the teacher and students represented a level of engagement I observed across all 28 observations.

Student work. To gather evidence of student understanding of the science lessons, I received permission from 74% of students and their parents to collect, copy, and review students' science notebooks and quizzes. The use of science notebooks by elementary students was encouraged by the school district administration. The teacher

participated in professional development activities on the use of science notebooks (Douglas, Klentschy, Worth, & Binder, 2006) and science and literacy learning benefits of science notebooks (Amaral, Garrison, & Klentschy, 2002).

From students' science notebooks, I reviewed the scores and teacher comments from (a) 12 activity worksheets, and (b) overall comments on neatness, grammar, and organization of the science notebooks, and presence and order of activity sheets in the science notebooks. Students completed two quizzes during my 28 observations on the following topics: (a) vertebrate characteristics, and (b) vertebrates and Colorado life zones. I reviewed and transferred the students' scores and grammatical errors into a spreadsheet for analysis. The student work was collected and copied after their teacher had evaluated student work and recorded the scores.

Internal Review Board (IRB) process. The research application was submitted and accepted by both UNC's Internal Review Board and Weld School District 6's Research Application Review Committee. Teacher, parent and student consent was received and this allowed me to audio- and video-record their interactions, and collect student work. I did not collect student work or identify verbal or non-verbal interactions from students whose parents did not provide approval. The consent letters to the teacher and parents of students in the fourth-grade classroom are presented in Appendix E. The parent letter was translated to Spanish to seek permission from the non-English speaking parents. The student assent letter and approval letter from UNC's Internal Review Board are also found in Appendix E. For copies of the approved parent and student letters, I used the a pseudonym for the teacher and avoided identifying the school.

Data Analysis

Research data were analyzed by following case-study guidelines provided by Merriam (1998) and Stake (1995). I analyzed these data in distinct phases: (a) transcribed audio-recordings of classroom interactions and interviews, (b) aligned video-recordings with audio-recording to identify and establish the contexts within which interactions occurred (c) aligned transcriptions of classroom interactions with the instructional materials, (d) identified the Topic Related Sequences (TRS), (e) identified participants' roles, (f) identified power categories, (g) identified questioning categories, (h) compared participant roles, power and questioning coding, and (i) compared student understanding of lesson concepts to learning objectives, and participant roles, power, and questioning categories.

Field notes and audio-transcripts analysis. I used field notes and the video-recordings to provide context to verbal interactions transcribed from the audio-recordings. The field notes and audio-transcripts were analyzed to identify classroom interaction themes and patterns (Stake, 1995). This analysis enabled me to compare and contrast how the teacher interacted with students, and students with each other. In the analysis, I specifically identified classroom activity patterns within each science lesson, and determined how participation roles, and power and questioning outcomes occurred within the observed activities and interactions of the elementary science lessons.

Data transcription. When transcribing the audio-recordings, I used transcription conventions mostly adapted from Adger (2003) and used in previous work (Cochran &

Reinsvold, 2010) to characterize the discourse. Specifically I used conventions that denoted who was speaking, level of sound, emphasis, pauses, nonlinguistic sounds, and researcher comments. The adopted conventions are summarized in Table 3.

Table 3

Transcription Conventions – Adapted from Adger (2003)

Code	Character
T	Teacher
S	Unnamed student (S1, S2, etc, for more than one student talking in a conversation)
Ss	Unnamed students
.	Period, end of sentence
?	Question
.	One second pause
. .	Two second pause (further periods represent additional one-second pauses)
<u>Line</u>	An emphasis when speaking; above the normal speech level
CAP	Extra emphasis when speaking; at a shouting level
[ ]	Overlapping speech among two or more speakers
=	Speaker's talk continues or second speaker's talk is latched onto first speaker's talk without noticeable pause
( )	Nonlinguistic sounds, e.g. laughing
↑	Rising intonation
↓	Falling intonation
(( ))	Comments by researcher

Audio-recordings selected from three science lessons were transcribed for this study, since these lessons typified teacher-student interactions and investigations observed in the 28 observations. These science lessons took place over five observations (Observations 12 – 16, see Appendix D). The teacher and student names and identities were protected by using pseudonyms for identification. The transcriptions were entered into QSR NVIVO 8 qualitative data analysis software (QSR International, 2008). The video-recordings were aligned with the audio-recordings to verify who the teacher was talking with and what they were doing as they spoke. Descriptions of non-verbal interactions were entered as researcher comments in the audio-transcripts (Table 3).

Participant categories. The transcripts were initially coded in terms of three participant categories. Participant categories included *Student* (S), *Students* (Ss) (meaning multiple student responses at the same time, sometimes in unison), and *Teacher* (T). A S, Ss, or T was placed in front of each utterance by a student, students, or teacher, respectively. Table 5 provides an example of a partial transcript with the participants coded.

Topic related sequences. To understand the context within which particular interactions occurred, each science lesson transcript was evaluated for classroom episodes (activities) or Topic Related Sequences (TRS) adapted from Mehan (1979). A TRS was defined as a subject matter topic or activity developed through a thematic activity, where a substantive content concept was addressed. A sequence began by the teacher's initiation, and ended with either an evaluation by the teacher; ending of activity due to time; transition to an application of content such as group activity; or a shift to a new subject matter concept. Instructions and classroom organization processes

supporting an activity were included in the TRS. A change of activity was considered a new TRS. Based on previous research (Cochran & Reinsvold, 2010) each TRS could include science content and a variety of question types. My intention was to identify each TRS through coding (e.g., TRS1, TRS2, TRS3) and to provide a brief description of each. I used the TRSs to identify the range of classroom discourse interaction dynamics.

Participation roles. Classroom interaction transcripts were used to identify and organize the participation roles within the classroom discourse. A data matrix modified from the Initiation/Response/Evaluation (IRE) framework (Cazden, 2001; Mehan, 1979) and Scott, Mortimer, and Aguiar's (2006) participant role framework was used. The IRE framework was expanded to include a Prompt and two more Response roles (Cochran & Reinsvold, 2010). These additional roles were added to denote a "chain of interactions" (Scott, et al., 2006) between the teacher and students. A Prompt role is employed by a teacher or student to ask a question or elaborate on the content. A Response was added after the Prompt role, and a Response was added after the Feedback role (see Table 4). The Evaluation role was relabeled "Feedback," based on Wells' research (cited in Cazden, 2001).

The matrix used for the transcripts was organized in a table format with column headings: *Initiation*, *Response 1, Prompt*, *Response 2*, *Feedback*, and *Response 3*. Coding rules for placement of discourse in this matrix were developed by Scott et al. (2006). Definitions and examples of participation roles are found in Table 4. An example of the final matrix is presented in Table 5.

Table 4

Definitions and Examples of Participation Roles

Participation Role	Definition	Example
Initiation **(I)**	Teacher or student may ask a question or make a statement or comment that starts a sequence on a specific topic. Includes rhetorical questions, providing initial foundational information for a task, or setting the stage for a task.	T: Think about your graph. . . Did it go up? Did it go down?
Response 1 **(R1)**	Teacher or student may provide a question, statement, or comment related to or occurring as a result of an Initiation.	S: . . it went down.
Prompt **(P)**	Teacher or student may provide a question, statement, or comment that focuses on <u>continued engagement</u> on the topic and encourages or seeks conceptual understanding. This includes facilitating a student's verbal explanation or seeking elaboration or clarification of what was said. This also includes teacher questions or statements reminding students of appropriate behavior.	T: When was the force the strongest? S: So, do we move them again?
Response 2 **(R2)**	Teacher or student may provide a question, statement, or comment related to or occurring as a result of a Prompt.	S: With just one spacer.
Feedback **(F)**	Teacher or student may provide a question, statement, or comment that conveys a level of correctness, appropriateness, or usefulness of an idea, understanding, or an evaluation of student behavior.	T: With just one spacer. T: Yes
Response 3 **(R3)**	Teacher or student may provide a question, statement, or comment related to or occurring as a result of Feedback.	S: Ok

Table 5

Example of the Final Transcription Matrix

Time	Initiation	Response 1	Prompt	Response 2	Feedback	Response 3
6.34	T: Okay? So, it's thirteen. Also when you're at station thirteen, Maria ..so graciously brought her fire belly toad that she wrote about.					
		S: Oh				
		Maria: Mr. Hopperson				
			T: And his name is Mr. Hopperson. Now does he match the mammals that we are studying right today?			
				Ss: No.		
6.57			T: What type of vertebrate <u>is he</u>?.. Get ready to say it. One, two, three			
				Ss: Amphibian ((Unison))		
					T: He's an amphibian. Right	
			T: So you may look at him too while you are waiting at your station. Okay?			

Power categories. To describe power, six categories were used from previous research (Cochran & Reinsvold, 2010) to describe the nature of the power dynamics observed among the teacher and students in an elementary classroom (Table 6). These categories were adaptations of descriptions and characteristics of power found in previous literature (Gore, 2002). During this study, I found that students often referred to their classmate's thinking, and used their classmate's name. Because I wanted to identify when a student referred to another student's contributions in a discussion, I developed another code for the Individual Voice Power category, Student Student Individual Voice (SSIV). These power categories are not mutually exclusive.

Table 6

Definitions, Abbreviations, and Examples of Power Categories

Category	Definition	Form and Abbreviation	Examples
Conventionality Power	These indicate control supporting conventions and rules (procedural and non-subject matter) in the classroom, including behavioral reminders, feedback, reinforcements, and punishments.	Teacher Conventionality Power **(TCON)** – Includes behavioral reminders. Student Conventionality Power **(SCON)** - Indicates "buy in" to conventional classrooms rules and includes UNISON group responses.	**TCON** – Marsha, Fred, and Jeff, you will be in this group.. **SCON** – Can I pass out the hand lenses?
Organizational Power	These indicate control of subject-matter procedures in classroom activities or recall of a previous activity.	Teacher Organizational Power **(TOR)** Student Organizational Power **(SOR)**	**TOR** – We want to be scientists and make careful observations. **SOR** – We should put "write our conclusions" so we don't forget.
Individual Voice Power	Use of the pronoun "I"; or indication of an individual having an opportunity to speak; or referring to a particular person's idea, conception or contribution.	Student Individual Voice **(SIV)** Student Student Individual Voice. **(SSIV)** The student refers to another student by name. Teacher Individual Voice **(TIV)** Teacher Student Individual Voice **(TSIV)** - The teacher acknowledges a student's voice, usually by name or in the context of a specific conversation, including a small group. Does not include behavioral reminders.	**SIV** – I never thought of that. **SSIV** – I agree with Weston's idea. **TIV** – I need to look up the meaning of "radioactive". **TSIV** – Mark what do you think? What did your group decide?
Group Power	Explicit or implicit use of a "we" perspective or acknowledging a group-level or consensus idea(s).	Teacher Group Power **(TGR)** - Includes classroom level responses. Student Group Power **(SGR)** - Includes UNISON responses.	**TGR** – We looked at force on Friday. **SGR** – Our group thinks so too.
Subject Matter Power	Speakers use the discipline as a source of knowledge, to clarify or explain subject matter concepts, using the discipline vocabulary, and demonstrates ownership of subject matter ideas.	Teacher Subject Matter Power **(TSM)** Student Subject Matter Power **(SSM)**	**TSM** – When we make a prediction we are stating a hypothesis. **SSM** – The rock is red, so it must be an asteroid.

Question categories. For the analysis of classroom questions, Erodgram and Campbell's (2008) qualitative coding scheme for question characteristics, modified from Graesser and Person's (1994) original design, was adopted from previous research (Cochran & Reinsvold, 2010) and was used in this study. Main categories included C*losed-ended questions*, *Open-ended questions*, and *Task-oriented questions* (Table 7).

Closed-ended questions were defined as requiring a brief word or phrase response, placing little cognitive demand on students. Open-ended questions were defined as requiring extended answers and student reasoning. Task-oriented questions were defined as requiring clarification of directions as students interact with classroom activities. Open-ended question categories two through seven (*interpretation, causal antecedent, causal consequence, enablement, expectational, judgmental, process*) were considered to be consistent with inquiry and constructivist views of science teaching. When coding these questions, I identified and coded all Open-ended question subtypes because I wanted to evaluate inquiry-based interactions. Therefore, I did not code for sub-types of the Closed-ended or Task-oriented questions, but simply coded these questions CE or TO to reduce the complexity of the analysis.

Table 7

Definitions and Examples of Question Categories and Types

Question Type	Definition	Examples
Closed-ended questions		
1.Verification (CEV)	Requests a yes or no response.	Do we get them now? Okay?
2. Disjunction (CED)	Request a choice between two or more options.	Did it go up or down?
3. Concept completion (CECC)	Fills in the blank or completes a definition.	Magnetism is what kind of …..? This is called a what?
4. Feature specification (CEF)	Determines qualitative attributes of an object or situation.	What other categories can we use to categorize the types of rocks we have observed?
5. Quantification (CEQ)	Determines quantitative attributes of an object or situation.	How many categories can we use to sort our rocks?
Open-ended questions		
1. Definition (OED)	Ask for or determines meaning of a concept.	What is size?
2. Interpretation (OEI)	Seeks a description of what can be inferred from pattern of data. Often includes a "How do you know?" type of question.	How would we describe a size that is between small and big?
3. Causal antecedent (OECA)	Seeks an explanation of what state led to the current state.	What caused the motor to turn on?
4. Causal consequence (OECC)	Seeks an explanation of the consequence of an event.	What would happen to the layer of silt in the water if we shook the bottle?
5. Enablement (OEE)	A teacher invites a student to talk by naming the student. A student requests the teacher for help or information. These questions occur in interactions with subject matter.	Mrs. Wilson? What is different about it, Mary?
6. Process (OEP)	Seeks an explanation of a process that allows a person to perform an action.	How would you figure out where the magnets are inside the box?
7. Expectational (OEEX)	Seeks expectations or predictions.	Before you connect the wires to the motor, what will happen to the motor when you close the switch?
8. Judgmental (OEJ)	Seeks a value placed on idea, advice, or plan.	What do you think about their plan to find the magnet?
Task-oriented questions		
1. Monitoring (TOM)	Checks on progress of a task, seeks a plan. Not generally related to content.	I am going to put some circles over here on the board, okay?
2. Need clarification (TONC)	Seeks clarification of a statement or confirmation of previous statement. Not generally related to content.	I am sorry, I did not hear you. You said a compass is a magnet?
3. Requests/directive (TORD)	Request a specific action or a response. Includes calling on a student, either by name or implicitly; not related to subject matter.	Can you help her think of how size can be described? See this one?

Student work. Assessment data gathered by the teacher provided evidence of student understanding of the five types of vertebrates: reptiles, amphibians, mammals, birds, and fish. The teacher provided comments and scores on the completeness, organization, and neatness of the students' science notebooks. She evaluated activity worksheets that were produced during their classroom investigations. These activity sheets were glued into the students' science notebooks. The teacher also graded two short-response quizzes. I compared each student score on their activity worksheet, science notebook, and quiz with the corresponding classroom session's discourse interactions. The patterns of interactions within each classroom lesson were compared to the learning objectives and to the level of student understanding as evaluated by the teacher's assessments.

Validity and Reliability

To increase the likelihood that any findings or conclusions derived from this case study were valid and reliable, I used the procedure of triangulation and peer and participant examination of the data and findings (Merriam, 1998; Stake, 1995). All interviews, observations, student work, and instructional materials provided triangulation, facilitating the study's validity. I used these data sources and interview questions (Appendix B and Appendix C) to develop and guide my interpretations of how the teacher assisted students in building their science understanding through their interactions.

To ensure reliability of my analysis, I asked three different individuals who had successfully completed undergraduate science and English classes, and were familiar with my research. These reviewers were: (a) a senior in college majoring in Pre-Med, (b)

a graduate student majoring in Biology, and (b) Dr. Cochran, my dissertation advisor. They verified my transcriptions of the interviews. Dr. Cochran verified my observation transcripts, and the coding of TRS, participant roles, and power and questioning categories. The results of these codings were compared and all differences in transcription and coding were discussed. To ensure that Dr. Cochran and I used each code consistently, together we identified utterances that typified each type of code. We used our discussion to analyze any differences and determine how the utterances should be coded. A final transcription document was made for each of the five observations in this study, and the five final coding matrices were entered into NIVO for analysis. I also asked the participating teacher to review the interview and classroom transcripts to ensure that what was transcribed correctly captured the conversations. After the teacher's review, I met with her to receive feedback and come to agreement. I made two changes to the interview and classroom observation transcripts to reflect agreement, including removal of non-relevant personnel comments and a discussion about a controversial issue in her school.

I also asked the teacher to review Chapter 4, *Context of Interactions*, of this study. I used this chapter to describe the research setting: school, classroom, teacher, students, instructional materials, and observations. I met with the teacher after her review, and she did not identify any inaccurate information and was comfortable with what I described in Chapter 4.

The results of the interpretations among myself, the undergraduate and graduate students, Dr. Cochran, and the teacher were documented within the transcripts. This peer and participant review was conducted to ensure that our interpretations of gathered data

were congruent and reflected consensus. Rich, thick descriptions are presented in the *Results* to help readers build a detailed understanding of this study (Merriam, 1998; Stake, 1995).

