TEACHING LONG-TERM SCIENCE INVESTIGATIONS:
A MATTER OF TALK, TEXT, AND TIME

By

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ABSTRACT

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Science educators regard long-term investigations as one impactful form of teaching science through inquiry in K-12 classrooms. While we have idealized notions of what this work looks like, we have few, if any, descriptive studies about investigations that engage students in sustained, focused work over a period of time longer than a few days or even weeks. In a policy context that calls for teachers to develop strategies for engaging students in authentic science practices, such as those that can come from long-term science investigations, we would do well to learn from experienced teachers. This study followed three middle school science teachers in a large U. S. urban school district as they conducted long-term investigations. Using discourse analysis and taking a sociocultural perspective, this study documented the classroom talk and interaction of teachers and their students. The study's goals were to describe how teachers engage students in long-term investigations and the ways that classroom interaction involved specific reform-based science practices. Data include field notes and transcripts of audio recordings from 15 observations of three experienced middle school science teachers, three semi-structured interviews with each teacher, curriculum materials, student work, and classroom demographic data.

Teachers engaged students in whole group, small group, and one-on-one conversations about several stages of the long-term investigations. Teachers most often discussed two of the eight science practices: 1) planning and carrying out investigations; and 2) obtaining, evaluating, and communicating information. The planning discussions involved conversations about

identifying and describing variables, measuring and recording data, and concerns about data collection procedures. Conversations about using and communicating scientific information included talk about formal science writing conventions, and using background information to support all other parts of the investigation process.

In all of the observed lessons, regardless of the practice or types of investigations students were to engage, teachers used curricular tools to support students' work, scaffolding students' introduction to and use of scientific content, practices, and discourse. In these ways, teachers helped students master a science-specific vocabulary and set of practices that allow for the authentic exploration of science concepts. This study describes how teachers who generate opportunities for students to experience two science practices more often than others, which may have implications for science education and science education research - especially concerning how science practices are engaged in classrooms - moving forward.

for my father

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This project would not have been possible without the teachers who opened their classrooms to me for five months. They graciously wore a microphone during their teaching, a scary prospect for any teacher. They were generous and flexible with their time, talked with me as colleagues even after data collection was over, and cheered me on as I reached new benchmarks in the work. And most importantly, they welcomed me, a total stranger, into their teaching space. I learned much from their creativity, confidence in their teaching, love of science, belief in their students, and comfort with the ambiguities of the process - their own, as well as mine.

My loving friends are who sustained me in this work. I moved my home twice during the writing of this dissertation. I have met new people and developed a new life twice in the past two years. And through all of that, it is the people who I respect and love and who respect and love me in return who kept this process humane, and celebrated with and for me even the smallest of victories.

For three years, Bill and Leslie Hart-Davidson, and daughter, Lily, literally opened their home to me. My life "on the compound" is singularly responsible for my getting to the dissertation stage. They fed me, made me laugh, and made sure I got enough wine and bike time. Around their kitchen table, Bill counseled me during all stages of graduate school. Leslie kept me laughing, and hugged me when I needed it. They celebrated with me on the day of my defense. All of "the HDs" reminded me that life is good - even when it felt very much like it wasn't - and taught me about giving in ways I have never known.

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Constance Winter, the author of a blog "Lovely Bicycle," said, "There are some people who help you and you feel grateful, indebted, and then there are others who help you and you don't even know it. Those people have achieved a state of grace." This line personifies my dissertation director, mentor, and friend, Suzanne Wilson. She helped me in ways I have very much noticed, and she helped me in ways that I am sure I have yet to discover. Her infinite gifts, wisdom and generosity of her heart seep into each day in surprising ways. Her talents have impacted my thinking and my writing, in how I read, in how I see myself as a teacher, in how I think about and understand people. With you on my shoulder, I trust the process more, I trust myself more, and I know I will produce good things. "Grateful" and "indebted" do not adequately describe my appreciation of your impact. You are grace in my life.

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Finally, this is for my father, who passed away in my second year of graduate school. His pride beamed through his pained and tired eyes even in his last days. I know he's here in spirit, laughing, and delighting in saying "Dr. Bills" (a play on words he was eager to say). Thanks, Dad, for raising me to believe that no matter what, I would always "land on my feet."

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KEY TO SYMBOLS

Transcription Notation

(Jefferson, 1978, Schegloff, 2007)

Note: punctuation marks are not used grammatically. They indicate intonation. A period therefore, indicates a falling intonation contour, not necessarily the end of a sentence. A question mark does the same thing. A comma indicates a pause (or "clause boundary" Schegloff, 2007).

.. two periods indicate a pause shorter than 2 seconds.

... three periods indicate a pause that lasts approximately 2 seconds. longer pauses are indictated by time inside of brackets, as in, [10 seconds].

(( )) double parentheses mark the transcriber's description of the events.

( ) text between parentheses indicate the transcriber's most likely guess as to what is being said.

CAP words or parts of words in all capital letters indicate extra emphasis, not volume

:: double colons after a vowel indicate elongation of the vowel sound. For example, "goo::d" in transcription stands in for "gooooooood" in speech.

= equals signs have two functions: 1) to indicate the continuous talk of one speaker, even if interrupted by another speaker, or 2) if located at the end and begining of two different speakers' continuous lines, this indicates "latching" or that the second speaker continues, or latches onto, the first speaker's utterance.

In some cases, pronunciation is indicated by spelling as in "gonna" for "going to" or "wanna" for "want to." This is done to indicate the correct level of formality of a person's speech, and to differentiate from moments when articulation of each word in a lexical bundle (i.e., going to) are pronounced fully.