CHAPTER IV

CONTEXT OF INTERACTIONS

A fourth-grade teacher and students in the U.S. Rocky Mountain region classroom served as the participants and the setting for this study. The context of interactions among this teacher and her students are based on field notes and video-recordings from observations and teacher interviews (Appendix A). Table 8 provides data on the distribution of student ethnicity (Colorado Department of Education, 2010a) and students qualifying for Free and Reduced Lunch (Colorado Department of Education, 2010b) for the school and its school district. The school served mostly Latino and European-American students; almost half the students qualified for Free and Reduced Lunch. The school's distribution of student ethnicity was similar to that of the school district's, however, overall the district had more students needing access to free and reduced lunches.

Table 8

Distribution of Student Ethnicity and Free and Reduced Lunch Frequencies

	American Indian or Alaska Native	Asian	Black or African American	Hispanic or Latino	European-American	Native Hawaiian or Other Pacific Islander	Students of Two or More Races	% Free and Reduced Lunch
School	0.2%	0.9%	0.2%	52.0%	44.9%	0.4%	1.4%	46.1%
School District	0.3%	1.4%	1.3%	58.3%	37.2%	0.2%	1.2%	60.5%

For each observation, I entered the school building just after the first bell of the morning at 8:25 AM. Late students were rushing off to their classes as I entered the main office to check in and pick up my visitor badge. I was often greeted by the office staff. As I entered the main hallway, the building was quiet, and I often saw the Principal and other administrative staff walking the halls. They ensured that everyone was where they should be in order to begin a new day of learning.

In the main hallway was a photo of the school patron, a former town leader. A large, colorful banner hung from the second floor, displaying the school's motto for behavior; it encouraged students to strive for their best and respect each other. There was a bench, a set of chairs, and a picnic table with an umbrella in the main hallway. I saw parents use this area to sit and meet. The school walls displayed considerable pride with a mascot image and announcements of school events, such as after-school athletic games and club meetings. It was a very welcoming entry to the school.

The fourth-grade classroom I observed for this study was located in a hallway off the main entry area. Third and fifth grade classrooms were also found there. As I entered the classroom for my observations, most students were settling in their seats, and others completing routine classroom jobs: collecting homework, feeding the hamster, sharpening pencils, and taking attendance. Twenty-three students (fifteen boys and eight girls) were in this class. Thirteen were European-American, nine Latino, and one was Malaysian. The families of five of the Latino students did not speak or read English. Half of the students qualified for Free and Reduced Lunch. Two students with special needs had Individualized Education Plans (IEP).

When I began my observations, students were very curious about me and seemed to watch my every move. After a week, most did not notice my arrival, and some would say “Hi”. I often arrived just in time for the Pledge of Allegiance. After the pledge, the teacher asked for a student to lead singing of the Star Spangle Banner. With hands over their hearts, students and teacher sang joyfully.

Figure 1 (p. 63) depicts the room layout. Student desks were arranged in small groups, often four students in a group. Because of this, the desks and students could be reconfigured daily. Students who worked well together sat in the same group and collaborated on activities. Often, one student in the group was a leader. The leader kept the group on task or helped others with reading and writing during classroom activities. If students in the group were noisy, the students would be separated and moved to different groups.

The classroom walls were completely covered with colorful literacy and mathematics posters. The literacy posters consisted of the alphabet, lists of vocabulary words, and forms of speech. The mathematics posters contained geometry diagrams, such as rectangles, triangles, and lines. A poster with *Today’s Schedule* was also placed to the left of the white board; this informed the class of the day’s schedule. To the right of the white board was a list of classroom duties with a number next to each duty. The number identified a specific student who completed his or her duty for the week.

The morning instructional activities always began with a short, ten-minute, mathematics activity and a short literacy activity. Every elementary classroom teacher in the school district began the instructional day this way. In the fourth-grade classroom observed in this study, science started after these opening activities.

Teacher Background and Teaching Perspectives

I used the interviews (Appendix A) to learn about Mrs. Allen's (a pseudonym) education background, her teaching and learning perspectives, and her view of the students' learning abilities. Mrs. Allen had earned an elementary education degree, and completed her student teaching at the school where this research was conducted. After her student teaching and graduation, she received a teaching position at the school. At the time of this study, she was beginning her seventh year of teaching. She had participated in over twelve hours of science and science education professional development activities. She was a member of the district's elementary science leadership team. She shared the team's work with her building teachers. She described the purpose of this group:

> We're supposed to be kind of the liaison between the building and then, um, district, the administration. So we have a meeting and we talk about how our kids, are they coming out where they need to? Are they what they need to be filled with? Are they missing things? Umm, we talk about how it's working, how people [teachers] are, umm, accomplishing their work. [Teacher Interview 2, p. 2]

During my observations, Mrs. Allen taught the unit *Colorado Wildlife* (Block-Gandy, 2001). She did not receive specific professional development support on how to use these instructional resources, but relied on conversations with district science leadership team members to guide her use of the resources. The team recommended the number of classroom sessions that should be used to complete the activities, ideas for integrating writing into the science lessons, and how to assess student understanding.

Mrs. Allen supplemented the unit instructional book with two other instructional guides from the Colorado Division of Wildlife: *Mammal hides activity guide for mammal hides critter crate* (Becker, et al., 1997b); *Animal sign activity guide for animal sign*

critter crate (Becker, et al., 1997a). The authors designed these activities to provide students opportunities to observe, collect, and analyze information about animals. By participating in these activities, students would practice the skills of scientific inquiry.

The instructional materials included information on animal features and behaviors, and strategies for identifying animal pelts, tracks, and scat. The critter crates that accompanied these guides included animal pelts and rubber molds of animal tracks and scat. She also provided the students with a booklet, *Lions, ferrets, and bears: A guide to mammals of Colorado* (Armstrong, 1993) to read, and showed the students a video, *Simply Wildlife* (Colorado Division of Wildlife, 1994). The school district's science resource center provided Mrs. Allen these instructional resources, and she shared them with another fourth-grade teacher at her school. Because of this, the fourth-grade teachers had to work together and plan when they intended to use specific resources.

Mrs. Allen described her teaching philosophy:

> I believe that all children can learn. I am there to help facilitate that. I am not there to preach at them. I am there to help them discover, to create their own learning. I believe that it is good for them to work together, collaborate. I know there is a time where they have to show what they know, just themselves . . . . . I think it is amazing that they can teach me things, too. So, as we are going along, and I don't have all the answers, and I tell them that. Because I have to look up tons of stuff, hah hah . . . . . And, I think it's okay. And if they think they know something and I'm not sure. I don't just say "You're wrong." We'll go look it up and see, because there might be some truth behind what they are saying. They may have it right, and I am wrong (laugh). [Teacher Interview 1, p. 1]

Mrs. Allen possessed a learner-centered (Lambert & McCombs, 1998) and constructivist learning (Tobin & Tippins, 1993; Vygotsky, 1978) perspective. She expressed her views of inquiry as related to her own learning of science:

> I think that in the world there're questions that you'll come across and you want to answer, and there is an approach, scientific approach, that you can go about that. And so, you can collect, well, you can make an experiment and try to find

> out the answer by, but you'll have to control your variables and then try to answer your question and a lot of times it just leads to another question . . . . It's kinda an ongoing process of discovering our world is basically how I look at inquiry. [Teacher Interview 1, p. 1 – 2]

Mrs. Allen understood the process of investigating the natural world in which she lived. When reflecting how she helped students explore and understand science, she stated:

> I think kids can always learn science, see science, do science. Even when they are really young they are full of questions. People are full of questions. [Teacher Interview 1, p. 2]
>
> ….and then they'll [scientists] find out that that was wrong or that was different or they can split now .. into smaller particles, or whatever .. so . . . I want them to think about science in that way, then. That's a theory . . that's what . . with all the evidence .. that we've seen so far? That's what we think of . . or. . is . . is going on. But, certainly, they can investigate that and see . . someday . . is that really what's going on here . . you know . . and you can pretty much approach it in any .. you know . . in any way. [Teacher Interview 3, p. 2]

Mrs. Allen wanted her students to be unafraid to ask questions and seek answers (Duschl, et al., 2006) about the natural world.

To learn more about her learner-centered focus, I asked Mrs. Allen how she interacted and engaged her students in the process of learning science. She stated:

> I have an agenda of where I want them to kinda go, so we will talk in a big group, then go do an experiment, then we'll come back , talk about what we found out. We might then want to change some variable, go back, do an experiment. That is what we are doing on days when we do experiments. Other days, we'll have, where we read what other people have found out, cause you need to do that too. Because why redo something that someone else has already done? So, we will read different stories and things that relate to it. [Teacher Interview 1, p. 2]

For classroom observations in this study, every classroom lesson began with Mrs. Allen initiating a whole-class conversation that invited students to share what they knew about vertebrates. She then introduced an activity and asked them to work in small groups or facilitated whole-class discussions. When students were organized in small groups, she visited each group and asked what they were learning. Generally, Mrs. Allen

brought each lesson to closure by summarizing what they had accomplished and what they will do in the next science lesson. She described how she interacted with students during whole-class and small group conversations:

> [I'm] getting their brains to think, because if you just sit there and tell them?↑ You'll have the students that are "school children". . and they'll listen to every word you say . . and they'll probably understand a lot of it?↑ But you'll lose a majority of kids that . . "she's preaching at us again" . . which I do some too, you know . . . [Teacher Interview 3, p. 2]

> I wanted them to get there with me without me just telling them. Because I knew that wouldn't really internalize it if they didn't think of it kinda on their own . . . And I was just going to guide them into that thinking. [Teacher Interview 6, p. 1]

Mrs. Allen sought to assist students as they developed their understanding. She guided them through the Zone of Proximal Development (Tudge, 1990) as they verbalized what they knew.

Fourth-grade students

Mrs. Allen shared how students in this study interacted with her. She stated:

> Well, I think they're fairly thoughtful and they. .they are transferring a lot of what, um, they've learned, as far as using their background knowledge, though. And I try to reiterate that when they'll say something. I'll go "oh, you used your background knowledge" or, you know, I feel like they try to tie in . . and I still try to tie in with them to so they will, um how we read . . our reading strategies that they go with that . . and tie in everything so it's integrated. But, I think this group seems very thoughtful about what they're saying and excited about it, um. So, and usually what what . . they say . . I treat them more like . . I mean they're just little people so . . I mean they have a lot of great ideas and they have different background than I do. And since I told you science isn't really [laughter] my background . . which is kind of interesting, though I don't mind it because then we can talk and share and I think they really feel that . . I'm not just up there telling them things. So sometimes, um, I was thinking about that last night, I thought, it's interesting that, um . . if I came up and just said, "this is this", and just basically was teaching them and writing on the board and, "write this down". I don't think they'd get as involved because they know that Mrs. [A]'s not infallible, that I can make mistakes or that I haven't thought of certain things.

> ‘Cause I tell them all the time, “why I never thought of that” and really I haven’t . . I mean, I’m not just um, patronizing them, I really don’t . . I never thought of that. And I think they know the difference, kids do. And so, um, I think we get a lot better conversations because of doing it that way. [Teacher Interview 5, pp. 2 - 3]

Mrs. Allen liked her students and wanted to share opportunities to learn with them. She recognized and respected knowledge they brought to the learning activities. This perspective is similar to findings about teachers’ views by Cornelius and Herrenkohl (2004) and Candela (1998, 2005); Mrs. Allen desired to provide students opportunities to share, defend, or agree with science explanations. She wanted them to share what they knew and likewise, she would share what she knew and how it is linked to what students learned in fourth grade.

Mrs. Allen devoted time during science lessons for students to show their vertebrate pets. During my visits, a toad, mourning dove, and garter snake were brought into the classroom. The students loved sharing their pets. During science lessons, they often reminded Mrs. Allen that they needed time to share. A non-English speaking family brought the mourning dove into the classroom during a science lesson. Their son, Manuel (a pseudonym), was very proud as he shared and talked with the students about features and behavior of the bird.

Information about the seventeen students that agreed to participate in this study are listed in Table 9. The table provides student names (pseudonyms), gender, ethnicity, and characteristics.

Table 9

Student Information

Name	Gender	Ethnicity/Race	Student Characteristics
Ellie	F	EA	Enjoyed sharing experiences Leader in small group Often worked with Maria
Sam	M	As	Leader in small group Enjoyed sharing experiences Often worked with Tom
Trisha	F	EA	Leader in small group Confident when speaking Often worked with Julie and Jane; they seemed to have fun working together.
Jose	M	L	English as Second Language (ESL) student though seemed comfortable talking and interacting with students and teacher. Enjoyed sharing experiences Often worked with Manuel
Jane	F	EA	Helpful to teacher and fellow students Confident when speaking Often worked with Trisha and Julie; they seemed to have fun working together.
Carlos	M	L	Leader in small group Enjoyed sharing experiences Often worked with Luis
Lisa	F	EA	Often giggled Focused on activities Often worked with Chris
Julie	F	EA	Concerned about process of activities Confident when speaking Often worked with Trisha and Jane; they seemed to have fun working together.
Chris	M	EA	Quiet Focused on activities Often worked with Lisa
Manuel	M	L	ESL student Shy Attended this school since kindergarten Often worked with Jose
Maria	F	L	Enjoyed working with Ellie Shy
Ian	M	EA	Enjoyed helping with technology Delayed in writing skills Scored Advanced on state-wide standardized tests Often worked with Ned
Mike	M	EA	Delayed in writing skills Did not like to explain answers or reason through problems. Often worked with Sam and Tom.
Tom	M	EA	Quiet Liked to work with Sam Most of the time sat next to Manuel Often absent
Ned	M	EA	On Individualized Education Plan (IEP) Enjoyed sharing experiences Often worked with Ian
Luis	M	L	ESL student Liked working with Carlos
Ricardo	M	L	ESL student Shy Not attentive to lessons

Note: Gender: Female – F, Male – M.; Ethnicity & Race: European American – EA, Latino – L, Asian – AS

Students enjoyed science and were very engaged in the activities. When the teacher or a student asked a question, many hands were raised to respond. Students seemed excited to share what they knew about the topic at hand. The teacher allowed all students to take turns in sharing. For those who were shy, the teacher asked them specific questions or invited them to lead a whole-class investigation. Because of the high level of engagement, the science class period often consumed time from the next class, Specials (Physical Education or Library). Sometimes, a science activity was completed when students returned from their Specials.

Students used a science notebook (a spiral notebook) (Douglas, et al., 2006) to write their hypotheses, procedures, results, and conclusions for investigations, and to hold their worksheets from investigations. During my first observation, Mrs. Allen introduced the students to the purpose and use of the science notebook, and guided them to create a Table of Contents that listed all their investigations. They also numbered every page of their notebook, so they could reference their investigations in the Table of Contents. The students used their science notebook for every lesson by either entering investigation information or referring to the information to help answer questions.

Observations for the Study

This study focused on three lessons from Mrs. Allen's Colorado Wildlife unit. These lessons allowed students to investigate and identify animal pelts, tracks, and scat. The science lessons took place over five classroom observations (Observations 12 – 16, see Appendix D). The lessons occurred midway through the unit, so the teacher and students were focused and following a familiar routine to learn features and behaviors of vertebrates. The interactions among the teacher and students during these five

observations were representative of the level of engagement I noted across all 28 observations. Table 10 provides characteristics for each observation in this study.

Table 10

Characteristics of the Observations

Observation & Topic (Length)	*Materials*	*Activity*
12: Investigating Animal Pelts (51.26 min)	17 numbered animal pelts (badger, beaver, Big Horn Sheep, Black Bear, raccoon, Cottontail Rabbit, elk, Ermine, Long Tailed Weasel, moose, Mule Deer, opossum, porcupine, Pronghorn, Red Fox, Striped Skunk, White Tailed Deer) were dispersed over eight stations (tables). 17 Clue cards holding facts about each animal were placed next to each pelt. Teacher used information from *Mammal hides activity guide for mammal hides critter crate* (Becker, et al., 1997b). Activity sheet: *Pelts Matching*, contained a list of animal names, and a blank list numbered 1 though 17 that corresponded to the pelt numbers. Video of animal pictures: *Simply Wildlife* (Colorado Division of Wildlife, 1994). Science notebooks.	Mrs. Allen began the class with a whole-group discussion. She asked students to share what they knew about vertebrates. She introduced the activity; students worked in small groups at each station, observed pelts (each numbered) and the video displayed at the front of the class, and read clue cards to identify the animals. They were asked to treat the pelts with care. Before students moved into small groups, the teacher asked students to look at the animal slides that were displayed by the *Simply Wildlife* video. The teacher identified each animal as it appeared in the video. Students joined their small group and moved through each station. Students wrote the name of the animal next to number of the pelt on the Pelt Matching worksheet. As each small group made their observations at the stations, the teacher visited each group to learn what they were finding. Student observations and matching were brought to an end by the teacher, and she reminded students how to handle animal pelts properly.
13: Investigating Animal Tracks (43.00 min)	19 numbered rubber molds of animal tracks (badger, beaver, Black Bear, Bobcat, Cottontail Rabbit, coyote, eagle, elk, House Mouse, moose, Mountain Lion, Mule Deer, porcupine, ptarmigan, raccoon, shrew, Snapping Turtle, Striped Skunk, Woodpecker) were set out on the back table. Each mold had a name tag. Teacher used information from *Animal sign activity guide for animal sign critter crate* (Becker, et al., 1997a).	Teacher facilitated a whole-class discussion on how she and the students would find and identify vertebrates when walking about a nature center. The students realized they needed evidence to know that an animal was present, and animal tracks would be one form of evidence. As teacher and students looked at the animal tracks, the whole-class discussion continued, and they realized that each type of animal had a unique track.