Chapter 1

The Landscape of Talk in Long-Term Investigations

Current concerns for improving science education for all students emphasize the need for student active engagement in science and the need for an inquiry orientation. According to the *National Standards for Science Education,* inquiry is:

> A multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations and predictions; and communicating the results. (NRC, 1996, p. 23)

As researchers, reformers, and teachers have sought to put these ideas into practice, it has become increasingly clear how difficult it is to move science education away from the didactic and toward the active. In part, this is due to inquiry being defined in many different ways. In an effort to move forward, the *Next Generation Science Standards* (Achieve, Inc., 2013) shifted the discourse away from "inquiry" toward "practices," specific actions that are observable like developing and using models or analyzing and interpreting data.

While this focus on the concrete might help, the rhetoric of reforms like NGSS still hold considerable challenges for the teachers who are responsible for turning these visions into realities for U.S. schoolchildren. Shifting to a stance of active engagement for children requires more interactions between teachers and students, and students and students. This amounts to a cultural revolution in classrooms, and entails much more science talk in whole and small groups, as well as one on one. In particular, students need to learn to use the highly specialized language of science (Lemke, 1990).

This is a difficult challenge for most students, even for some who come to school having mastered the more formal forms of school language. However, for those who speak non-dominant forms of language, learning to "talk science" (Lemke, 1990, p. 1) means bridging an even wider divide between everyday language and the language of science. The purpose of this study is to describe how three teachers engage students interactionally in science classrooms, the nature of those interactions, and the specific discourse skills teachers work on with students across cultural and linguistic boundaries.

Specifically, I explore the role of language (specifically, talk and writing) in long-term investigations (LTIs), structured projects that take place over several weeks (or more) and involve inquiry-based practices. While LTIs are not the only form of inquiry-oriented learning that teachers and students engage in in U.S. science classrooms, they offer a relevant context for exploring talk and how it unfolds when teachers are aiming to engage their students in inquiry. Two questions guide my inquiry:

How do experienced teachers enact long-term investigations?

What is the role of language in the long-term investigation?

Long-Term Investigations and Discourse

This study builds on two bodies of research: 1) research on long-term investigations and scientific inquiry, and 2) research on discourse in science classrooms. Though I separate them in this review, these are not mutually exclusive bodies of research. Many studies on long-term investigations involve studies of language and discourse, and reflexively, studies of language and discourse in classrooms have been conducted in inquiry-based science classrooms where teachers enacted long-term investigations. I provide a review of literature on long-term investigations, followed by research on discourse and talk in science classrooms.

Research on Long-Term Investigations

Research on LTIs highlights the complexity with inquiry-based teaching. First, the definition of and research on inquiry is diffuse, which makes it difficult to identify the field's research goals and visions for classroom practice (Minner & Levy, 2010). While inquiry-based teaching can include several different strategies, there are few, if any, detailed descriptions of how teachers enact sustained inquiry projects, or long-term investigations. That is, the field lacks a detailed portrait of experienced teachers' engagement of long-term inquiry projects (investigations) that I provide in this study.

I begin with an exemplar of research on one model of an LTI, Project Based Science (PBS). Project-based science is defined as sustained scientific inquiry situated in real problems for which students seek answers to their authentic questions using multiple tools and strategies alongside peers and their teachers. For example, students might explore a “driving question” such as, “What’s in our water?” and spend extended time – weeks, perhaps even months or the entire school year – collaboratively researching the answer by exploring a local river and watershed (Ladewski, Krajcik, & Harvey, 1994; Marx, et al., 1994). In fact, PBS research represents the closest example of the kind of curriculum I observed teachers using in this study. In fact, one teacher, Diana, used the Project Based Inquiry Science (PBIS) program materials (Kolodner, Krajcik, Edelson, Reiser, & Starr, 2009) (see chapter 3 for a fuller description of Diana's curriculum materials). Because this dissertation primarily concerns teacher practice, I then present additional studies that illuminate other salient aspects of inquiry-based science, such as the debate about explicit and implicit approaches to teaching science inquiry practices (NRC, 1996, 2011), and teachers' roles in teaching inquiry-based science.

In their foundational work on project based science, Krajcik and colleagues (Krajcik &

Blumenfeld, 2006; Krajcik, Blumenfeld, Marx, Bass & Fredericks, 1998; Krajcik, Czerniak, & Berger, 1999) report on students' engagement in PBS units. A typical PBS unit - such as the "What's in Our Water?" (Ladewski, Krajcik, & Harvey, 1994) or "Why Do I Have to Wear a Bike Helmet?" (Schneider, Krajcik, & Blumenfeld, 2004) units - involves students in several different kinds of experiences wherein they work collaboratively to answer the guiding question. In "What's in Our Water?" students study a local river, collect data, conduct background research, and communicate with local community members who can provide assistance with the project. Students work in small groups throughout the project, and in regular classroom discussion opportunities, they practice reasoning and argumentation skills as they report findings to other groups, and make decisions about proceding to the next part of the project -- gathering more information to support or refute claims, to test accuracy of data collection, to redesign the study, or further test a particular conjecture, etc.

Researchers have pursued a number of questions concerning PBS, including questions about teacher enactment of PBS curriculum materials (Marx, et a.l, 1994), motivational factors for engaging in project-based work (Blumenfeld, et al., 1991), teacher learning (Ladewski, Krajcik, & Harvey, 1994), student learning (Krajcik, et al., 1998), as well as the affordances and constraints of PBS curriculum materials on teacher enactment of classroom discussions (Alozie, Moje, & Krajcik, 2009). Most of this work comprises implementation studies conducted with teachers who have a range of years of experience and knowledge of inquiry-based teaching. The research follows a research and development tradition, using design studies, which were typically conducted over the course of a school year. The major interest of these researchers are the influences of teacher knowledge and practice on the extent to which they have success implementing PBS in their classrooms as the researchers intended. The researchers -- who are also the curriculum developers in most cases -- then use findings to revise curriculum materials and to provide ongoing professional development support for the teachers using PBS materials. This body of research is relevant to this study because it provides a comprehensive view of teachers' and students' practices during sustained long-term classroom science inquiry.

Blumenfeld, et al. (1991) reported that project design was an influential factor in the success of project-based learning. They argue that "student interest and perceived value are enhanced when, 1) tasks are varied and include novel elements, 2) the problem is authentic and has value, 3) the problem is challenging, 4) there is closure, an artifact is created, 5) there is choice about how the work is done, and 6) there are opportunities to work with others" (p. 375).

Teachers using PBS for the first time face many challenges to their own knowledge and learning about inquiry based teaching. PBS research suggests that teachers' roles involve, "1) creating a classroom community that is conducive to collaborative work, 2) scaffold student learning and help students create manageable tasks, 3) support students' metacognitive development, and 4) assess progress and provide feedback" (Blumenfeld, et al., 1991, p. 381). Additionally, successful enactment of PBS requires teachers to be especially skilled at management of classroom behaviors and tools, as well as able to deal with the ambiguity of the work and be able to adjust accordingly. In short, "teachers play a critical role" (Blumenfeld, et al., p. 381).

Marx et al. (1999) discuss several challenges that teachers face when learning to conduct PBS projects. These challenges reflect those reported in studies on other inquiry based teaching strategies more generally (Crawford, 2000, 2007; DeLisi, McNeil, Minner, 2011; Minner, Levy, & Century, 2010). In a case study of four middle grades teachers, Marx and his colleagues found that developing an appropriate research question– one that is authentic, and generates motivation to study a topic relevant to students' lives over a long period of time – is challenging, especially in a science reform context. Also, teachers felt that releasing some of the responsibility for the direction of a project was a concern – that is, it was sometimes impossible to balance curricular and standards requirements while supporting the natural directions that students' own authentic questions take. Time was also an issue, as the development of a project takes several weeks, which can lead to marginalizing other curricular content. The researchers also noe that ongoing formal professional development or participation in a community of learners is essential for teacher support.

Some common challenges in implementing PBS teaching entail time, behavior management, covering the content, teachers' abilities to embrace project goals, and understanding the tools (especially technological ones). For example, Moje, Collazo, Carillo, and Marx (2001) studied the enactment of a long-term project with a high school life sciences teacher in a Spanish immersion classroom in Detroit. They found that the local school district policies and teachers' stance about constructivist teaching presented considerable challenges for PBS implementation. For example, the researchers found that "competing d/Discourses" in the classroom impacted the ways that the teacher implemented PBS. For example, the teacher was unfamiliar with some of the pedagogical strategies in projects, such as coordinating student-lead investigations based in their own questions. The process of incorporating new strategies was difficult for this teacher, and helped to contribute to competing discourses. The researchers state,

> ... project-based pedagogy with its emphasis on authenticity, sustained inquiry, and collaboration introduces a classroom Discourse that may be unfamiliar or even contradictory to the Discourses to which students have become accustomed or which students believe will afford them opportunities for future success in the ``culture of

power" (Delpit, 1988, p. 122).

That is, in this classroom, a largely Latino, Spanish-speaking classroom in a large urban school district presented considerable challenges for both the teacher and his students to bridge these discourses, that of school, of the teacher's own ideas about teaching science, and the students' ideas about language and culture in the midst of learning academic language.

Research on PBS has also illuminated importance of students' appropriation of science discourse – central to the PBS vision for high quality teaching and learning -- is paramount to their learning. In a more recent study, Alozie, Moje, and Krajcik (2009) explored how the PBS curriculum materials supported teachers' efforts to develop dialogic interaction between teachers and students. Using a mixed methods approach, and based on data from classroom observations, teacher interviews, and pre- post- student achievement scores along with extensive discourse analysis of observation data, the researchers were interested in whether the curriculum supports they created would enable dialogic discussion.

The researchers found that the curriculum supports -- lesson discussion rationales and enactment strategies -- did not support teachers' development of dialogic interactions as expected. Teachers still struggled to limit their central roles in conversations and sustain student interactions; their interactions still largely followed the IRE format. The researchers concluded that their materials would need to be revised to include a rationale for the discussion, higher-level questions that simulate discussion, strategies for teaching students to engage in dialogic discussions, and strategies for helping the teacher to guide discussions. This work echoes the common refrain in the research literature on inquiry-based teaching, that it is difficult to enact and to affect change in teaching practice (Minner, Levy, & Century, 2010).

Another prevalent question in the literature on inquiry-based teaching is the relative of effectiveness of using explicit or implicit approaches to teach science practices. Some teachers keenly feel a tension between of constrained instructional time and mandates to cover the curriculum with creating sustained attention to science practices and processes (NRC, 2012). Fradd and Lee (1998) investigated different teachers' personal positions in regard to inquiry by examining their roles during instruction. The authors position their study in the long-standing debate about how to balance science instruction between approaches that are "*explicit*, with teachers leading students through predetermined lessons and activities, or *exploratory*, with teachers guiding children to consider their own questions and interests" (p. 15, italics in original).