Table 10 Continued

Observation & Topic (Length)	*Materials*	*Activity*
	Video of animal pictures: *Simply Wildlife* (Colorado Division of Wildlife, 1994). Activity sheet: *Tracks Matching* contained a list of animal names, and a blank list numbered 1 though 19, corresponding to the animal track numbers. Science notebooks.	Teacher and students looked at the animal pictures in the video and discussed what type of track the animals would leave. They classified tracks into four groups: paws, claws, hooves, and "webbed". Together, they studied the rubber mold tracks, reviewed the animal pictures, discussed how each animal used its feet, and matched the animals with their tracks. Teacher and students wrote the animal name next to the number on the Tracks Matching worksheet At the end of the lesson, teacher and students compared their list with name tags that were on each rubber mold.
14: Investigating Animal Scat (26.14 min)	13 numbered rubber molds of animal scat (bat, beaver, bobcat, coyote, deer, elk, grouse, moose, Mountain Lion, mouse, porcupine, rabbit, raccoon) were set on the back table. Each mold had a name tag. Teacher used information from *Animal sign activity guide for animal sign critter crate* (Becker, et al., 1997a). Activity sheet: *Scat Matching* contained a list of animal names, and a blank list numbered 1 though 13 that corresponded to animal scat numbers. Science notebooks.	Mrs. Allen began the class with a whole-class discussion asking students what they knew about vertebrates. The discussion continued by the students and teacher; they realized that scat served as another form of evidence to identify an animal at the nature center. The students and teacher shared what they knew about animal scat. The whole-class discussion continued as students and teacher looked at the scat and tried to determine why they were different. Students and teacher decided that the size of the animal and what they eat affected the type of scat the animals left. During the discussion, students and teacher used terms: carnivore, herbivore, omnivore, and insectivore to describe what different animals ate. Students and teacher were not sure what each animal ate. The class came to an end and the teacher asked students to spend some time at home to investigate what certain animals ate. She explained

Table 10 Continued

Observation & Topic (Length)	*Materials*	*Activity*
		that during the next science class, they would continue to determine what animals ate so they could identify the scat.
15: Continuation of Investigating Animal Scat: What do animals eat? (44.04 min)	Booklet*: Lions, ferrets, and bears: A guide to mammals of Colorado* (Armstrong, 1993) for each student. Teacher used information from *Animal sign activity guide for animal sign critter crate* (Becker, et al., 1997a). Science notebooks	Mrs. Allen began the class with a whole-class discussion that asked students whether they found any information about what animals ate. She introduced the booklet, and asked students what information they needed to learn from the book to help them identify the scat. Students opened their science notebooks and updated their Table of Contents. They glued their Pelts Matching and Track Matching worksheets in their science notebooks. Students were given the booklet, and decided how they would find information about each animal. Teacher paired students; each group was assigned an animal to read about. They read to learn the animal's size, what they ate, and a fun fact. They wrote the information in their science notebooks. A pair of students was given the grouse. The booklet did not contain information about the grouse, so they used the Internet with the teacher to learn characteristics of the grouse. As the small groups read and wrote the information in their science notebooks, the teacher visited each group to learn what they were finding. Each group shared their animal information with the whole class. All students were given an opportunity to view a video about the grouse.

Table 10 continued

Observation & Topic (Length)	*Materials*	*Activity*
16: Continuation of Investigating Animal Scat (38.14 min)	13 rubber molds of animal scat (bat, beaver, bobcat, coyote, deer, elk, grouse, moose, mountain lion, mouse, porcupine, rabbit, raccoon) were set at the back table. Teacher used information from *Animal sign activity guide for animal sign critter crate* (Becker, et al., 1997a). Activity sheet: Scat Matching. Science notebooks.	Mrs. Allen began the class by reviewing what they learned about the animals. Teacher and students discussed how the animals in the list should be classified based on what they ate: herbivore, carnivore, omnivore, or insectivore. Mrs. Allen and the students examined each scat sample, considered evidence they collected from their reading and experiences, and decided what scat belonged to each animal. When they all agreed and identified each scat mold, the name tag on the scat was revealed to the class by a student-teacher, Mr. Smith (pseudonym). A student shared a Discovery Channel video from the Internet with the class. The video showed how scientists film animals in Africa.

My field notes, the video-recordings of the observations, and interviews with the teacher allowed me to understand the context within which the teacher and students of this study interacted to learn science. Mrs. Allen indicated that she had developed her understanding of how to teach science by using helpful resources, discussing teaching and learning strategies with members of the district's science leadership team, and providing her students with opportunities for interactions and conversations in the classroom. She sought to support her students as they constructed their understanding of features and behavior of vertebrates. She intended to give them opportunities to explore and reflect on what they knew and why they knew it. She carefully grouped her students so each student had opportunities to interact and investigate vertebrates through activities. Mrs. Allen strived to create a learner-centered and interactive science classroom.

CHAPTER V

RESULTS

My goal for this study was to understand how Mrs. Allen and her fourth-grade science students interacted and used power dynamics and questioning strategies to learn the features and behavior of vertebrates. Data sources included teacher interviews, audio- and video-taped classroom observations, classroom instructional materials, and student work from the elementary science lessons. Transcriptions from five classroom observations and teacher interviews, and data from student work were analyzed to answer the research questions in this study:

Main Question:

Q1 How do power and questioning strategies in an elementary classroom support student understanding of science?

Specific questions:

A How does a teacher use questioning strategies in classroom discourse to engage students to understand science?

B How does a teacher use power in classroom discourse to engage students to understand science?

C How do students use questions in classroom discourse to understand science?

D How do students use power in classroom discourse to understand science?

E How does the use of power relate to questions in classroom discourse?

In my analysis of the data, I used quantitative results to provide an overview of the interactions, and qualitative descriptions to illustrate the relationships between teacher and student power dynamics and questioning strategies.

Preliminary Coding Analyses

Queries. I entered the five observation transcripts for this study in the qualitative software package QSR NVivo 8 (QSR International, 2008). To address my research questions, I entered inquires or queries into the software which used Boolean search procedures and generated text and graphic results. I used these search mechanisms to determine frequencies and relationships between code categories (participants, participation roles, power categories, question categories). Queries were made about: (a) the frequencies of each code for each observation, (b) type of teacher and student participation occurring within each observed lesson and all observed lessons of this study, (c) power and questioning categories relative to the speaker (teacher or student) emerged within each observed lesson and all observed lessons of this study, and (d) power and questioning categories occurring together within each observed lesson and all observed lessons of this study. Chi Square (X^2) analyses of code frequencies were calculated to determine whether there were quantitative differences between the codes and across the observations. To estimate the effect size and the extent of the significant differences, Cramer's Phi (Φ) was calculated, and I used Cohen's (1992) guidelines to determine criteria for effect size, small effect size, $\Phi = 0.1$; medium effect size, $\Phi = 0.3$; and large effect size, $\Phi = 0.5$.

Participant utterances. The frequencies of the total numbers of utterances for students and teachers for each observation in this study are shown in Table 11. An utterance is what a teacher or student says during their turn to talk. It can be a statement, question, phrase, or a single word.

Table 11

Comparison of Student and Teacher Utterances

Observation	Topic	Student Freq. (%)	Teacher Freq. (%)
12	Investigating Animal Pelts	448 (52%)	410 (48%)
13	Investigating Animal Tracks	395 (50%)	394 (50%)
14	Investigating Animal Scat	198 (49%)	208 (51%)
15	Continuation of Investigating Animal Scat: What do animals eat?	319 (46%)	378 (54%)
16	Continuation of Investigating Animal Scat	257 (44%)	332 (56%)
Total Utterances		1617 (48%)	1722 (52%)

Note: Percentages are for each observation.

Overall, total teacher utterances were significantly higher than the total student utterances across all observations, X^2 (4) = 13.19, p < .01, Φ= 0.1 (small effect size). These statistics indicate that although the differences were significant, the actual importance of these differences is low. However, I separately compared the total teacher and student utterances for each observation (α = .01). No significant differences were noted in Observation 12: X^2 (1) = 1.683, p < .194; Observation 13: X^2 (1) = 0.001, p < .974;

Observation 14: X^2 (1) = 0.246, $p < 0.620$; and Observation 15: X^2 (1) = 4.994, $p < .025$. A significant difference between the total teacher and student utterances were found for Observation 16: X^2 (1) = 9.55, $p < .002$, $\Phi = 0.1$ (small effect size).

Observations with no significant differences between student and teacher total utterances need an explanation since educational researchers (Candela, 1999; Cazden, 2001; Cochran & Reinsvold, 2010; Erickson, 1996; Lemke, 1990; Mehan, 1979; Scott, et al., 2006) have usually expected teachers to contribute most to such conversations. Students in Observations 12, 13, 14, and 15 talk as much as their teacher. There was a balance between student and teacher verbal participation. The differences and similarities between total utterances in these observations will be discussed later with scenarios in the section called *Power and Questioning Dynamics*.

Participation roles. I developed Appendix F to provide a comparison of student and teacher utterances across participation roles for each observation. These data were used to compare the distribution of total teacher and student utterances across the six Participation Roles of Initiation, Response 1, Prompt, Response 2, Feedback and Response 3 (see Table 12). Definitions of Participation Roles are found in Table 4. Overall, the teacher participation roles were significantly different than student participation roles, X^2 (5) =2055.19, $p < .001$, $\Phi = 0.78$ (large effect size).

Table 12

Distribution of Teacher and Student Participation Roles

Participation Role	Student Freq. (%)	Teacher Freq. (%)
Initiation	83 (42%)	115 (58%)
Response 1	102 (78%)	29 (22%)
Prompt	171 (16%)	930 (84%)
Response 2	1154 (96%)	46 (4%)
Feedback	59 (9%)	592 (91%)
Response 3	31(97%)	1(3%)
Total Participation Roles	1600 (48%)	1713 (52%)

Note: These data were combined across all observations. Percentages are for each participant role.

The distribution of total teacher and student utterances for each six participation role were separately compared (α = .01). The Initiation participation role of teacher and student across observations showed no significant differences X^2 (1) = 5.172, p < .022. There were, however, significant differences in the other participation roles: (a) Response 1, X^2 (1) = 40.679, p < .001, Φ = 0.56 (large effect size); (b) Prompt, X^2 (1) = 523.234, p <.001, Φ = 0.48 (medium effect size); (c) Response 2, X^2 (1) = 1023.053, p < .001, Φ = 0.92 (large effect size; (d) Feedback, X^2 (1) = 436.389, p <.001, Φ = 0.82 (large effect size); and (e) Response 3, X^2 (1) = 28.125, p < .001, Φ = 0.94 (large effect size). These results indicate that there were significant and substantial teacher and student differences in all participation roles except Initiation.

Student utterances occurred in all three response categories substantially more frequently than did teacher's utterances. Students participated less frequently than the teacher in Initiation and Feedback roles. The number of teacher utterances were highest in Prompt and Feedback and less so in Response 1 and Response 3. Overall, the teacher and students were very active in discussions specifically in Prompt, Response 2, and Feedback participation roles. Eighty-nine percent of total utterances for these five observations occurred during these three interaction roles. This is a concentration of interactions; the teacher provided students with opportunities to explain (Prompt), what they knew (Response 2). Mrs. Allen supported these interactions by frequent Feedback comments she gave her students. These data show that students were actively engaged in classroom verbal discourse. Below is an example of these concentrated interactions between Mrs. Allen and Manuel, speaking about what they knew about the type of animal evidence they might observe in an upcoming field trip to an outdoor learning center.

8.36	Prompt	Teacher: Manuel?
	Response 2	S: Yeah
	Response 2	Manuel: You know how dogs do it= ((students talking))
	Feedback	Teacher: Oh, wait a minute. Manuel is speaking so we're gonna be listening.
	Response 2	Manuel: You know how dogs bury their bones?
	Feedback	Teacher: Oh, yeah!
8.45	Response 2	Manuel: You know, um probably turtles . .we could see marks from digging.
	Feedback	Teacher: From digging! Marks from digging..
	Prompt	Teacher: =because a lot of animals burrow.
8.55	Feedback	Teacher: Excellent. ↑Ooh. I didn't even think of all these.

Power categories. To begin the investigation of power dynamics, I compared the distribution of power categories across teacher and students, and observations. I found that, overall, the students had more frequent use of the power 51% compared to Mrs.

Allen, 49%, and these were substantially different across observations, X^2 (4) = 50.572, p < .001, Φ = 0.09 (small effect size). The distribution of power categories across all observations is found in Table 13.

Table 13

Distribution of Total Power Categories Across Teacher, Students, and Observations

Observation	Topic	Student Freq. (%)	Teacher Freq. (%)
12	Investigating Animal Pelts	866 (57%)	653 (43%)
13	Investigating Animal Tracks	849 (54%)	721 (46%)
14	Investigating Animal Scat	422 (48%)	455 (52%)
15	Continuation of Investigating Animal Scat: What do animals eat?	615 (48%)	660 (52%)
16	Continuation of Investigating Animal Scat	513 (45%)	623 (55%)
Total Power Categories		3267 (51%)	3112 (49%)

Note: Percentages are for each observation.

In previous research, Cochran and Reinsvold (2010) found that in a third-grade science classroom, the teacher had more frequent use of power (68%) in two classroom sessions compared to the students (32%) during their discussions. In this study, students had more frequent use of power than the teacher as they learned science in five classroom sessions.

I compared teacher and student power for each observation, and found that there were significant differences (α = .01) in Observation 12, X^2 (1) = 30.381, p = < .001, Φ = 0.14 (small effect size); Observation 13, X^2 (1) = 10.436, p = .001, Φ = 0.08 (small effect size); and Observation 16, X^2 (1) = 10.651, p = .001, Φ = 0.09 (small effect size). These

statistics indicate that although the differences were significant, the actual importance of these differences is low. Based on the percentages, students used power more frequently in Observations 12 and 13, and the teacher used power more frequently in Observation 16. However, there were no significant differences in Observation 14, X^2 (1) = 1.242, p = .265 and Observation 15, X^2 (1) = 1.588, p = .208. Overall, based on these data, the students and Mrs. Allen had similar frequencies of power across the five classroom sessions.

The power categories for teacher and students for each observation are found in Appendix G. From Appendix G data, the frequencies of power categories for all observations for students and Mrs. Allen were compared and are reported in Table 14. Definitions of the power categories are found in Table 6. Student and teacher power categories combined across all observations are significantly different, X^2 (4) = 2024.835, $p < .001$, $\Phi = 0.32$ (medium effect size). The frequency for Individual Voice power for students included (a) when students spoke (Student Individual Voice, SIV), (b) when a student referred to another student's thought or action (Student Student Individual Voice, SSIV), and, (c) when the teacher referred to or addressed a student (Teacher Student Individual Voice, TSIV). The frequency for Individual Voice for the teacher consisted of when the teacher referred to her own thoughts (Teacher Individual Voice, TIV).

Table 14

Power Categories for Students and Teacher

Power Categories	Student Freq. (%)	Teacher Freq. (%)
Conventional	118 (16%)	694 (84%)
Group	199 (35%)	378 (65%)
Individual Voice	1884 (87%)	283 (13%)
Organizational	234 (21%)	886 (79%)
Subject Matter	832 (48%)	891 (52%)
Total Power Categories	3267 (51%)	3112 (49%)

Note: These data were combined across all observations. Percentages are for each power category.

I next compared the frequencies in each power category between the students and the teacher. The following differences were found: 1) Conventional power, X^2 (1) = 408.59, $p < .001$, $\Phi = 0.50$ (large effect size); 2) Group power, X^2 (1) = 55.53, $p < .001$, $\Phi = 0.01$ (small effect size); 3) Individual Voice, X^2 (1) = 1182.83, $p < .001$, $\Phi = 0.55$ (large effect size); 4) Organizational power, X^2 (1) = 379.56, $p < .001$, $\Phi = 0.34$ (medium effect size); and 5) for Subject Matter power, X^2 (1) = 2.02, $p = .155$, there was no significant difference.

When comparing Mrs. Allen's power categories to her total power, she used Subject Matter (29%) and Organizational (28%) power the most, followed by Conventional power (22%). When comparing student power categories, they were provided with many opportunities to speak through Individualized power (58%) and acknowledged by other students and Mrs. Allen. Students also tended to use Subject

Matter (25%) power. This shows that students were talking about science subject matter, which Duschl (2006) and Lemke (1990) argued is critical for the development of science understanding.

Questioning categories. To begin the investigation of questioning strategies, I found that overall Mrs. Allen asked more questions (73%) than the students (27%) during all interactions, and there was a significant difference, X^2 (1) = 221.177, p < .001, Φ = 0.47 (medium effect size). The distribution of student and teacher questions across types of questioning categories is found in Table 15. Definitions of questioning categories are found in Table 7. Student and teacher frequency of question types across all observations were significantly different, X^2 (2) = 13.352, p < .001, Φ = 0.12 (small effect size).