Similar to the PBS work, Fradd and Lee conducted professional development programs with teachers who shared languages and cultures with their students, who were either mono-lingual or bilingual Spanish or Haitian Creole speakers. They found that teachers enacted instructional stances that the researchers labeled as "teacher-as-transmitter" or "teacher-as-facilitator." They found that transmitters embraced an explicit approach (i.e., direct instruction) to teaching, and facilitators embraced strategies more aligned with inquiry-based strategies as discussed in the NSES (author?, 1996). Moroever, teachers tended to choose the roles that felt the most comfortable to them, based on a number of factors – some cultural, some pedagogical, some contextual – and many steadfastly believed that "the explicit approach was essential until students acquired the basic concepts and skills for engaging in science inquiry" (p. 19).

Researchers are also concerned with how inquiry-based teaching impacts student learning. Though the research on the achievement gains is relatively sparse, I elected one recent study to present here because it explores how teacher discourse moves as well as more macro-level activities – both concerns of this dissertation – play a role in inquiry-based teaching and learning. DeLisi, McNeill, and Minner (2011) conducted case studies of three high school science teachers as they taught an urban ecology curriculum for which they received professional development. One goal of the research was to provide microanalyses of the nature of teachers' verbal practices and the types of activities teachers use" in inquiry based teaching (p. 1). The researchers video recorded classroom observations and analyzed the recordings according to teachers' behaviors, which included larger activities (e.g., whole group v. small group configurations, or writing v. reading) as well as smaller, micro- "verbal practices" such as rephrasing, eliciting student responses, asking a fact-based question, or giving a scientific explanation, among several others. The research team also developed and conducted a pre- post-assessment on student knowledge that covered materials from three modules in the curriculum, and included a combination of open-ended and multiple choice questions. They found that one teacher taught primarily with teacher-directed activities as opposed to student-directed activities; while the other two teachers balanced these two activity types. All three teachers spent more time on instruction (e.g., directed teaching), writing, and reading. And in all three teachers' classrooms, students spent more time in whole class instruction than in smaller groups or working as individuals.

Two of the three case study teachers taught with the greatest proportion of student-centered practices and had the highest student outcomes. The teacher who used more teacher-directed activities had lower student achievement. As the authors state, "These findings align with previous research which suggests that inquiry-based instruction that emphasizes student active thinking results in greater student science conceptual learning."

Researchers define teachers' roles in inquiry-based classrooms in general, and in long-term investigations in particular, as to design meaningful, student-centered investigation experiences for students that engage active thinking and sensemaking around various texts in collaboration with others. But teachers are challenged with balancing their responsibilities toward achievement based in state and national standards with the time required to develop student-centered and meaningful long-term science investigation experiences. Teachers still grapple with the demands of process skills to make meaningful content connections during inquiry based instruction, which means that they also must ask their students to produce artifacts of their knowledge that can be evaluated based on state standards (Alozie, Moje, & Krajcik, 2009; Schneider & Krajcik, 2002). However, oftentimes, the artifacts of inquiry-based work demand more time and resources than available to teachers -- whether in project-based work, or through other sustained inquiry experiences.

In general, there is still much that we do not know about how experienced teachers conduct LTIs. In particular, we lack careful descriptions of what it takes for teachers to enact long-term investigations. And central to those investigations is engaging students in classroom conversations, either as a whole group or in smaller grouping. I now turn to the literature on discourse in science classrooms, as it bears directly on understanding teachers' practices when helping their students pursue LTIs.

Discourse in Science Classrooms

The literature on discourse in science classrooms is similarly broad. Much of this research was in response to the NRC (1996) call for inquiry based teaching in K-12 classrooms, which emphasized constructivist-based learning and greater attention to developing teachers' skills in conducting productive discourse with students (Driver, et al., 1994; Engle & Conant, 2002; Lave & Wenger, 1998). What is the connection between these two paragraphs?

As interest in creating more classroom conversations has risen, so too has researchers' awareness of the need to help students from minority cultural and language communities with respect to science learning (Calabrese Barton, 2001; Calabrese Barton & Tan, 2009; Fradd & Lee, 1999; Moje, Collazo, Carillo, & Marx, 2011; Lee, Fradd, & Sutman, 1995; Lee & Fradd, 1998; Rosebery & Warren, 2000; Rosebery, Warren, & Conant, 1992). Most of these studies, centered in sociocultural theory and cultural learning theory, aim to bridge the distance between students' everyday discourses and experiences with the world with formal science D/discourse (Gee, 2008a, 2008b).

One assumption researchers make is that in the normative discourse space of the science classroom – with its attendant expectations about formal language, specificity, and formalized processes of knowledge construction (Driver et al., 1998; Lemke, 1990) – students from minority language groups use their diverse funds of knowledge as resources for meaning making (Calabrese Barton & Tan, 2009; Moll, Amanti, Neff, & Gonzalez, 1992; Moje et al., 2004; Rosebery & Warren, 2000). As Calabrese Barton and Tan (2009) state, "valuing diverse funds of knowledge and Discourse as legitimate science classroom resources positions minority students as rightful experts of certain knowledges directly related and applicable to school science" (p. 52).

Thus the job of the teacher is to recognize and build upon those funds. The funds of knowledge – defined here as cultural ways of doing, being, acting, speaking, and knowing the world (citations) -- are brought to bear in classrooms where teachers open up spaces for joint negotiation around compelling science ideas. When teachers create equitable discourse spaces, inclusive of the heterogeneity of students' ideas, all students benefit (Rosebery, Ogonowski, DiShino, & Warren, 2010).

In demonstrating what inclusive science discourse looks like, Rosebery et al. (2010) conducted a design study in which they specifically designed lessons that "broadened the Discourse space beyond what is ordinarily sanctioned in school science" (p. 330). That is, they collaborated with the classroom teacher to develop science talk, or an interactive discourse space in which all students explored questions in an open-ended, student-lead discussion about some phenomenon. In a unit about thermodynamics in a third grade classroom, students participated in a science talk on the second law of thermodynamics (e.g., heat moves from objects of higher temperatures to lower temperatures). They found that students' conceptualizations of heat – prompted by the authentic question "why do we wear a coat in the winter?" – became much more dynamic and animated, after students were surprised by a serendipitous fire drill which sent them out into the cold air without their coats. The experience of seeing thermodynamics in action – students saw "steam" rising from one of the researcher's heads as they stood in the cold – prompted the students to "interanimate" their ideas and experience with the phenomenon. That is, the students physically represented their ideas using their bodies and their voices to illustrate concepts they described using their everyday language repertoires. The discourse that resulted taught the researchers that "children are always making sense, even when teachers and researchers do not understand them" (p. 351), and that students drove the "analytic work" of the authentic inquiry about heat because their teacher (and the researchers) set up opportunities, in the form of the science talk, for students to do so.

Calabrese Barton and Tan (2009) report on a project in which students helped in planning a project about nutrition. The researchers asked four girls in a middle school science classroom in an underserved urban community to help them develop ideas for a project that was designed to open up the discursive space for more active student talk and engagement. Calabrese Barton and Tan found out that increased student participation in all aspects of the project were partially contingent on these students' perspectives, the project's design, and the teacher's ability to directly allow time and space for students to present their ideas freely, sometimes veering from the original intent of the discussion – especially those that connected directly to their own lives. For example, an activity called "The Healthiest Snack Contest," challenged students, within a given budget, to purchase snacks at a local bodega near their school. Upon returning to class, they then calculated and compared their snacks' nutritional information to other groups' snacks. But, students were reluctant to share their findings aloud in a formal report. However, when the teacher asked them about what they ate over the weekend, and to tell about its nutritional value (involving several scientific concepts they had studied in the unit), participation markedly rose. With this simple shift in bridging discourses -- between those of the students and that of school science -- students were compelled to share.

In these examples, studies in urban science classrooms with students from minority cultural and linguistic communities we have seen that: 1) allowing for more open-ended student talk takes more than just an ideological interest in that stance, teachers must make pointedly strategic shifts in the structures of the discourse space – as in a science talk that shifted how students were expected to talk to one another, to getting students involved in planning the unit, or a teacher's willingness to follow a student's ideas (like the heat exchange example where the students made observations about standing out in the cold), and 2) ongoing reflection on the units as they unfolded was particularly helpful to the success of the unit. In both of these examples, I should point out, the reflective piece was possible because these were design studies that involved the classroom teacher as co-researcher. Design studies are specifically designed to involve on-going data collection and analysis so as to encourage the research team to reflect on the project's evolving effectiveness.

But, successfully leading large- or small-group classroom discussions (as I've shown in the above examples) that engage students in science discourse is not necessarily a natural part of an experienced teacher's skill set. It is relatively rare for teachers to successfully engage students in open-ended disucssions (or dialogic discourse), or to work within the ambiguities of open-ended investigation work (Herrenkohl & Guerra,1998; Mehan, 1979; Oliveira, 2009; Scott, Mortimer, & Aquilar, 2006). Research on professional development specifically aimed at the teacher's role in classroom discussions report that focused learning about discourse can enhance teachers' ability to use small groups well, and to encourage broader student participation in classroom discourse (Baker, Lewis, Purzer, Watts, & Perkins, 2009; Buxton, Lee, & Santau, 2008; Herrenkohl & Guerra,1998; Lee, Luykx, Buxton, & Shaver, 2007; Oliveira, 2009). One important finding in these studies is that explicit teaching about the group task, or about group members' roles as they discuss science content, promotes more thoughtful contributions by students and focuses groups on task completion. Studies in classrooms where teachers learned about and implemented specific discourse strategies reported greater gains in overall student engagement (Herrenkohl & Guerra, 1998).

For example, in a study about small group discussion in an affluent elementary science classroom, Herrenkohl and Guerra (1998) found that explicitly teaching teachers about the roles of group talk increased the numbers of substantive student contributions. Researchers assessed the engagement of students in two comparison participation structures that they created, one in which they defined and taught students' roles as audience members and a control group who had not included audience roles. They found that students learned specific audience roles were more active in engaging in classroom discussion. The class receiving the intervention created a "classroom situation in which understanding, clarifying, and sharing meaning as a whole class were more central" (p. 466). In the control group, where the roles were not defined, students assumed a more "passive" stance toward their engagement.

On a more micro scale, Brown and colleagues (Brown & Spang, 2007; Brown & Ryoo, 2008) investigated the roles of explicit teaching about science vocabulary as a non-vernacular language that all students could add to their linguistic repertoires. They differentiated between everyday and scientific language in what they call a “content first” approach (Brown & Ryoo, 2008). The approach involved the teacher intentionally using vernacular forms of language –or, language forms that are more aligned with the language of the local community – to engage students in the content before moving to more formal forms of science discourse. For example, they argue that vernacular forms of language – people’s everyday language forms – contrast to non-vernacular language forms – like the language that football players share with their coaches – become highly technical and important for communication in that particular context. They become “specialized ways of using language for specific purposes” (p. 530). The same is true, they argue, in science. They ask “what is the best approach for helping students make a non-vernacular genre of language (e.g., scientific language) “vernacular” for new users?” (p. 531). They contrast foreign language instruction (which teaches students new language forms for familiar ideas) and science (which teaches new language forms for new ideas), and that one role of science education is to “deconstruct science teaching into conceptual and language components” (p. 532). They examined this position through a series of assessments given to 5th grade students after using several computer programs designed to engage students in vernacular and non-vernacular forms of language to present the same concepts. A control group received computer-based instruction on only the scientific language forms (e.g., using terms like *glucose* and *chloroplasts* to explain photosynthesis), and the experimental group received computer-based instruction which made explicit links between the specific and the non-specific language forms (e.g., for the same screen on photosynthesis, the terms are *food* and *pigments*). Their findings were that students' learning improved when they learned new science concepts using the scaffolded, matched computer activities. In other words, teaching the vernacular forms first improved students' learning of the non-vernacular (i.e., scientific) forms.