Table 15

Distribution of Student and Teacher Questions Across Questioning Categories

Question Type	*Student Freq. (%)*	*Teacher Freq. (%)*
Task-oriented	47 (28%)	119 (72%)
Closed-ended	167 (30%)	388 (70%)
Open-ended		
Definition	17	21
Interpretation	9	95
Causal Antecedent	1	4
Causal Consequence	1	1
Enablement	23	92
Process	1	17
Expectational	0	0
Judgmental	0	0
Open ended Total	52 (18%)	230 (82%)
Total Questions	266 (27%)	737 (73%)

Note: These data were combined across all observations. Percentages are for each type of question.

I compared each question category for the students and teacher. The following differences were found: 1) Task-oriented questions, X^2 (1) = 31.229, $p < .001$, $\Phi = 0.43$ (medium effect size); 2) Closed-ended questions, X^2 (1) = 88.002, $p < .001$, $\Phi = 0.40$ (medium effect size); and 3) Open-ended questions, X^2 (1) = 112.355, $p < .001$, $\Phi = 0.63$ (large effect size). There were thus substantial differences between the types of questions the teacher and students asked.

There were difference between the three types of teacher questions, with more Closed-ended questions than other type, X^2 (2) = 148.77, $p < .001$, $\Phi = 0.45$ (medium effect size). This evidence is contrary to expectations, based on the inquiry nature of the instructional materials used and Mrs. Allen's teaching perspective (see teacher interview discussion on p. 86). Thirty-one percent of Mrs. Allen's questions in this study were Open-ended, with most being Interpretation and Enablement. While this percent might seem low, in previous research, Cochran and Reinsvold (2010) found that a third-grade science teacher asked only 17% Open-ended questions. Since little data exists for comparison purposes, the meaning of this difference is yet to be determined.
Interpretation questions were defined as the teacher asking a student for a description of what can be inferred from the pattern of data, and Enablement questions were defined as the teacher inviting a student to talk by naming the student and providing an opportunity for engagement. Below are unrelated examples of these types of Open-ended questioning categories.

Interpretation
T: And then, so what do you know about the quills?
T: What do you see that's different?

Enablement
T: Ned, what is something different about those?
T: Amy, what is your question?

Differences among the three types of student questions also revealed more Closed-ended questions than any other type, X^2 (2) = 103.95, $p < .001$, $\Phi = 0.62$ (large effect size). Only 20% of the students' questions in this study were Open-ended questions with the majority being Enablement and Definition. By comparison, in previous research, Cochran and Reinsvold (2010) found that third-grade students asked only 7% Open-ended questions. All student questions coded as Enablement (23 of 52) were students asking Mrs. Allen for help or information. Those questions coded as Definition (17 of 52) were students asking about characteristics of vertebrates. Student Open-ended questions occurred both during small-group and whole-class conversations. Below are unrelated examples of Enablement and Definition questions:

Enablement
S: Mrs. Allen?

Definition
S: What's a shrew?
Julie: What's quills?

Task-oriented questions posed by Mrs. Allen and her students showed the lowest frequencies of all questioning categories, 16% and 17%, respectively. For students, most Task-oriented questions were clarifying procedures when working in small groups. Below is an example of Task-oriented questions from a conversation in Observation 12 where the teacher and students discussed how to interact with animal pelts at stations where they were displayed.

15.05	Prompt	T: And then there's another antler that goes with this um hide so you guys can look at these as you go and look at the clues. Any questions? **(TO)**
	Response 2	S: Can we just write in our notebook if you have a question, the question? **(TO)**
	Feedback	T: Oh I love that. If you would like to take your science notebook and write a few clues that you can refer to, I will certainly let you do that. Okay? **(TO)** That was a great idea.
	Prompt	T: Okay Julie? **(OEE)**
	Response 2	Julie: Are we going to switch tables to look at? **(TO)**
15.35	Feedback	T: Yep. So you are going to start now, that is the tricky part. Julie, I love that you thought that up. See why I love you guys? **(CE)** You are great.

Student work. Assessment data gathered by Mrs. Allen was used to provide evidence of student understanding of the five types of vertebrates: reptiles, amphibians, mammals, birds, and fish. Student work gathered in the five observations of this study included three activity sheets (Pelt Matching, Track Matching, Scat Matching) and a writing assignment (Facts about Mammals). Teacher scores for student work are found in Appendix H. The total score for each activity sheet was four points. Each sheet had numbered blank lines, and a box entitled "Word Bank" with a list of vertebrate names. An example of an activity sheet is found in Appendix I. Each activity sheet number represented a tag on the pelt, track, or scat sample. During Observations 12, 13, and 16, Mrs. Allen and the students completed activity sheets together. During these lessons, Mrs. Allen displayed her activity sheet on an overhead projector at the front of the classroom. As Mrs. Allen and the students decided what vertebrate matched the tag numbers of the samples, Mrs. Allen wrote the name of the vertebrate on the appropriate blank line of her sheet, and students did the same. Overall, the majority of the students

received full points for these three activity sheets. Those who did not earn full points were marked down because of spelling errors. Mrs. Allen expected students to spell the vertebrate names correctly because they were written in the Word Bank.

There was one writing assignment, *Facts about Mammals,* in the students' science notebooks that was completed and graded during the this study's observations. Students could earn four points for this assignment. During Observation 15, most students worked in small groups to read from *Lions, ferrets, and bears: A guide to mammals of Colorado* (Armstrong, 1993*)* and gathered vertebrate facts that they could use to match the scat mold to the vertebrate. Pairs of students were assigned one or two vertebrates to investigate. Two students searched the Internet with Mrs. Allen to gather facts about the grouse. As the students read or searched the Internet, they wrote these facts in their science notebooks: what their animal ate, size of the animal, and a fun fact. Below is an example of a conversation between a student, Julie, and Mrs. Allen, as Julie presented the coyote facts to the whole class:

37.37 Teacher: Okay. Julie next one.
37.39 Julie: I'm doing the coyote. It's um the size is, it's about the size of a small shepherd dog 'cause it looks exactly like it.
Teacher: Okay.
37.49 Julie: And the, um, it's four feet long and then its tail is 14 inches.
Teacher: Oh, 14 inches. Okay. A little longer.
Julie: And then it's four feet. ((laughs))
Teacher: Yeah this is what? ((showing a meter stick)) Is this a meter? Oh, this is a meter stick. So there's three feet. So about four feet. Yep.
38.10 Julie: And then um the coyotes are an omnivore.
Teacher: <u>Ooh</u> I messed up on that one. Okay
Julie: Because it said it liked, um, it ate meat and, um, trash.
Teacher: Good, good to know.
Julie: And um females breed, this is my fun fact, females breed in January to March and have a litter of six pups and then um, I did the weight last, it's 30 to 40 pounds.
Teacher: 30 to 40 pounds. So a beaver's bigger. ((laughs)) The beaver's bigger. Okay thank you. Very, very well done.

Julie's science notebook entry for coyote information and the other vertebrate assigned to her group, the badger, are found in Appendix J. Julie's written phrases about the coyote are similar to words she used to verbally describe the coyote. Her written work reflects Subject Matter content and vertebrate understanding of classroom contributions. She made one spelling mistake, but received full points, 4, for her work. Overall, the majority of students received full points for their writing assignment on Facts about Mammals. Those who received less than four points were marked down due to spelling mistakes. Mrs. Allen expected the students to spell words correctly because they came from the mammal guide or the Internet.

In Appendix H, I also provide each student's overall grade for all student work during my 28 observations. This grade included results from assignments within the observations of this study, and other assignments, including two short-response quizzes, two investigations that were placed in their science notebooks, four other activity sheets that were placed in their science notebooks, and points on the completeness, organization, and neatness of their science notebooks. Ricardo, an ESL student, was the only student that did not receive a passing grade (60% or better) in science during my observations. He had missing assignments, the writing assignments in his science notebook were not neat, and groups of letters did not form words or phrases.

Based on student work for the observations in this study, the majority of students in Mrs. Allen's fourth-grade class understood the features and behaviors of vertebrates. Mrs. Allen provided opportunities for the students to interact and learn from the investigations. The results from the preliminary coding analyses indicated that Mrs. Allen had more utterances and questions than the students for the observations in this

study. However, in four of the five observations (12, 13, 14, and 15), the student and teacher utterances were not significantly different from each other. Across the observations, the power shifted between the teacher and the students. The students had more power in Observations 12 and 13, the teacher and students shared power in Observations 14 and 15, and the teacher had more power in Observation 16. I use the next section to address my research questions by describing the power and questioning dynamics based on scenarios from the observations.

Power and Questioning Dynamics

In this section I describe the power and questioning dynamics that occurred during the observations and answer each research question of this study. Specifically I provide descriptions of scenarios when students exercised more frequent power than the teacher, when the teacher and students had similar frequencies of power, and when the teacher employed more frequent power than the students.

When students exercised more frequent power. To describe the type of interactions that took place to allow more student power, I analyzed the questioning categories (Table 15), and participation roles (Appendix F) data.

In Observation 12, before students began the small-group activity, Mrs. Allen initiated a whole-class discussion by asking the students to recall what they knew about vertebrates. She asked the students to apply what they knew about vertebrates to examples of students' pets that had been brought to school. Below is an example conversation transcript with power and question coding. Question codes are italicized and asterisked. Notice that the teacher allowed Student Voice power (TSIV or SIV) in nearly every step of this interaction.

10.35	Prompt	T:	You had an amphibian. We had a mammal yesterday. Um we had…which was the turtle? Is what also?	TSM TGR TSIV *CE* *OED**
10.41	Response 2	S:	I think that was a retile too	SIV SSM
	Response 2	Ian:	[It's] kinda both.	SIV
	Prompt	T:	[What] do you guys think?	TGR *OEI**
	Response 2	S:	No it's a reptile.	SIV SSM
10.46	Prompt	T:	Okay tell me both. Let's think about that Ian?	TOR TSIV TGR *OEE**

Mrs. Allen began the discussion by asking both Closed- and Open-ended questions to engage the students to think about what type of vertebrate a turtle is. Mrs. Allen's question gave Ian the opportunity to share his thinking, and he revealed a misconception that a turtle is both a reptile and an amphibian. Mrs. Allen addressed his misconception; she asked another Open-ended, Interpretation, question. Another student responded correctly, but she wanted to know what Ian thought. During my interview, Mrs. Allen talked about students who struggled:

> And, and it's okay to me if they struggle a little and then, and they don't have it solid in their brain yet. Yeah, I 'm not saying they have to have everything mastered, and I just want them to think. I want them to think, just think. [Teacher Interview 6, p. 3]

In this scenario Mrs. Allen provided the students with the opportunity to think, and not tell them what to think. In this scenario, Mrs. Allen guided the students with questions to understand what a vertebrate was. By using an Enablement question, Mrs. Allen asked Ian to explain his thinking. What follows is Ian's response to Mrs. Allen's question:

10.48	Response 2	Ian:	Um, like some turtle alls like like the like in a like in a pretty de deep pool and some of them like land like amphibians and some of them just on like land [like reptiles].	SIV SSM
11.08	Prompt	T:	[Okay so you] think turtles could be amphibians and reptiles? ((Video shows teacher looking at Ian, and Ian nodding his head in agreement. Other students raising their hands.))	TSM TSIV *CE**
	Response 2	S:	Oh, I know.	SIV
11.14	Prompt	T:	Okay. So let's think about, can someone tell him um… the.. characteristics or maybe Ian you can tell me what are the characteristics of a reptile again? They have to have what?	TGR TOR TSM TSIV *CE CE**
11.26	Response 2	Ian:	Umm…they have to have like a shell or scales?	SIV SSM *CE**
11.33	Prompt	T:	Hmm which one?	TSIV *CE**
11.35	Response 2	Ian:	Scales.	SIV SSM
11.37	Feedback	T:	Scales. Okay.	TSM TCON

Ian used science language and Subject Matter power to explain what he understood about amphibians and reptiles. Recognizing that Ian was still struggling with the differences between these vertebrates, the teacher used a Closed-ended question to get him to share the characteristics of a reptile. Mrs. Allen lowered the reasoning level for Ian with a simpler question in order to help him build his understanding of vertebrates. This questioning strategy is described by Bruner "The trick is to find the medium questions that can be answered and that take you somewhere" (Bruner, quoted in Driscoll

2005, p. 231). Ian's uncertainty persisted when he shared two characteristics of reptiles, shell and scales. Mrs. Allen asked him to decide which one was a characteristic of a reptile. He responded, "Scales," and she repeated his statement, "Scales," as feedback. Mrs. Allen continued to help Ian differentiate reptiles from amphibians:

11.37	Prompt	T:	Because there, I think there might be some reptiles that don't have shells. Remember that station we talked about and we are going to go over it a little more? ((Referring to another lesson.)) So let's think about that. So they have scales. What type of skin do amphibians have Ian?	TSM TOR TGR TSIV *CE CE OEE**
	Response 2	Ian:	Slippery smooth skin.	SIV SSM
	Feedback	T:	Smooth, slippery skin.	TSM TCON
11.55	Prompt	T:	So let's think about turtles. What did we say turtles have? What kind of skin?	TOR TGR TSM TSIV *CE**
	Response 2	Ian:	Scales.	SIV SSM

Mrs. Allen used Closed-ended questions and continued to ask Ian characteristics of both vertebrates. She used Subject Matter power and Ian did as well; they used science language to describe what they knew. As the conversation continued, Mrs. Allen verified that Ian knew the differences between the two vertebrates.

12.01	Prompt	T:	So are they ever an amphibian?	TSM TSIV *CE**
			((On video, Ian is shaking his head no.))	
	Feedback	T:	No. Did you just kind of get that straight in your mind?	TSIV TCON *CE**
	Response 3	Ian:	Uh huh	SIV

	Feedback	T:	That is so cool.	TCON
12.09	Prompt	T:	I love when I do that kind of stuff. I'm like, now wait a minute. I'm thinking this and then all of sudden I'm like ↑oh wait a minute I a know I'm going to think through this a little more. So that's what I want.	TIV TOR
	Feedback	T:	Ian is a perfect example of what I want you to be doing with vertebrates. You are going to get it straight in your mind where they fit. That's why we look at the characteristics.	TOR TSIV TSM

Mrs. Allen used Closed-ended questions to make sure Ian understood the differences between these vertebrates. At 12.09 minutes, she reflected on her thinking process through metacognition (Driscoll, 2005), and modeled how she wanted her students to think through what they knew and determine if it made sense to them. She was very supportive of Ian as he persisted with his misconceptions, and treated him with respect. Her questions, guidance (Organizational power), and feedback provided scaffolding (Driscoll, 2005) for Ian to construct his understanding of the differences between amphibians and reptiles

In Observation 13, Mrs. Allen and her students discussed ways to classify the type of feet animals have and how animals used their feet. The conversation led to the formation of the following classification and identification terms: paws, hooves, claws, and webbed. Mrs. Allen and the student used these terms to categorize the tracks, and then matched them to the animals:

14.14			((Teacher is projecting Tracks Matching activity on the overhead projector and discussing each vertebrate name in the Word Bank))	
	Initiation	T:	Okay so let's look at the badger. The badger, do you think it would have? Let's put P equals paw….C equals claw.. And H equals hoof… And let's put our name on it with our number.	TOR TGR TSM *CE**
	Initiation	S:	What was the other one? H stands for what? ((Teacher spending time to focus activity sheet on overhead projector.))	SIV SOR SSM *CE CE**
14.49	Prompt	T:	P equals paw…….((Writing on the activity sheet)) Oh there you can see that better.	TSM TOR
	Feedback	S:	Yeah.	SIV SCON
	Initiation	T:	Okay….. Okay…. So let's look at the badger. Write down what you think the badger would be. Put a P, C or H by it…………….Okay everyone tell me what you put.	TGR TOR TSM TOR
	Response 1	Ss:	P ((In unison.))	SGR SSM SCON
	Feedback	T:	P. I think so too.	TSM TIV TCON
15.24	Prompt	T:	How about beaver? Write it down….. What do you think it is?	TSM TOR TGR *CE CE**
	Response 2	Ss:	P. ((In unison))	SGR SSM
	Feedback	T:	P=	TSM TCON
	Prompt	T:	=Now something might be interesting about the beaver. What do we know about the beaver though? Carlos?	TSM TGR TSIV *OED OEE**

Mrs. Allen and the students decided on the track classification of the badger. She allowed students to think and write down on their paper what type of foot the badger had. As she shared in her interview, she wanted to provide students with opportunities to think through their answers and decide for themselves. She provided an Open-ended, Definition, question to have them recall what they learned about the beaver during the pelt activity. Carlos, a class leader and one who liked to share what he knew, received an opportunity to reply through the teacher's encouragement:

15.30	Response 2	Carlos:	That they have web?	SIV SSM *CE**
	Prompt	T:	So it might be more like a web. So I'm going to put a W by the beaver.	TSM TOR TIV
	Prompt	Lisa:	What is a web?	SIV SSM *OED**
	Response 2	T:	[Web is]	TSM
	Prompt	Carlos:	[Can I tell her?]	SIV SOR SSIV *TO**
	Response 2	T:	Yes Carlos tell her.	TSIV TOR
15.49	Prompt	Carlos:	It is like um you know how um, yeah yeah ducks, you know how they have things in-between=	SIV SSM
	Response 2	Lisa:	Oh yeah. Oh yeah, yeah.	SIV
	Prompt	Carlos:	=to swim. That's called webbing.	SIV SSM

In this scenario, Carlos used Organizational power to answer Lisa's question about "web". This interaction between students also occurred during the small-group lesson of Observation 12. Students asked Open-ended and Closed-ended questions and were quite comfortable answering each other. Mrs. Allen "stepped aside" and allowed students to engage with each other. Students used science language and showed Subject Matter power when discussing beavers and webbed feet. Overall, Subject Matter power was the second highest power category for students. The conversation continued when Julie asked a question and used power:

15.59	Response 2	Julie:	Can=?	SIV *CE**
16.00	Prompt	T:	Almost just like flippers you guys. 'Cause when you are in the water and you try to swim, if you claw, that is why we cup our hands ((teacher moving her arms and hands like a swimmer to show what she means)) to make it a solid so it's go through the water when we swim. Okay? But if we went like this we would flail and wouldn't get very far. Well um, aquatic animals then they have this like think skin between each =	TSM TGR TOR *CE**
	Response 2	S:	Ohhh, so they have extra skin ((inaudible)).	SIV SSM
	Prompt	T:	=toe or whatever and then it makes it more sold so they can swim better. It is almost like the fins you wear when you swim.	TSM TGR
	Response 2	S:	Turtles have them.	SIV SSM

Feedback	T:	Yeah, yeah. Okay.	TCON
Prompt	Julie	Can we write W equals=?	SIV SSM SOR *TO**
Feedback	T:	Oh yeah. W equals web. Excellent. Got to keep the key current. Excellent job.	TSM TCON

The teacher interrupted Julie and related webbed feet to how people use hands to swim. She used Subject Matter power and connected this characteristic of beaver to what the students might do when they swim. A student then extended and applied the concept of a webbed foot for swimming to the turtle. Mrs. Allen acknowledged this elaboration through feedback. Julie used Organizational power and wanted to add ‘W” to classification key. She took what they just learned and applied it to their process of classification. As in all observations of this study, the teacher provided reflective, positive, and complementary feedback to her students for what they added to the activity.