In sum, research suggests that, in order to help all students become more successful in classroom discussion – regardless of whether such participation is expected of the students' own cultural models for communication (Phillips, 1983), teachers must have support to 1) learn about, implement, and reflect upon specific discourse strategies; 2) recognize the cultural influences on learning (Nasir, Rosebery, Warren, & C. Lee, 2006; Gutierrez & Rogoff, 2003); 3) make direct changes in the participant structures of classroom organization (Herrenkohl & Guerra, 1998; Gallas, 1995; Rosebery et al. 2010); and 4) consider how different language forms influence concept development. Such shifts of participant structures may be as simple as deliberately changing a discourse strategy to something more open ended like Science Talk (Gallas, 1995; Rosebery & Warren, 2010), or to develop projects that draw upon students' funds of knowledge (Calabrese Barton & Tan, 2009; Moje et al., 2004), or which provide specific roles for students as they learn to participate productively in small group discussion (Bennett, Hogarth, Lubben, Campbell & Robinson, 2010; Engle & Conant, 2002; Herrenkohl & Guerra, 1998), or to develop specific strategies for helping students learn academic vocabulary (Brown & Spang, 2008; NRC, 2007; Gee, 2008b).

The results resonate with those found in studies about (general) language learning: that teachers are more successful with student engagement when they know about how discourse and language functions in classrooms (e.g., Adger, Snow, & Christian, 2002; Heath, 1983; Rosebery & Warren, 2008).

If we put together the research on long-term investigations with the literature of science talk in classrooms, we see the important role that language plays in learning science in sustained projects over time. The nature of teacher-student interactions influence, in part, the success of LTIs. Since language is the primary means by which people learn in classroom spaces, and since science is a language-rich enterprise (Lemke, 1990; NRC, 2012), the teachers' roles in the science classroom involve awareness and skillful orchestration of how discourse occurs among learners (Cazden, 2000; Gee, 2008a; Warren, Ballenger, Ogonowski, & Rosebery, 2001; Warren & Ogonowski, 1998). The skills with which teachers engage students in language in science classrooms are not always obvious, nor are they always easy to implement (Moje, et al., 2001; Warren, Ballenger, Ogonowski, & Rosebery, 2001). Sustaining and supporting student independence over time requires teachers to have a certain level of comfort with ambiguity, knowledge of and confidence in the investigative process, and the ability to help students become independent and interdependent active learners in the classroom (especially where small group work is involved).

However, we have few detailed descriptive studies of how experienced teachers develop and engage students in the language of science during long-term investigations as a regular part of their practice. Such studies would teach us about the nature of long-term investigations long after implementation, as they are practiced by experienced teachers, after they have become a regular part of the scope of the school year and regular practice in science classrooms. This dissertation seeks to fill that gap.

A Look Forward

In the chapters that follow, I show how three experienced middle school science teachers from different teaching contexts develop LTIs with their students. In particular, I explore the patterns of the macro contexts - those that comprise larger frameworks under which the teachers teach (e.g., curriculum) - and the micro contexts - the interactional patterns between teachers and students. These patterns allow me to describe a range of possibilities for teaching the LTI in different contexts, and the roles that language plays.

In chapters two and three, I contextualize the study. In chapter two, I describe the data collection and analysis methods. I begin with a description of the Urban Advantage professional development program in which these teachers participate. I describe the teacher-participants in general in this chapter, focusing mostly on the participant selection process. I then discuss the data collection procedures, including strategies for acquiring digital voice recordings of each teacher's teaching, how I conducted ethnographic observations in each classroom (e.g., field notes, curriculum materials and student work), and the timeline for my study. I then discuss in detail the discourse analysis strategies I employed, paying particular attention to the micro talk structures and my coding schemes. Chapter three provides a broadbrush portrait each teacher. Through interview data, I report how each came to teaching science, and their involvement in the UA program. I also describe their particular teaching contexts: their schools, their students, and their curricula, as they have some bearing on how teachers taught the LTI.

Chapter four explores how the teachers engage students in two science practices that they employed most often during the LTIs: Planning and Carrying Out Investigations, and Obtaining, Evaluating, and Communicating Information (Achieve, Inc., 2013). I explore the nature of the classroom discussion that engages students in each practice, and the ways in which teachers use other curricular textual tools to support these particular practices during the LITs. I also discuss factors that may help teachers sustain the work over time.

In chapter five, I provide the macro analysis of talk and interaction around the larger structures of each teacher's LTI. Using the construct of "language as a tool," I describe how teachers use language to engage students in the practices of scientific investigation (NRC, 2012) along three dimensions: vocabulary (lexical), talking about science language (syntactic/grammatical and semantic), and in writing (which also considers the lexical, syntactic, and semantic dimensions). For each dimension, I provide transcript data and analysis of each.

Chapter six comprises a micro-analysis of the teacher talk in lessons in which science practices are taught. Here is where I develop a model for thinking about the LTI, as a dialectic between the macro and the micro contexts in which these teachers work. I first map out this dialectic as it is represented on a visual map, and then I describe examples for each half (micro and macro) of the map using classroom talk data. I then theorize the map using Bakhtinian concepts of heteroglossia and intertexuality. In this way, I set the micro and macro examples of language use (both written and spoken) in a framework which helps to explain how these are in a dialectic relationship throughout the LTI. I then bring the theoretical back into the concrete examples through two elected "cases" of the macro and micro dialectic.[1] In each case, I present talk and text side-by-side to draw the parallel examples of the macro and micro working together, and to further concretize the concept of the macro-micro dialectic.