Research questions. The main research question for this study was composed of five specific questions. In this section, I show how these specific questions are addressed by the scenarios just discussed. The first of these was as follow*:* How does a teacher use questioning strategies in classroom discourse to engage students to understand science? When students exercised more power than the teacher, the teacher used questions to invite students to think and clarify what they knew. Mrs. Allen used Open-ended questioning strategies to engage student to think broadly about what they knew about vertebrates. Some students replied to these Open-ended questions; others needed Closed-ended questions to help them describe what they knew. Mrs. Allen used Task-oriented questions to guide and remind the students the process of the lesson: reading clue cards,

carefully looking at the animal samples, and writing neatly. Mrs. Allen was persistent in providing this scaffolding strategy to help students reason with her about what they knew.

The next specific research question was: How does a teacher use power in classroom discourse to engage students to understand science? Mrs. Allen used Organizational power to guide students to construct (Tudge, 1990; Vygotsky, 1978) their understanding of vertebrates. She reflected on what they said by acknowledging them using Teacher Student Individual Voice, and at times using a reflective toss (van Zee & Minstrell, 1997a) to review what they said and ask them clarifying questions. She frequently used Subject Matter power when interacting with her students in this way. By acknowledging her students, she gave them power to talk and think about the characteristics of vertebrates.

The third specific research question was: How do students use questions in classroom discourse to understand science? When students exercised more power, they used more Closed-ended questions to seek feedback on what they were thinking; many times they wanted to know if they were right. They used fewer Open-ended questions, but used them to seek understanding of concepts that were being discussed, “What is web?”, or asked Mrs. Allen to help them think through what they observed, “Mrs. Allen? We think it is a beaver.” Also, Mrs. Allen acknowledged their questions, and she answered their question or let other students answer. Task-oriented questions were used by students to help them understand what they had to do during the activities or to make suggestions on what process should be completed to carry out the activity, “If we think something different about number one, can we choose another vertebrate?”

The fourth specific research question was: How do students use power in classroom discourse to understand science? When students had more power, they used it to respond to questions and contribute to the organizational strategies used to identify the animal pelts and tracks. As reflected by the scenarios above, students used science language in the form of Subject Matter power as often as the teacher. This evidence is consistent with the views of Duschl (2006) and Lemke (1990) who argued that student use of science language is critical for the development of science understanding. Support for science understanding can also be seen through student work. My analysis of student work associated with Observations 12 and 13 (see Appendix H) shows that the majority of the students (14/17) earned full points on the Pelt and Tracks Matching activity sheets. Those who did not receive full points were either absent, the activity sheet was not turned in to the teacher, students had spelling errors, or their activity sheet was not graded. The class as a whole understood the characteristics of pelts and tracks of vertebrates. When students used power, they understood the characteristics of vertebrates.

The final specific research question was: How does the use of power relate to classroom questions in classroom discourse? Mrs. Allen and students used power and questioning strategies in a very complex and dynamic manner to learn about pelts and tracks. When students had more power, they had opportunities to voice what they knew because Mrs. Allen included them in investigating and discussing what they were learning. She used prompts such as “What do you think?”, “You decide what to write.” Mrs. Allen used questions to guide and support their construction of knowledge about pelts and tracks. Students used questions to ask what they didn’t know and to clarify

what they were learning. Mrs. Allen fostered shifts of power between her and the students by questioning students and acknowledging what they knew or what they needed to understand.

When students and the teacher share power. To understand the type of interactions that took place to allow a balance of power between Mrs. Allen and the students, I evaluated scenarios from Observations 14 and 15 where the overall power differences were found to be non-significant. .There also were no significant differences between teacher and student utterances. Mrs. Allen guided a whole-class discussion for Observation 14 and a small-group activity for Observation 15, so Mrs. Allen organized the lessons of these two observations differently.

The lesson in Observation 14, Investigating Animal Scat, the teacher and the students participated in a whole-class discussion to understand that scat is another piece of evidence that can be used to identify an animal. Mrs. Allen guided the students through a conversation about what scat is and what affects the scat that animals produce. Mrs. Allen and the students decided to focus on the size of animals; they made the assumption that big animals produce big scat and small animals produce small scat. Together, they decided they would classify the scat by size: small, medium, and big. Below is part of the conversation where they decided the size of scat for each vertebrate listed in their Word Bank on the Scat Matching activity sheet. They already discussed beaver and coyote, and in the example below they are deciding how they would classify the size of deer’s scat.

14.52	Prompt	T:	How about deer? Think about deer. Tell me.	TOR TSM TCON *CE**
	Response 2	Ss:	Medium. ((In unison.))	SGR SCON SSM
	Response 2	S:	Small	SIV SSM
	Response 2	S:	Big	SIV SSM
	Response 2	S:	Small	SIV SSM
	Response 2	S:	Medium	SIV SSM
	Feedback	T:	Wow.	TCON
14.59	Prompt	T:	This is <u>so</u> ((Laughing)) interesting because I've never done it this way before ((Classify by size)). I, I think that's interesting. I would have thought it big. [An animal.]	TIV TOR TSM

Mrs. Allen used the Prompt, "Tell me.", and a Closed-ended question to engage the students to think about the deer. She used this type of request in other observations too, and it was always followed by many students replying in unison with Subject Matter power. She wanted the students thinking carefully about the science concepts, and students used Subject Matter power to respond, and some responded differently. She shared her excitement regarding their decision, and modeled her reasoning (Driscoll, 2005) by using Individual Voice and Subject Matter power. The conversation continued as they shared power and negotiated the size of deer scat.

15.10	Response 2	S:	[I would've thought ((Inaudible.)).]	SIV SOR
	Prompt	T:	But=	TOR

15.12	Response 2	S:	But, I think,	SIV SOR
	Response 2	S:	I've seen deer scat.	SIV SSM
	Response 2	S:	Yeah	SIV
	Prompt	T:	We'll put=	TOR TGR
15.17	Response 2	Tom:	It's just tiny little balls.	SIV SSM

Here the power was shared between the students and Mrs. Allen. At minutes 15.10 and 15.12, students directly expressed their thinking; they copied how Mrs. Allen shared her thinking. Mrs. Allen tried to control what they would do "We'll put=", but Tom used Subject Matter power to interrupt and tell everyone what he knew about the size of deer scat. Tom compared the scat size to something he knew and had experienced. Students used power to negotiate and develop reasoning, suggesting that the size of the animal does not influence the size of the scat. Mrs. Allen responded with amazement to the students' use of Organizational and Subject Matter power in the next portion of the conversation.

15.18	Prompt	T:	↑Ohhhh. Okay now this is interesting. Okay Tom goes, because he knows deer and he's seen their feces/their scat and he says they are just tiny little balls.	TOR TSIV TSM
	Response 2	S:	I have too. I have ((Inaudible.))	SIV
	Response 2	Tom:	Tons of it.	SIV SSM
15.26	Feedback	T:	And tons of it.	TCON TSM

Mrs. Allen reflected Tom's thinking that the size of deer scat might be smaller than everyone thought. This encouraged another student to engage and to agree and share what he/she knew. This shifted their logic away from comparing animal size to scat size. Next in the scenario, Mrs. Allen clarified what they realized as groups:

15.31	Prompt	T:	Sooo….maybe..maybe big or small doesn't make a difference…What, okay so let's.	TOR TSM TGR
	Response 2	S:	Maybe	SIV
			((Students talking.))	
15.44	Feedback	T:	Hold on, Hold on. Shhh. Shhh.	TOR TCON
15.46	Prompt	T:	Maybe it is not how big or small, though, I mean that would make some difference like between a bat and a deer but maybe it is more about what they eat. Think about what a deer eats….	TOR TSM
	Response 2	S:	Plants	SIV SSM
	Response 2	S:	He just eats.	SIV SSM
16.00	Prompt	T:	What, he just eats what?	TOR TSM *CE**
	Response 2	Ss:	Plants ((In unison))	SGR SSM SCON
	Feedback	T:	Plants.	TCON TSM

Mrs. Allen guided them to recognize that the size of the animal does not matter as much. She further suggested to them that the animal's diet may play a role in the type of scat they produced. And then she began to lead them on a journey to identify what each

animal eats. As the conversation continued from the above point, Mrs. Allen redirected the conversation by asking the students to identify what animals eat, and to consider how this may affect the type of scat animals produce. Mrs. Allen guided the students to discover the use of new science words: omnivore, carnivore, insectivore, and herbivore to describe the eating habits of vertebrates. As found by other researchers of power dynamics in science classrooms (Bianchini, 1997; Candela, 1999, 2005; Cornelius & Herrenkohl, 2004; Shepardson, 1996), the power dynamics shifted in this scenario between the teacher and students as the teacher recognized the students' reasoning. Mrs. Allen guided a change in the conversation because of their new understanding about size and diet. Mrs. Allen frequently described in her interviews that she wanted to provide her students with opportunities to think and share what they knew, "Sometimes, I'm just wanting some conversation where we're thinking deeper." [Teacher Interview 6, p. 4]. These results indicate that Mrs. Allen provided and guided her students to reason through what they knew.

Observation 15 lesson was a continuation of Investigating Animal Scat. Because the scat molds for the lesson were being used by the other fourth-grade teacher, Mrs. Allen could not finish the scat lesson. She decided to extend the lesson and use a science booklet, *Lions, ferrets, and bears: A guide to the mammals of Coloardo* (Armstrong, 1993) with her students. Interestingly, she did not directly share this change with her students. To assist them to investigate what animals ate and identify the scat, Mrs. Allen introduced the booklet about Colorado mammals to her students. In the following scenario, she introduced the booklet and shared her excitement about reading about all

the different mammals. Mrs. Allen began a whole-class discussion by asking certain students what their pets ate, and what animals are called if they ate plants and/or animals (omnivore, herbivore, carnivore, insectivore).

4.11	Prompt	T:	I was glancing at it and it had the beaver and the harvest mice and prairie dogs and shrews, porcupines, black bears.	TIV TSM
	Response 2	Ss:	Ahhhhhhh	SGR
	Prompt	T:	And in it they were telling me whether they are omnivores or what.	TSM
	Response 2	Ss:	Ahhhhhhh	SGR
4.27	Prompt	T:	So I thought what I would do is assign you guys and when I found it I was like sitting there and I couldn't put it down because it is so interesting. You guys are going to be so tempted to read everything.	TIV TOR TGR

Using Subject Matter power, Mrs. Allen shared her interest with the information in the booklet and modeled (Driscoll, 2005) what her students should do when they read it. From the students' responses, they were interested to look at the book too. She then asked her students to explain how they can use the booklet to learn more about vertebrates.

5.28	Prompt	T:	Now, oh! Oh. What would be some good information that we might want to know as a class that you could share out? Lisa?	TOR TGR TSIV *OEP OEE**
5.33	Response 2	Lisa:	Um I think to know which animals are. ((Laughing.))	SIV SSM
	Feedback	T:	Okay so you are going to have to tell us what animal you have. That makes sense.	TCON TSM TSIV

	Response 3	Lisa:	No like to know like what the animal eats and stuff like that.	SIV SOR SSM
	Feedback	T:	What they eat? Okay	TCON TSM *CE**
5.48	Prompt	Carlos:	Like omnivores, herbivores.	SIV SOR SSM
	Prompt	T:	So [what=]	TOR
	Response 2	Lisa:	[Yeah] what they are.	SIV SOR
	Prompt	T:	Are they herbivores, carnivores, omnivores or insectivores?	TSM *CE**
	Feedback	T:	Good, that's the first thing I would look for and write in your notes.	TCON TOR TIV

Mrs. Allen's Open-ended questions engaged Lisa and Carlos to use Subject Matter power to describe what they would find. Carlos articulated what Lisa was suggesting about animal eating habits with Subject Matter and Organizational power and without teacher probing. Lisa was persistent in clarifying her use of science language without the teacher's support. Mrs. Allen allowed the students to describe their understanding, and modeled what she hoped they would do when they found the information on animal eating behaviors.

The students worked in small groups to identify the size of their assigned animal, what it ate, and a fun fact. She asked them to write their information, *Facts about Mammals*, in their science notebooks. After the students collected their information, they shared what they learned with the whole class. The following is an example illustrating how a student shared what she learned from the reading.

33.51	Prompt	T:	Okay tell them what animal you have.	TOR TSM
	Response 2	Trisha:	We have the bat and the beaver and I'm going to read the bat.	SIV SSM SOR SGR
	Feedback	T:	Okay	TCON
	Response 2	Trisha:	((Reading from her science notebook)) The bat, the hi, histrill ((Pipistrella)) bat weighs three inches and it's one tenth of an ounce.	SIV SSM
	Feedback	T:	Okay, so wait a minute.	TOR TCON
34.07	Prompt	T:	Does it weigh <u>three</u> inches?	TOR TSM TSIV *CE**
	Response 2	Trisha:	On, no. It is three inches [long.]	SIV SSM
	Feedback	T:	[Long.] Three inches.	TCON TSM
	Response 3	Trisha:	It's not very long.	SIV SSM
	Feedback	T:	Yeah	TCON
34.21	Prompt		Okay keep going babe. That's interesting.	TOR TSIV
	Response 2	Trisha:	Well, it eats insects…and the horing ((hoary)) bat is five and a half inches and weighs seven or eight pounds ((Seven-eighths of an ounce)).	SIV SSM
	Feedback	T:	Whoa! Okay.	TCON
	Prompt	T:	Um, so we know it's a insectivore. It is very small. What's your fun fact babe?	TOR TGR TSM TSIV *OEE**
	Response 3	Trisha:	Um that the western um..pipestone ((pipistrella)) is three inches and ((Inaudible)).	SIV SSM

34.55	Feedback	T:	Oh so you liked it's weight and stuff. Very interesting. Good. And we were correct. The bat is an insectivore. Okay great.	TCON TSM TGR TSIV

With Subject Matter feedback and clarifying questions, Mrs. Allen supported Trisha as she shared her bat facts. Trisha was complete in her bat facts, although, the common names for the bats were not pronounced correctly. In this scenario, Mrs. Allen called Trisha "babe"; she also used this term of endearment with other students during this study.

Research questions. In this section, I show how these specific questions are addressed by the scenarios just discussed. The first specific research question was: How does a teacher use questioning strategies in classroom discourse to engage students to understand science? When power was shared by Mrs. Allen and the students, Mrs. Allen used questions to engage students to think how they will proceed to evaluate animal samples or what information they need to collect from the booklet in order to indentify animal scat. Mrs. Allen tended to use Open-ended questions to initially engage students with the process of thinking, e.g., "What would be some good information that we might want to know as a class that you could share out?" (OEP). Mrs. Allen used Closed-ended questions to clarify and prompt student comments, e.g., "Does it weigh <u>three</u> inches? "

The next specific research question was: How does a teacher use power in classroom discourse to engage students to understand science? When power was shared by Mrs. Allen and the students, Mrs. Allen's use of power was similar to her use of power when student had more power. She used Organizational power to guide students to construct (Tudge, 1990; Vygotsky, 1978) their understanding of vertebrates. She reflected on what they said by acknowledging them, using Teacher Student Individual

Voice, and at times tossing back (van Zee & Minstrell, 1997a) what they said and asked them clarifying questions. She frequently used Subject Matter power when interacting with her students. By acknowledging (Teacher Student Individual Voice, Conventional, and Group power) her students, she gave them power to talk and think about the characteristics of vertebrates, e.g., "Oh so you liked it's weight and stuff. Very interesting. Good. And we were correct. The bat is an insectivore. Okay great." (TCON, TSM, TGR, TSIV).

The third specific research question was: How do students use questions in classroom discourse to understand science? When power was shared by Mrs. Allen and the students, students used more Closed-ended questions than Open-ended questions. They tended to use Closed-ended questions to seek feedback on what they were thinking; many times they wanted to know if they were right. They used Open-ended questions to seek understanding of concepts that were being discussed, "What's ferrets?", or asked Mrs. Allen to help them think through what they observed, "Mrs. Allen, How will we find out?" When students shared power, Mrs. Allen acknowledged and answered their questions. Task-oriented questions were used to understand what they had to do during the activities or to make suggestions on what process should be completed to carry out the activity, e.g. "We can't find the information?"

The fourth specific research question was: How do students use power in classroom discourse to understand science? When students shared power with Mrs. Allen, they used power to interrupt her Organizational power to explain what they meant. They used Subject Matter and Organizational power to provide a better explanation of what they knew, "No, like, to know, like what the animal eats and stuff like that." This

was done without Mrs. Allen's probing questions. Students completed one writing assignment during Observations 14 and Observation 15 (see Appendix H): *Facts about Mammals.* The majority of students (13/17) received the four full points for their writing. If the students did not receive full points, they had spelling mistakes and their handwriting was poor. The student who received a check mark had all required facts for the animal. The writing by the student who did not receive points only provided a line of letters that did not form words or phrases. This student was an English Language Learner. The class as a whole understood the characteristics of the vertebrates they read about in the booklet. When students used power they understood the characteristics of vertebrates.

The final specific research question was: How does the use of power relate to classroom questions in classroom discourse? Mrs. Allen and students used power and questioning strategies in a very complex and dynamic manner to learn about animal scat. When students shared power with Mrs. Allen, they still had opportunities to voice what they knew because Mrs. Allen included them in developing ways of understanding evidence, and investigating and discussing what they were learning, "How are you going to find the animal you need?", "What do you think Ned?" Mrs. Allen remained quiet as students discussed whether the size of the animal or what they ate affected an animal's scat. She would only intercede if they made errors in their logic or subject matter, "Does it <u>weigh</u> three inches?", ". . . maybe big or small doesn't make a difference." Mrs. Allen used questions to guide and support their construction of knowledge about scat. Students

used questions to ask what they didn't know and to clarify what they were learning. Mrs. Allen fostered shifts of power between her and the students by questioning students and acknowledging what they knew or what they needed to understand.

When the teacher used more power. In some cases Mrs. Allen used more power than the students. This was the third day for the scat investigation. Observation 16 was scheduled to last only one day, but because of the size verses eating behavior conversation during Observation 14 and the lack of scat materials during Observation 15, the teacher extended the investigation to a third day to help students understand what animals ate and how big they might become. For scheduling purposes, she needed to complete the scat lesson during Observation 16. During my interviews, she often shared with me, "I feel that I might be getting a little behind." This could be one reason why the teacher used slightly more power during this lesson; she wanted to provide more student guidance in order to complete the lesson.

There was a significant but small difference between the teacher and student use of power during this observation. There also were significant differences in number of teacher (332) and student (257) utterances; the teacher had more utterances overall. The frequencies of teacher Prompts and student Response 2 participation roles were greater than the other participation roles during these observations. Mrs. Allen guided a whole-class discussion for Observation 16 in order for the class to be able to identify each scat sample and complete the Scat Matching activity sheet.

In this lesson, like the lesson of Observation 14, the teacher led a whole-class discussion to investigate and identify the scat; however in this lesson, the teacher had more utterances than the students. In Observation 16, she took opportunities to explain

and connect what they learned about vertebrates in Observations 14 and 15. There were no opportunities in this observation for students to work with Mrs. Allen and decide how to develop a process for identification. That process was completed in Observations 14 and 15. During this class period, Mrs. Allen showed each scat sample on the overhead projector, and together they decided what vertebrate produced the scat. To help the students through this identification process, Mrs. Allen facilitated a discussion on the similarities and differences between scat. The students grouped the scat into different categories, sizes and shapes. The following is an example of a conversation illustrating how the teacher used the whole-class discussion to explain content and probe student understanding in order to identify the scat. Notice that in this part of the class, the teacher's utterances outnumber the students' utterances and that she is controlling the conversation even though she is using Open-Ended questioning.

4.43	Initiation	T:	((Teacher using overhead projector in front of room to display different scat.)) Now . . this, I went over to the scat and I picked, remember how on the, um footprints we picked the biggest footprints. We went between paws, hooves and claws? Now I picked some of the biggest, um scat and what, what animals do you think would have some of the largest scat?	TOR TIV TSM TGR *CE OEI**
5.05	Response 1	S:	Ohh. ((Students raising their hands.))	SIV
	Prompt	T:	Chris what do you think might be one?	TSIV TOR *OEI* *OEE**
	Response 2	Chris:	Oh, um, I don't really know but I think the, ki the one on, um, the, on the right, right might be the largest.	SIV SSM

	Prompt	T:	Well, and tell my why you think that.	TOR TSIV
	Response 2	Chris:	Because, ah, it so ((inaud)) dog's poop looks like.	SIV SSM
5.27	Feedback	T:	Interesting. So he's taking what he knows, his background knowledge, and he's like, man my dog looks like that so it might be a coyote. Right?	TSIV TOR TSM TCON *CE**

Mrs. Allen began the discussion to identify the scat by asking an Open-ended (Interpretation) question to engage the students to think about what animals would have the largest scat. The videotape showed many students responding, hands rose; they were ready and eager to reply. Chris struggled with his reply, and provided a simple answer, "the largest", but Mrs. Allen prompted him to think. She used her Organization power and asked him to describe why he thought "the largest". Chris used his prior knowledge (Driscoll, 2005) to relate his answer to what he knew about dogs. Mrs. Allen reflected his use of prior knowledge and explicitly modeled (Driscoll, 2005) how he used his prior knowledge for her students.

A few minutes later, as Mrs. Allen and the students decided what vertebrate went with the larger scats, Carlos wanted to share something. This part of the scenario shows more balance of power.

7.14	Response 2	Carlos	Um well why, what, what, it is knowledge and stuff but I think, think one of those might be moose because mooses are pretty big animals and so I=	SIV SOR SSM
	Feedback	T:	So possibly.	TCON
7.31	Response 2	Carlos:	Because you, and you said, we were talking about size matters also. The size of animal.	SIV SSM SGR

Prompt	T:	Well we thought that=	
Feedback	Carlos:	Yeah.	SIV SCON
Prompt	T:	=and then Tom said something like the elk it's just like round balls or something=	TOR TSIV TSM
Feedback	Carlos:	Uh, huh	SIV SCON
Prompt	T:	=and so then we decided it was more what they eat. But we don't know. Well, let's take, ((Picking up the largest scat sample.)) this is the biggest scat, and let's go with our theory on carnivores and see if um, which would be the biggest animal out of the bobcat, coyote, mountain lion, raccoon?	TGR TSM TOR *CE**

Carlos stated the type of information he wanted to share and reflected on his thinking, demonstrating metacognition (Driscoll, 2005). Carlos used Subject Matter power to remind Mrs. Allen that because the moose is the largest vertebrate, the moose has the largest scat. Mrs. Allen used Organizational and Subject Matter power to help Carlos remember what they learned during the class in Observation 14. She did not tell Carlos he was wrong, but supported him with Subject Matter power to explain the new reasoning from the discussion about the relationship between what animals ate and the size and shape of scat.

This is also a good example of what Mrs. Allen shared in her interviews. She indicated that she did not want to make a point of telling students that their thinking was wrong, but she wanted to provide explanations or questions to help students construct the correct understanding.

> They know when you are really interested in what they're thinking, and that you value their opinion on . . when they say that . . like I didn't just, you know, go 'No, ((Student)), I'm right 'cause I say so'. Oh you know what, cause I do think about . . woa. They got a good point. And when they think that I.. I'm listening to them and they're making a good point, then they'll really try to think. I f I dismiss them, they're not gonna ask me, or they're just gonna be . . pat questions they expect me to ask. [Teacher Interview 2, p. 3]

Also, Mrs. Allen often used *we* and *us* in her explanations to emphasize the group-based nature of these understandings. I have specified this strategy as Group power and she often used this approach in other observations of this study to recognize student contributions.

Research questions. In this section, I show how these specific questions are addressed by the scenarios just discussed. The first specific research question was: How does a teacher use questioning strategies in classroom discourse to engage students to understand science? Even when Mrs. Allen used more power than the students, Mrs. Allen used questions to engage students to think how they would compare scat shapes and sizes to actual vertebrate samples. Mrs. Allen used initial Open-ended questions to engage students in the process of thinking, e.g. "Now I picked some of the biggest, um scat and what, what animals do you think would have some of the largest scat?" (OEI). Mrs. Allen used Closed-ended questions to ask students to decide which vertebrate matched the scat, e.g., "Do we think that this might be the coyote or bobcat now? " Overall however, Mrs. Allen did not ask as many questions when she had power as when she shared power with the students or when the students used more power than the teacher.

The next specific research question was: How does a teacher use power in classroom discourse to engage students to understand science? Mrs. Allen used Organizational and Subject Matter power to guide students to construct (Tudge, 1990; Vygotsky, 1978) their understanding of vertebrates. She reflected on what they said by acknowledging them (using Teacher Student Individual Voice), and at times tossing back (van Zee & Minstrell, 1997a) what they said and asked them clarifying questions, "Chris what do you think might be one?" By acknowledging her students through Teacher Student Individual Voice, Conventional, and Group power, she continued to give her students power to talk and think about the characteristics of vertebrates, e.g., "Oh we had good reasoning on that one." (TCON, TGR, TSIV).

The third specific research question was: How do students use questions in classroom discourse to understand science? When Mrs. Allen used more power, students tended to use more Closed-ended questions than Open-ended question. They asked fewer questions when Mrs. Allen was using more power than when they had more power. The students tended to use Closed-ended questions to seek feedback on what they were thinking; at times they wanted to know if they were right. They only asked five Open-ended questions in this classroom session, and most of them were Enablement questions that asked for Mrs. Allen's attention. When Mrs. Allen had power, she acknowledged most of their questions, but she did not address those that just asked for her attention. Students used Task-oriented questions to offer help to Mrs. Allen as she organized the scat to display on the overhead projector, or to display an animal site on the Internet.

The fourth specific research question was: How do students use power in classroom discourse to understand science? When Mrs. Allen used more power than the students, the students used power to respond to questions and offer ideas to explain why certain scat belonged to certain vertebrates. In this observation, some students used power to share information about animals they learned from the Internet. As reflected in the scenario above, students used Subject Matter, but less than when they had more power overall. For the student work graded for Observation 16 (see Appendix H), the majority of the students (14/17) earned full points on the Scat Matching activity sheet. Those who did not receive full points did not turn in the activity sheet, made spelling errors and writing was illegible, or the activity sheet was not graded. The class as a whole was able to match the scat to the vertebrate when they had characteristics of the vertebrates. When students used power they understood the characteristics of vertebrates.

The final specific research question was: How does the use of power relate to classroom questions in classroom discourse? Mrs. Allen and students used power and questioning strategies in a complex and dynamic manner to learn about animal scat. Mrs. Allen used power and questions to provide students with opportunities to voice what they knew about scat shapes and sizes and how those characteristics relate to different vertebrates, “Chris what do you think might be one?”, “Well tell me why you think that.” Unlike the other observations, during this lesson Mrs. Allen took time made specific decisions about what they would do, “How about if we (laughing) how about if we go to instead of the big we go to small?” She used Organizational, Group and Subject Matter power and an Open-ended question to make the connections for the students. In the other scenarios, she asked her students to decide how to match the animal samples to the

animals. However, she still used questions to guide and support their construction of knowledge about scat. Students used questions to ask what they didn't know and to clarify what they were learning. Mrs. Allen used more power and fewer questioning strategies so that she and the student could complete the task to match the scat to the animals. The results of the student work indicate that with the teacher's guidance, the students understood the characteristics of the scat in order to match it with a vertebrate, however, their use of power and questioning strategies were not as prominent as in other observations of this study.

Summary

In this study the teachers and the students used power and questioning strategies to understand the characteristics of different vertebrates in order to identify pelts, tracks, and scat. For the five observations in this study, I used the coding analysis to understand the dynamics and the distribution of teacher and student utterances, participation roles, power categories, and questioning categories.

To address my main research question, *How do power and questioning strategies in an elementary classroom support student understanding of science?* I analyzed the quantitative and qualitative data when Mrs. Allen and her students used power differently. I found students had slightly more power in Observations 12 and 13; however, there were no significant differences in the frequencies of the students and teacher utterances. In these scenarios, the teacher asked more questions of the students and the students asked more questions. There was more engagement and exchange between the teacher and the students during Prompt and the Response 2 participation roles compared to the other observations. The teacher used guided discovery (Driscoll,

2005) with the students to explore and learn about different animal pelts. She also guided them to develop and use a classification system to successfully identify different animal tracks. Mrs. Allen used questions to guide and engage students to think, "What do you know about the beaver though? What do you think it is?" These types of Open-ended questions by the teacher provided students with the opportunity to think through and explain what they knew about vertebrates. In a sense there was a generation of power by the teacher as she used scaffolding to aid the students in constructing their understanding of vertebrates. Through discourse, Mrs. Allen and the students built a deeper understanding of science through inquiry by the exchange and negotiation of meaning (Carlsen, 2007; Kelly & Green, 1998; Lemke, 1990; Moje, et al., 2001; Singer, et al., 2000).

I found that Mrs. Allen and her students shared power in Observations 14 and 15. There were no significant differences in the frequencies of teacher and student utterances. However, the total utterances were somewhat less than when the students had more power. Mrs. Allen asked more questions than the students, but she asked fewer questions of the students compared to those times when the students had more power. Students tended to exercise more power and utterances when Mrs. Allen asked more questions, both Open- and Closed-ended. Student questions were fewer when they had less power. Students' use of subject matter in their conversations decreased as teachers asked fewer questions. Mrs. Allen provided fewer Prompts and the students had fewer Response 2 utterances when they had less power. The teacher used prompts to ask questions and elaborate on subject matter. When they shared power, Mrs. Allen probed students and

provided them with opportunities to think “How are you going to find the animal you need?”, “What do you think Ned?” The students tended to respond to these questions.

In Observation 16, Mrs. Allen needed to complete the scat investigation. She expressed to me that she was “a bit behind” the district’s curriculum schedule. She also had to share instructional materials for each investigation with the other fourth-grade teacher. Mrs. Allen needed to follow their material schedule as well. These circumstances influenced the interactions in Observations 16 when Mrs. Allen tended to use more power than the students. She had more utterances and more questions than the students. She used fewer questioning strategies than the observations when students had power. Because students had fewer responses, they used Subject Matter power less frequently than the other scenarios. As Mrs. Allen and the students identified the scat, Mrs. Allen did not generate many opportunities for the students to discuss and decide how to match the scat; the teacher made decisions for them, “How about if we (laughing) how about if we go to instead of the big we go to small?” Even though she used power to guide the investigation, Mrs. Allen continued to probe the students to share what they knew, “Chris what do you think might be one?”, “. . . tell my why you think that.”

Throughout all the observations in this study, Mrs. Allen and the students used power and questioning strategies to exchange and negotiate their understanding of vertebrates. From this study, it is apparent that, as the teacher engaged students to collaborate on processes for investigation (NRC, 2000), and provided them with opportunities to explain their understanding, students used more power such as Subject Matter. Student work provided evidence that the majority of the students understood characteristics of vertebrates, however, only one (Facts about Mammals) of the four

assignments was completed by the students on their own. The three activity sheets glued in their science notebooks were completed together as a class. Overall, there were few differences in student work during the observations in this study.

The teacher modeled ways of thinking (Driscoll, 2005) during this study, and students often shared their thinking. Throughout the observations, Mrs. Allen showed great care for her students and always acknowledged their contributions. During my interview, Mrs. Allen reflected about her students, “But, I think they feel respected and that um, ... well I’m just really considering what they’re thinking.” Even with different levels of power and questioning dynamics in Mrs. Allen’s class, students used opportunities to talk about vertebrates, and as a result, they learned (Duschl, et al., 2006; Lemke, 1990) about the characteristics of vertebrates.

CHAPTER VI

CONCLUSION AND DISCUSSION

> **. . . .** you ((Lori)) watching me is making me think too. . . Like I mean, I've always been concerned, but maybe now at my 7th year, I started to feel a little easier to, um, really, I mean I use to be just be, "How do I get this accomplished?" this, you know, but now I feel a little more comfortable to say, "Why am I accomplishing, why am I trying to get to accomplish this?" Which, you know, I normally do, I mean I understand that they need this scientific experiment, but I'm kinda digging deeper this year I feel like than I ever have. Which I think is to the advantage of the kids . . . . I wasn't getting my kids over to the advance ((advance is an achievement level on Colorado's standardized test)), and I have the high group, and so, um, we, I talked with the gifted teacher, and she said maybe I'm not digging deep enough. I'm doing the surface meaning, and so they're good at that, but which keep them at proficient ((proficient is an achievement level on Colorado's standardized test)), high proficient. But to get to the advanced level, they're going to have to really dig deep which maybe I wasn't doing in my own mind . . . [Teacher Interview 7, p. 1]

During my interview with Mrs. Allen, she explained how she was spending more time reflecting on how she was interacting with her students. She thought this way because she was comfortable with the instructional materials and procedures she used teaching science. Our conversations motivated her to reflect on and improve her students' conceptual understanding of science, and how she assisted them to "dig deep", and reach a higher-level of thinking.