[1] Here, I use the term "cases" to identify cases of the dialectic at play. I do not consider each teacher's teaching practice that I elect to illustrate the dialectic as a "case." The distinction between a case used for case study and a "case" as in an example of some construct is important to this chapter.

Finally, in chapter seven, I summarize three major lessons learned from the study and set those lessons in the context of a Bakhtinian (1981) theoretical framework that drove my interpretation of the data. I conclude with comments about the potential new questions for the field of science education to which this study may contribute.

Chapter 2

Method

The research reported here was designed as a field study that draws upon ethnographic research methods and uses a sociocultural lens from which to understand teaching and learning (Adger, 2003; Cazden, John, & Hymes, 1985; Florio-Ruane, 1987; Gee, 2005, 2008a; Gee & Green, 1998; Hymes, 1980; Johnstone, 2008). Data analysis methods included both ethnographic and discourse approaches. Here I describe the processes of participant selection, data collection, and analysis.

Background and Context

Urban Advantage (UA) is a multi-site collaborative professional development program between cultural institutions in New York City and the city's public schools. The program offers middle school teachers sustained professional development focused on science inquiry through involvement in long-term scientific investigations, exploration of the city's multiple cultural institutions, and sustained support in classrooms with school-based UA leadership. Teachers in UA attend three cycles of professional development in their first year in the program in three New York City science institutions, and are provided material support in their classrooms, such as notebooks for data collection and tools for investigation. First year UA teachers are eligible to enroll in a continuing professional development program which engages them in long-term science investigations across all eight participating cultural institutions as well as in-school curricular and classroom-based support. Professional development seminars are lead by teams of scientists and educators; seminars are held at one of eight science cultural institutions around New York City (e.g., the American Museum of Natural History, New York Botanical Garden, Brooklyn Botanical Garden, Bronx Zoo, Queens Botanical Garden, New York Hall of Science, New York Aquarium, and Staten Island Zoo). Each institution employs "lead teachers" to assist with planning curriculum, developing the plans for, and facilitating professional development workshops. These leaders are selected through a competitive application process, and are evaluated annually by UA leaders. Approximately 20 lead teachers work for UA in addition to their regular work as teachers in the NYC Public Schools.

Sample and Participant Selection

The study built upon and extended a larger mixed methods study funded by a National Science Foundation.[2] That study documented the professional development offered in UA, as well as the teaching and learning of new teachers participating in professional development in secondary research. In that study, we observed several lead teachers collaborate in teaching the professional development seminars; however, that study did not involve documenting their classroom teaching or their learning over time as UA participants. In the study I report on here, I documented the science teaching practices of three successful UA lead teachers – Diana, Carrie, and Marilyn – in order to provide an account of how successful teachers engage students in long-term investigations.

Participant selection proceeded through a combination of nominations and convenience sampling. After receiving approval from the Institutional Review Board from both Michigan State University and the New York Public Schools, I contacted a UA staff member for recommendations for participants. My criteria (in no particular order) were: 1) skilled in conducting classroom discussion and talk with students, 2) highly successful in teaching inquiry-based science, and 3) comfortable with classroom visitors. While I asked for nominations of exemplary teachers of inquiry science, I was aware that even in a program that selects for this

[2] National Science Foundation DRK-12 Grant # 0918560

quality, there is always a range of skill and experience. Because one goal of this dissertation is to learn from, and tell the stories of, experienced, skilled teachers' practice, my first priority was to invite the most skilled teachers from the pool of UA lead teachers.

I first sent email invitations to the recommended teachers' school administrators to get permission to conduct a study in the school, as required by the New York City Public Schools. I then sent email invitations to the recommended teachers in buildings where I received approval. This initial letter introduced the study, myself, and outlined their possible commitment of time outside of school hours (e.g., no more than 5 hours). Of eight teachers to receive the initial invitation, three agreed to participate. At that point, I sent each a letter outlining the IRB considerations and other study-specific information, including a possible observation schedule. I provide full portraits of each teacher in chapter 3.

Data Collection

Data collection proceeded through a series of five periodic classroom observations of LTIs in each teacher's classroom, resulting in approximately 15 total hours of classroom observation per teacher? Or as a while? These observations took place during five trips to NYC from Michigan in which I was able to visit each teacher's classroom, sometimes more than once during the visit. During each observation, I recorded teachers' talk, and took field notes (Emerson, Fretz, & Shaw, 1995). In addition to recording teacher talk, I also used two additional digital recorders, placed at student tables, to record their small group talk during each lesson. In between research trips, I produced analytic memos, and transcribed lesson recordings. I also conducted three interviews with each teacher at the beginning, mid-point, and at the end of the project (Kvale, 1996). I collected student work samples, instructional handouts, and curricular materials for as many lessons teachers could provide. I also collected digital versions of final student projects for each teacher. I describe each in more detail below.

Digital audio recordings of science lessons. The primary goal for each observation was to obtain classroom discourse data using digital audio recording equipment.[3] I used three hand-held high-fidelity digital audio recorders with stereo microphones, and one wireless lapel microphone to record the teachers' instruction, as well as to record small group discussion among students. Teachers wore the wireless lapel microphone during each observation, allowing me to monitor sound input from a recorder/receiver that I kept with me as I moved about the classroom. After several test runs of the equipment before leaving for the first observation, I was pleased to find out that if the lapel microphone were to fail at any given moment, the recorders' microphones were able to pick up the teacher's voice from anywhere in the classroom. And thankfully, if the digital data card were to fill during recording, replacing it with another was relatively simple, which meant that very few minutes of possible recording time were lost.