Across the five observations of this study, Mrs. Allen was flexible in order to engage and provide students with opportunities to "dig deep" in their understanding of the characteristics of vertebrates. She and the students collaboratively decided how to classify animal tracks and scat in order to identify them. She extended the scat

investigation beyond a day in order for the students to explore the sizes and eating habits of animals. When students wanted to answer other students' questions or share their knowledge, she allowed them without hesitation, "Okay, let me get a few of these questions out of the way and then we'll continue on." Though she used more Closed-ended questions than Open-ended questions, her questions were effective in asking students to share their thinking and clarify their reasoning. Students always responded to her questions. Through her discussions and interactions with the students, she generated power and used questioning dynamics so students had opportunities to explore, negotiate, and construct their understanding of science. This is consistent with what she shared during my interviews with her, "I wanted them to get there with me without me just telling them. Because I knew that wouldn't really internalize it if they didn't think of it kinda on their own." As Mrs. Allen was "digging deep", she employed guided inquiry (BSCS, 2006; National Research Council, 2000) to support students as they constructed their understanding of vertebrates (Tobin & Tippins, 1993; Tudge, 1990; Vygotsky, 1978).

The fourth-grade students used power and questioning dynamics to explore and negotiate their understanding of vertebrates. When they used power in their conversations, they spoke frequently and used Subject Matter to discuss what they knew. Duschl (2006) and Lemke (1990) argued that this was critical for the development of science understanding. In responding to Mrs. Allen's prompts, they were not afraid to share what they knew or disagree with what was being said. Some students offered to answer other students' questions. The students asked fewer questions than Mrs. Allen, but they used questioning strategies to seek Mrs. Allen's help or verify what they were

thinking. Through these social interactions, the students were able to test their understanding and ideas of vertebrates (Bruer, 1994; Erickson & Shultz, 1992; Lemke, 1990; Tobin et al, 1990). Mrs. Allen engaged the students to use power and questioning dynamics to “dig deep” in their understanding (Engle & Conant, 2002).

The student work (Pet Matching, Track Matching, Scat Matching, and Facts about Mammals) collected for the observations of this study only provided a superficial assessment of what students knew. The students completed the matching activity sheets as a group, and the writing assignment, Facts about Mammals, was completed on their own. As the students identified the animal samples, they would write down the name of the animal on the appropriate numbered line. The writing assignments required the students to report information taken from a non-fiction science book about mammals. During the interviews, the teacher shared that she graded these assignments on correct spelling, and the neatness and legibility of their handwriting. The assignments did not allow the students to demonstrate much depth of understanding in science. Because of this, I relied on the presence of Subject Matter power to understand if students understood the characteristics of vertebrates more than the subject assessment data. Through the analysis of classroom discourse, I found that most of the students used Subject Matter correctly throughout their classroom conversations. I cannot draw definitive conclusions about their individual understandings of vertebrates.

Defining Power Dynamics?

As I began this dissertation, I read literature to understand what power and power dynamics “looked like” as the teacher and the students constructed their understanding of science. I relied on the work by Fairclough (1989) and van Dijk (2003) to provide the foundation for my understanding. Below are the definitions I used in this study that shows my perspective on power and power dynamics:

Power: Power is defined as the state of having or exerting control over the actions and thoughts of others (Fairclough, 1989; van Dijk, 2003). Within social interactions, power is determined by the institutional roles, socio-economic status, gender, or ethnicity of the participants. In this study, power is defined by five categories of classroom interactions: Conventional, Group, Individual Voice, Organizational, and Subject Matter (Cochran & Reinsvold, 2010; Gore, 2002)

Power Dynamics: The dynamics of power involves the creation, promotion, facilitation, resistance, and exchange of power in social interactions (van Dijk, 2003).

After evaluating my results, I still accept these original definitions of power and power dynamics. Mrs. Allen followed the district’s instructional materials and policies to teach science to her fourth-grade students. During my interview with her, she recognized her authority in the classroom, “. . . well there’s just some content I really need them to get.”, but she did not feel she had complete control over their actions and thoughts. She shared, “I wanted them to get there with me, without me just telling them. Because I knew that wouldn’t really internalize it if they didn’t think of it kinda on their own.” The quantitative and qualitative data I provided in this study indicate that Mrs. Allen generated power, providing learning opportunities with questioning strategies and use of

subject matter and feedback, so that her students would talk and think through what they knew. She reflected on her interactions with the students:

> . . . . . . we can talk and share and I think they really feel that . . I'm not just up there telling them things. So sometimes, um, I was thinking about that last night, I thought, it's interesting that, um . . if I came up and just said 'this is this' and just basically was teaching them and writing on the board and 'write this down.' I don't think they'd get as involved . . . [Teacher Interview 4, p. 2]

I found that students utilized power and were engaged in the classroom activities with Subject Matter to explain *how* and *why* they knew something and to ask for help in understanding or verifying what they knew. As classroom tasks unfolded in this study, discourse emerged among the teacher and students, as did power dynamics between students and teachers (Fairclough, 1989; van Dijk, 1996).

Implications of Power and Questioning Dynamics on Practice

At the beginning of this chapter, I shared a quote from my last interview with Mrs. Allen. She explained her thinking about the delivery of her lessons and her interactions with the students. She shared that because of my weekly interviews, she became more reflective of how she interacted with her students. As an elementary teacher in her seventh year of teaching, she would rather focus on supporting students to reach a higher-level of thinking than focus on the procedures she needed to complete her lessons. She has become more concerned by helping her students learn rather than teaching. In the interviews, she also shared that she does not have frequent opportunities to talk with others and reflect on her classroom practices.

Practicing teachers like Mrs. Allen need opportunities to talk with peers about their teaching and learning practices (Loucks-Horsley, Love, Stiles, & Mundry, 2003). In relation to the findings of this study, teachers need frequent conversations about how they

engage and provide opportunities for their students to share *how* and *why* they know concepts in science. They need to consider *how* questioning strategies support student engagement. In some school settings, science teachers and administrators form Professional Learning Communities (PLC) (Mundry & Stiles, 2009) to reflect on how to improve student learning. The PLC meets regularly to reflect upon effective use of inquiry instruction, questioning strategies, and use of power that supports student learning. Pre-service teachers also need opportunities to reflect on how their practice influences student understanding (Darling-Hammond & Bransford, 2005).

Pre-service elementary teachers spend their undergraduate education by 1) building their knowledge of how young students learn, 2) exploring methodologies of teaching young students, 3) observing learning activities in elementary classrooms, and 4) practicing teaching in elementary classroom. As these undergraduates complete these experiences, they need opportunities to reflect upon their learning and practice (Darling-Hammond & Bransford, 2005) so they can build their repertoire of strategies that support student understanding. They can't be reflective on their own; they need someone, perhaps their coordinating teacher or their faculty supervisor, to help them interpret what they are encountering and support them as they develop effective use of inquiry instruction, questioning strategies, and use of power to engage students so they have opportunities to share what they know.

Future Research

In this study, I used a method to analyze classroom science discourse to describe the complex interactions, power and questioning dynamics, in one elementary classroom. The method can be used to elucidate the complexity of interactions between students as

they use power and questioning strategies in an inquiry-based setting. Some possible other research questions that have arisen as a result of this research are: How do student leaders of small-groups generate power for others?, How do students of different gender and ethnicities use power and questioning strategies to learn science?, How do students of different ages use power and questioning strategies to learn science?, and How do students and teachers us power and questioning dynamics in understanding subject matter besides science?

The methodology can also be used to understand how power and questioning dynamics occur between teachers and students in lecture and small groups. These instructional settings occur in K-12 and undergraduate classrooms. In this study, I found that the teacher generated power in whole-class and small-group discussions. To better understand these interactions, the following research questions could be investigated: How does the teacher generate power in lecture and small-group education settings across grade levels?, and How is student learning impacted when students and teachers use power in lecture and small-group interactions?

After all my classroom observations, I returned to Mrs. Allen's classroom to meet with her. I sought her feedback on my transcripts and writing. During one of my visits, she shared what she and the students were doing in science. She shared that as students gained more experiences in her science classroom, they were much more engaged in sharing what they knew. She said, "Lori, you should see them now!" This conversation motivates me to explore how power and questioning dynamics among the teacher and students change over a school year, and to consider how the students' understanding of

science changes over this same time. It would also be interesting to trace power use over shorter periods of time and understand how it 'flows' from teacher to student and its relation to questioning during and across classroom sessions.

Limitations of the Study

A few limitations of this study make my conclusions tentative. First, these data include surface and short term indicators of student *learning*. The student assessments completed during the five observations of this study did not provide information on each student's depth of understanding, or their ability to use their knowledge at a later time. Verbal indications of Student Subject Matter power in the discourse show student engagement with science, but more study is necessary to determine the relationships between student learning and use of subject matter in various aspects of classroom activities. Second, the data I collected does not include representations of *student-to-student* discourse dynamics, which also needs to be addressed from the perspective of interactions between power and questioning, particularly with respect to what forms of student-to-student discourse is allowed or encouraged by the teacher. Third, the results of my study reveal power and questioning dynamics in only five continuous sessions for one teacher. I need to investigate other teachers' classrooms and compare these interactions.

Through this study, I have added to the research that describes the social relationships and discourse among teachers and students where opportunities are used to develop science reasoning and understanding (Candela, 2005; Chin, 2007; Erdogan & Campbell, 2008; Herrenkohl & Guerra, 1998; Moje, et al., 2001; Roth & Lucas, 1997; Scott, et al., 2006; van Zee, et al., 2001; van Zee & Minstrell, 1997b). In this study, the

teacher used power, questioning strategies, and guided inquiry to support students to take the responsibility to collaborate in investigations and talk to solve problems (Cornelius & Herrenkohl, 2004; Duschl, et al., 2006; Kelly & Brown, 2003; Lemke, 1990; Roychoudhury & Roth, 1996; Tudge, 1990; Vygotsky, 1978). This research framework for describing classroom interactions holds promise for continued investigations of inquiry processes, student engagement in subject matter content, and resulting improvement in teaching and student learning.

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APPENDIX A

TEACHER INTERVIEWS, DATES, AND TIMES

Teacher Interviews, Dates, and Times

Interview Title	Date	Time
Teacher Interview 1 Structured interview before first observation	September 1, 2010	3:49 p.m.
Teacher Interview 2 Reflected on scientific method, student roles and responsibilities, science leadership team, students with special needs.	September 8, 2010	3:42 p.m.
Teacher Interview 3 Reflected on researcher impact on class, teacher questioning strategy, what engaged students.	September 14, 2010	3:41 p.m.
Teacher Interview 4 Reflected on students’ prior experience with learning science, big ideas from vertebrate lesson, and interactions with small groups.	September 22, 2010	3:44 p.m.
Teacher Interview 5 Reflected on students’ confidence to interact during science lessons, and strategies to include all students into interactions.	September 29, 2010	12:21 p.m.

Teacher Interview 6 Reflected on science activity comparing different life zones, concrete verses abstract thinking, students listening verses thinking, and organization of science notebooks.	October 6, 2010	3:48 p.m.
Teacher Interview 7 Reflected on Shell Shocked Investigation, strategies to help students think deeper about what they are learning, and augmenting science class with demonstrations that allows students to understand concepts.	October 13, 2010	3:55 p.m.
Teacher Interview 8 Reflected on students' overall understanding of vertebrates and life zones, strategies to change students' alternative conceptions, and teacher assistance with using instructional materials.	October 21, 2010	12:20 p.m.

APPENDIX B

QUESTION PROMPTS FOR CLASSROOM OBSERVATIONS

Question Prompts for Classroom Observations

- How does the teacher make content available to students?
- How does the teacher use discourse to cultivate conceptual understanding?
- How does the teacher encourage and manage student questions?
- How do students respond to the teacher's questions?
- How does the teacher develop students' sense-making of content?
- Does the teacher portray science content as a dynamic body of knowledge comprising an interaction of questions, predictions, investigations, evaluations, findings, and conclusions based on evidence? If so, how does this develop?
- What is the nature of student-teacher and student-student interactions as science learning is constructed?
- To what extent are learning activities teacher-centered or student-centered?
- To what extent does the teacher use the 5Es instructional model (engage, explore, explain, elaborate, evaluate) to facilitate scientific inquiry in the classroom?

APPENDIX C

QUESTION PROMPTS FOR INTERVIEWS AND OBSERVATIONS DEVELOPED FROM CLASSROOM OBSERVATIONS

Question Prompts for Interviews and Observations
Developed from Classroom Observations

- How do students use a science notebook?
- What roles and responsibilities do students have?
- How does the teacher use questioning strategies?
- When do students talk?
- How are students assigned to small groups?
- What do the teacher and students talk about when the teacher visits small groups?
- How does the teacher know that students are learning the science concepts?
- How do students explain what they know?
- What differences does the teacher notice in the students’ responses and explanations?
- How is the students’ understanding of vertebrates and life zones shaping?

APPENDIX D

CLASSROOM OBSERVATIONS AND LESSON TOPICS

Classroom Observations and Lesson Topics

Observation	Date		Lesson Topic
Observation 1	9/7/2010		Dr. Crazy Cats Introduces the Scientific Method
Observation 2	9/8/2010		Apply scientific method: Popper Investigation
Observation 3	9/9/2010		Apply scientific method: Popper Investigation
Observation 4	9/10/2010		Apply scientific method: Popper Investigation
Observation 5	9/13/2010		Jigsaw reading activity to learn about vertebrates
Observation 6	9/14/2010		Jigsaw reading activity to learn about vertebrates
Observation 7	9/15/2010		Jigsaw reading activity to learn about vertebrates
Observation 8	9/16/2010		Jigsaw reading activity to learn about vertebrates
Observation 9	9/20/2010		Review vertebrate features and introduction to stations
Observation 10	9/21/2010		Vertebrate stations and study a turtle
Observation 11	9/22/2010		Investigate turtles
Observation 12	9/23/2010		Investigating animal pelts
Observation 13	9/24/2010		Investigating animal tracks
Observation 14	9/27/2010		Investigating animal scats
Observation 15	9/28/2010		Continuation of Investigating Animal Scat: What do animals eat?
Observation 16	9/29/2010		Continuation of Investigating Animal Scat
Observation 17	10/1/2010		Current events: read from local newspaper about planets & bears
Observation 18	10/4/2010		Play Vertebrate Jeopardy
Observation 19	10/6/2010		Introduction to Colorado Plains
Observation 20	10/7/2010		Investigate Colorado Plains
Observation 21	10/8/2010		View video about Colorado animals and life zones, and investigate animal skulls
Observation 22	10/11/2010		Investigation: Shell Shocked (What material could serve as a turtle's shell?)
Observation 23	10/12/2010		Investigation: Shell Shocked (What material could serve as a turtle's shell?)
Observation 24	10/13/2010		Investigation: Shell Shocked (What material could serve as a turtle's shell?)
Observation 25	10/14/2010		Field trip to local nature center
Observation 26	10/18/2010		Discussion about what was seen and learned at the nature center; Introduction to energy pyramid
Observation 27	10/19/2010		Introduction to food chains and webs; Slide-show of characteristics of Colorado Prairies
Observation 28	10/20/2010		Perch (fish) dissection

APPENDIX E

IRB CONSENT AND ASSENT LETTERS, AND APPROVAL

Teacher

Informed Consent for Participation in Research

University of Northern Colorado

Project Title: Understanding teacher-student discourse in an elementary science classroom

Researcher: Lori Reinsvold, Doctoral Student, School of Psychological Sciences, UNC, ph: 970-351-1280; Dr. Kathy Cochran, School of Psychological Sciences, ph.970-351-1681.

We are interested in understanding how fourth-grade elementary students and their teacher use discussions or discourse to build science knowledge in an inquiry-based classroom. The purpose of this qualitative study is to use discourse analysis to identify and describe elementary science classroom episodes and interactions where teachers and students are provided the opportunities to ask questions and discuss what they know about science. This study will be used for Lori Reinsvold's doctoral dissertation, and the data will be presented at meetings and through publications.

We would like to observe the science lessons in one science unit and note the interactions that occur between you and your students during the Fall 2010 semester. Specifically we would like to (a) use an audio-recorder and interview you prior to your delivery of the first science lesson to learn about your background and the students, (b) to learn the goal and objectives of the lessons, (c) to observe and audio- and video- record classroom interactions during the lessons, (d) use an audio-recorder to interview you after completing each science lesson to learn your interpretation of what occurred, and (e) to review the student work that you collect for each lesson. The first interview will last about forty-minutes, and the interviews after each lesson will last about thirty minutes. We do not want to interrupt your instructional time, so we can decide what times are best for the interviews.

When transcribing the conversations, you and your students' names will be changed to pseudonyms. Your identities will be protected during the study and any publications. All tapes and transcripts will be kept private and locked in Lori Reinsvold's office. After transcription is completed the tapes will be destroyed.

Participation is voluntary. You may decide not to participate in this study and if you begin participation, you may still decide to stop and withdraw at any time. Your decision will be respected. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. A copy of this form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

Thank you!

_________________________ _____________________________ ___________

Participant's Name, printed Participant's signature Date

_____________________________ ____________

Researcher's signature Date

Parent

Informed Consent for Student Participation in Research

University of Northern Colorado

Project Title: Understanding teacher-student discourse in an elementary science classroom

Researcher: Lori Reinsvold, Doctoral Student, School of Psychological Sciences, UNC, ph: 970-351-1280; Dr. Kathy Cochran, School of Psychological Sciences, ph.970-351-1681.

We are interested in understanding how your student, other students, and Ms. Allen share what they know or want to know about science during Ms. Allen's science class. The purpose of this study is to observe the science classroom conversations, and identify and describe science classroom interactions between teachers and students. We would like to understand and describe the opportunities students have to ask questions and discuss what they know about science. This study will be used for Lori Reinsvold's doctoral research, and presented at meetings and through publications. In the future, the study's findings may be used to support elementary teachers teach science so all students learn.

As described in the information letter about the research we would like to do in Ms. Allen Science classroom; we would like your permission to 1) observe your student for ten to twenty science lessons, 2) audio- and video-record the student conversations and science activities for ten to twenty lessons, and 3) review your student's written work that Ms. Allen collects for these science lessons. This research will take place from September 2, 2010 to November 9, 2010. As we transcribe these conversations, we will use pseudonyms for student names when a student talks, or if a student name is used by the teacher or another student. All tapes will be secured in a locked cabinet in Lori Reinsvold's office (Ross Hall 2279D). Once all tapes are transcribed, the audio- and video-tapes will be destroyed. The real names of students and the teacher will not appear in any professional reports of this research. We foresee no risks to your student beyond those that are normally encountered when your child learns science in an elementary classroom. This study is designed not to impact the science lessons your child learns during the day at school.

Participation is voluntary. You may decide not to allow your child to participate in this study and if (s)he begins participation you may still decide to stop and withdraw your child at any time. Your decision will be respected. Having read the above and having had an opportunity to ask any questions, **please sign below if you want your child to participate in this research and return a copy to your student's science teacher classroom**. You may keep the second copy of this form for future reference. Following your consent your child will have an opportunity to provide consent too.

If you have any concerns about your child's selection or treatment as a research participant, please contact the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639; 970-351-2161.

Many thanks for your time and attention.

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Child's Full Name (please print)

__________________________________ ____________________

Parent/Guardian's Signature Date

__________________________________ ____________________

Researcher's Signature Date

**CONSENTIMIENTO INFORMADO PARA PARTICIPAR EN UNA INVESTIGACIÓN
UNIVERSIDAD DEL NORTE DE COLORADO**

Título del Proyecto: Entendiendo la conversación entre maestro(a) y estudiante en el salón de clase de ciencias en una escuela primaria.

Investigadora: Lori Reinsvold, estudiante de doctorado, escuela de Ciencias Sicológicas UNC, teléfono: 970-351-1280. Doctora Kathryn Cochran, consejera de doctorado, escuela de Ciencias Sicológicas UNC, teléfono: 970-351-1681.

Estamos interesadas en entender como su estudiante, otros estudiantes, y la maestra Allen comparten lo que saben acerca de la materia de ciencias, durante la clase de ciencias de la maestra Allen. El propósito de este estudio es observar las conversaciones en la clase de ciencias e identificar y distinguir las interacciones en la clase de ciencias entre maestros y estudiantes. Nos gustaría entender y describir las oportunidades que los estudiantes tienen para hacer las preguntas y tener discusiones sobre lo que saben acerca de las ciencias.

Como está explicado en la carta de información acerca de la investigación que queremos hacer en la clase de la maestra Allen, le pedimos su permiso para: 1) observar su estudiante por un periodo de diez a veinte lecciones, 2) grabar las conversaciones de su estudiante en voz y video y las actividades de la clase de ciencias durante diez a veinte lecciones, y 3) revisar el trabajo escrito de su hijo/hija que la maestra Allen de estas lecciones de ciencias. Esta investigación tomará lugar de septiembre 2, 2010 a 9 noviembre 9, 2010. A medida que copiamos exactamente las conversaciones usaremos nombres ficticios (inventados) para los nombres de los estudiantes cuando un estudiante habla o si hay nombres usados por la maestra u otro estudiante. Todas las grabaciones se guardarán en un lugar privado y con llave en la oficina de Lori Reinsvold (Ross Hall 2279D). Después de que las grabaciones de voz y video han sido copiadas, los videos serán destruidos. Los nombres reales de los estudiantes y la maestra no aparecerán en ningún reporte profesional de esta investigación. No vemos de antemano ningún riesgo para su estudiante fuera de los riesgos normales que todos los estudiantes encuentran cuando aprenden ciencias en un salón de clase en la escuela primaria. Este estudio no está diseñado para impactar (cambiar) las lecciones de ciencias que su estudiante aprende durante el día en la escuela.

La participación es voluntaria. Usted puede decidir el no permitir que su estudiante participe en este estudio y si el (ella) comienza la participación puede decidir sacar a su estudiante a cualquier momento. Su decisión será respetada. Después de leer lo anterior y después de haber tenido oportunidad de hacer preguntas, por favor firme debajo si quiere que su estudiante participe en esta investigación y devuelva una copia al salón del maestro/la maestra de ciencias de su estudiante. Una copia de esta forma se le dará a usted para que la use como referencia en el futuro. Si tiene alguna pregunta o preocupación acerca de la selección de su hijo/hija como participante en esta investigación, por favor póngase en contacto con la Oficina de Programas Patrocinados (Sponsored Programs), Kepner Hall, Universidad del Norte de Colorado Greeley, CO 80639, 970-351-2161

____
Nombre completo del estudiante (use letra en imprenta)

____ ________________________
Firma del padre o guardián Fecha

__________________________________ __________________________
Firma del (la) investigador(a) Fecha

ASSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH

UNIVERSITY OF NORTHERN COLORADO

Hi!

My name is Lori Reinsvold and I'm a student at the University of Northern Colorado. I do research on teaching and learning science. That means I study the way teachers and students talk about science to learn science. I would like watch and listen to fourth-graders as they learn science with their teacher. I would like you to be one of the students I watch.

If you want me to watch and listen to you, I will sit in the back of the classroom as you, your friends and teacher learn science. The teacher will wear a tape recorder to record the conversations for each lesson I watch. I will place a video camera in the back of the room to record all the activities of the science lesson. I will visit your science classroom about 8 times to watch and listen to you, your friends and teacher talk and learn science. Your name will not be used in the information I collect,

I would also like to see your written work for the science lessons. I will not use your name when I take information from your written work. If it is okay with you, Ms. Allen will give me your written work. When I am done reading your work, I will give it back to her.

I hope that my research will help your teacher find good ways of teaching science. Your parents have said it's okay for me to watch, listen and read your written work, but you don't have to. It's up to you. Also, if you say "yes" but then change your mind, I can stop watching and listening to you.

Do you have any questions for me about my research?

If you want to be in my research and allow me to watch, listen, and read your written work as you learn science, sign your name below and write today's date next to it. Thanks!

Student Date

Researcher Date

STUDENT'S COPY

UNIVERSITY of NORTHERN COLORADO
Institutional Review Board (IRB)

June 22, 2010

TO: Heather Helm
School of Applied Psychology & Counselor Education

FROM: Megan Babkes Stellino, Co-Chair
UNC Institutional Review Board

RE: Expedited Review of Proposal, *Understanding Teacher-student Discourse in an Elementary Science Classroom,* submitted by Lori Reinsvold (Research Advisor: Kathryn Cochran)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Megan Babkes Stellino, School of Sport and Exercise Science, Campus Box 39, (x1809). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as is. Heather Helm 8.4.10
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as proposed for a period of one year: August 19, 2010 to August 19, 2011

Megan B Stellino 8/19/2010
Megan Babkes Stellino, Co-Chair Date

Comments:
need to revise info letters & consent forms.

APPENDIX F

COMPARISON OF STUDENT AND TEACHER UTTERANCES ACROSS THE SIX PARTICIPATION ROLES

Comparison of Student and Teacher Utterances Across the Six Participation Roles

	Initiation Freq. (%)		Response 1 Freq. (%)		Prompt Freq. (%)		Response 2 Freq. (%)		Feedback Freq. (%)		Response 3 Freq. (%)	
Observations	S	T	S	T	S	T	S	T	S	T	S	T
12	23 (28)	33 (28)	32 (31)	4 (14)	82 (48)	224 (24)	285 (25)	6 (14)	5 (8)	140 (24)	17 (46)	0 (0)
13	21 (25)	27 (23)	28 (27)	12 (41)	28 (16)	222 (24)	289 (25)	11 (24)	21 (36)	119 (20)	4 (11)	0 (0)
14	5 (6)	19 (17)	19 (19)	1 (3)	0 (0)	108 (15)	172 (15)	2 (4)	2 (3)	76 (13)	0 (0)	0 (0)
15	16 (19)	17 (15)	11 (11)	8 (28)	36 (21)	198 (21)	231 (20)	14 (30)	11 (19)	140 (24)	14 (38)	0 (0)
16	18 (22)	19 (17)	12 (12)	4 (14)	25 (15)	178 (19)	177 (15)	13 (28)	20 (34)	117 (19)	2 (5)	1 (100)
Total	83 (100)	115 (100)	102 (100)	29 (100)	171 (100)	930 (100)	1154 (100)	46 (100)	59 (100)	592 (100)	37 (100)	1 (100)

APPENDIX G

DISTRIBUTION OF POWER CATEGORIES ACROSS OBSERVATIONS

Distribution of Frequencies of Power Categories Across Observations

Obs.	Power									
	SCON	TCON	SGR	TGR	S/IV	TIV	SOR	TOR	SSM	TSM
12	18 (15%)	160 (23%)	37 (19%)	89 (24%)	479 (26%)	91 (22%)	63 (26%)	184 (21%)	224 (27%)	176 (20%)
13	53 (45%)	147 (21%)	68 (34%)	101 (27%)	456 (25%)	102 (23%)	59 (25%)	194 (22%)	218 (26%)	222 (25%)
14	17 (15%)	99 (14%)	33 (17%)	46 (12%)	210 (12%)	47 (16%)	20 (9%)	119 (13%)	140 (17%)	146 (17%)
15	6 (5%)	157 (23%)	31 (15%)	55 (15%)	373 (21%)	89 (21%)	55 (24%)	205 (23%)	136 (16%)	168 (20%)
16	24 (20%)	131 (19%)	30 (15%)	87 (22%)	291 (16%)	79 (18%)	37 (16%)	184 (21%)	114 (14%)	159 (18%)
Total	118	694	199	378	1809	408	234	886	832	871

Note: S/IV is total frequencies of Student Individual Voice, Student Student Individual Voice, and Teacher Student Individual Voice.

APPENDIX H

COMPARISON OF STUDENT ACADEMIC SCORES AND PERFORMANCE IN SCIENCE

Comparison of Student Academic Scores and Performance in Science

Name	**Gender**	**Ethnicity/ Race**	**Pelt ID (4)**	**Track ID (4)**	**Scat ID (4)**	**Facts about Mammals (4)**	**Overall Grade as percent of 82 total points**	**Science Notebook- All assignments present and in order**
Ellie	F	EA	4	4	4	4	98.8	x
Sam	M	As	4	4	4	4	97.6	
Trisha	F	EA	4	4	4	4	97.6	x
Jose	M	L	4	4	4	4	96.3	
Jane	F	EA	4	4	4	4	93.9	x
Carlos	M	L	4	4	4	4	93.9	x
Lisa	F	EA	No Grade	4	4	4	92.7	x
Julie	F	EA	4	4	4	4	86.6	x
Chris	M	EA	4	4	4	4	85.4	x
Manuel	M	L	4	4	4	Check mark	84.1	
Maria	F	L	4	4	4	4	82.9	
Ian	M	EA	4	3	3	4	81.7	
Mike	M	EA	4	4	4	2	79.3	x
Tom	M	EA	Absent	Absent	4	4	79.3	
Ned	M	EA	4	4	Missing	4	75.6	
Luis	M	L	4	4	4	2	69.5	
Ricardo	M	L	Missing	Missing	No Grade	No Grade	47.6	

Note: Ethnicity/Race: EA = European American, L = Latino, As = Asian

APPENDIX I

EXAMPLE OF AN ACTIVITY SHEET USED FOR THE LESSONS OF THIS STUDY

Example of an Activity Sheet Used for the Lessons of this Study

Pelt Matching

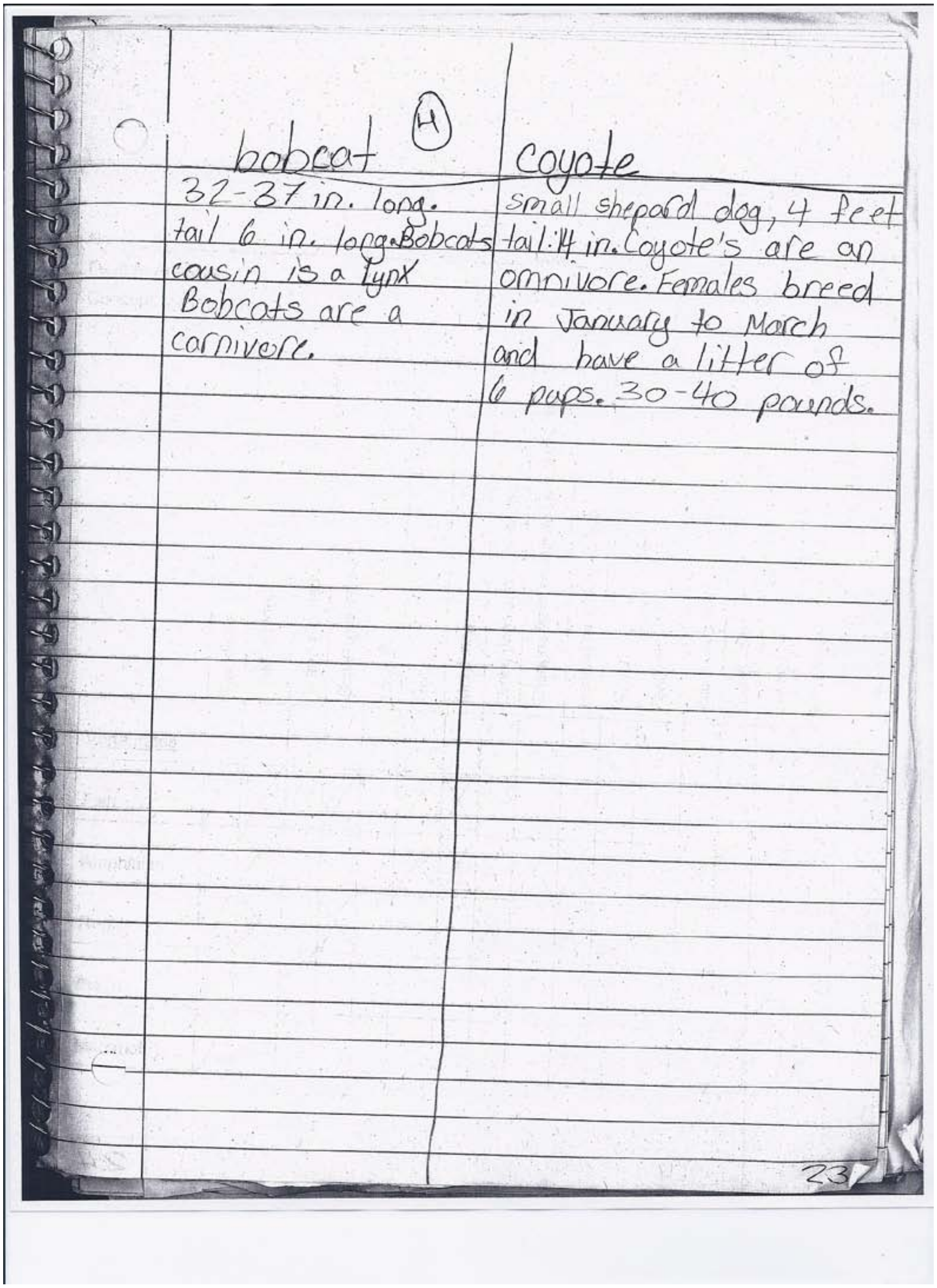
Name: ________________________________

1.__________________________	<u>Word Bank</u>
2.__________________________	badger
3.__________________________	beaver
4.__________________________	big horn sheep
5.__________________________	black bear
6.__________________________	coon
7.__________________________	cottontail rabbit
8.__________________________	elk
9.__________________________	ermine (short tailed weasel)
10.__________________________	long tailed weasel
11.__________________________	moose
12.__________________________	mule deer
13.__________________________	opossum
14.__________________________	porcupine
15.__________________________	pronghorn
16.__________________________	red fox
17.__________________________	striped skunk
	white tailed deer

APPENDIX J

EXAMPLE OF STUDENT WORK: SCIENCE NOTEBOOK ENTRY ABOUT FACTS OF A BOBCAT AND COYOTE

Example of Student Work: Science Notebook Entry about Facts of a Bobcat and Coyote



(H)

bobcat	coyote
32-37 in. long. tail 6 in. long. Bobcats cousin is a lynx Bobcats are a carnivore.	small shepard dog, 4 feet tail: 14 in. Coyote's are an omnivore. Females breed in January to March and have a litter of 6 pups. 30-40 pounds.

23