Of course, working with digital recording equipment is not without risk, and I did what I could to prevent any loss of data, and planned two back up devices (including field notes) where possible. But there were some brief moments when that could not be avoided. Teachers move around the room, which presents a challenge in capturing recordings of every conversation they might have with students. I taught each teacher how to turn off and on the transmitter that we connected to her clothing, giving all of them both the option of having privacy by turning off the device when they were having private conversations with students, talking with parents, or answering the classroom telephone. Because we connected the microphones well before each class session, this also allowed them to turn on the device when their lesson began, so that we did

[3] The NYCPS do not allow video recordings in classrooms, which would have been preferred.

not record all of their extraneous talk with students, parents, or other teachers as they arrived to class. Since I was interested in instructional talk, this not only helped to focus the recordings, but in a more practical sense, it also prevented us from using up valuable battery power and space on the memory card for talk that I was not likely to transcribe. Since I was traveling around the city sometimes for entire school days without time to return to my hotel room to recharge batteries, this procedural economy was important.

However, on one occasion, the teacher unknowingly flipped the transmitter to "off." Not knowing this until later in my hotel room, this meant that I could not solve the problem immediately, and did not capture her individual conversation with small groups on this day. Luckily, other microphones placed around the room captured her whole group discussion, and I filled in the gaps with field notes.

After the first observation day, which was my first visit to each teacher's classroom and served to orient me to the general physical set up of the space, I asked about the typical student and teacher configurations I was bound to see in the remaining observations. All three teachers reported that their students worked in small groups every day, and that they (the teachers themselves) would be moving from group to group during the entire lesson. This helped me to decide several different places around the classroom where I could take field notes to capture teacher-student interaction.

Because I was interested also in small group conversations, after the first observation I brought two additional recorders to capture discussions among small groups of students with and without their teacher. I recorded a different pair of student groups during each visit. With eight small groups in each classroom, I captured the small group talk of nearly all of the groups in each class for the remaining four days of observation. I was able to record more than one conversation with the same group because in two cases, I did not record a group that included a student whose parents did not give approval for their child to be recorded.

I imagine that readers are wondering about placing expensive digital recording equipment with students during the sometimes messy endeavor that is inquiry-based science. On the first day, when the teachers introduced the project and me to their students, students were curious about the recorders. Teachers reported, before the study began, that my presence would soon not be noticed by anyone in the room, but that students were always welcoming, and quite used to having people observe. As busy classrooms go, visitors came and went, student teachers changed every few months, and various other adults visited throughout the day. So, new visitors to their classroom appeared not to be disruptive.

Students were respectful of me and of the equipment, oftentimes protecting it from other students from other groups who came by to ask about it. One student said, “Don’t touch that! It’s Patti’s.” One student reported to me when she saw the “data card full” message appear on the small digital screen so that I could take care of it. Another treated the recording device as his own, talking into it as if he were a news reporter, narrating what was happening, “Now, we are filling the fish tank with room temperature water….” Another spoke into it on their first day of recording, “Did you catch that, little person in the box?” And a pair of students said, “Is she recording what we say?” to which another student responded, “Yeah, so keep it clean, okay?” Their awareness of the “person in the box” slowly faded as they got to know me and “the box” a little better. Nevertheless, they took the recordings seriously. And after two sessions, they did not talk about the recorders, or my presence. Being forgotten felt like an accomplishment.

In addition, the two recorders in each session also served as back-up devices. There were a few moments in which the teacher’s lapel microphone did not pick up a student’s voice and the student recording provided what the students said. Likewise, the student recordings oftentimes captured the student voice, but the teacher's was not as clear. In these cases, I was able to use both recordings to stitch conversations together. Lastly, the extra recorders captured whole class conversations as well, providing a back up record of those teaching moments.

Lastly, while I collected several hours of conversations between students in their small group conversations, for this study -- which foregrounds teachers' discourse and classroom practices -- I directed my attention to the teacher recordings. That is, I used the student recordings as additional supportive artifacts for now, and will no doubt find these data useful for other analyses.

Semi-structured teacher interviews. To buttress and inform what I was able to glean from the recordings, I conducted three semi-structured audio-recorded interviews with each teacher. Following Kvale (1996), my goal was to conduct conversational research interviews, those that are "neither open conversation nor a highly structured questionnaire" (p. 27). In other words, my stance was very minimally as the "miner" as Kvale puts it, "digging nuggets of data" whose end product is as a rider on a "conveyor belt" whose value is "determined by correlating it with an objective, external, real world" (pp. 3-4). My approach more closely resembled the "traveler metaphor," in which "the interviewer-traveler wanders through the landscape… explores the many domains of the country" and one who "wanders together with" (p. 4). With this in mind, I designed interviews to gather as much information about the landscape of conducting the LTI as I could, and as I had originally planned, to learn about the teachers' experiences and ideas about discourse in science classrooms, especially with students who may speak minority languages at home.

I also embraced the dialectic nature of interviewing (Kvale, 1996). Collecting both micro- and macro-data would lend itself to naturally occurring contradictions and interdependencies. I could anticipate tensions between teachers' ideas about teaching and their own practice; I could not anticipate, nor did I enter the interview process with, these presuppositions, about what, exactly, those contradictions would entail. I could anticipate that both looking broadly at language, and also turning the microscope dial to focus on the minute meant that themes (or ideas or concepts, etc) would be in tension, and therefore produce new insights (Kvale, 1996). In short, I was (and am) philosophically oriented toward the dialectic, toward the possibilities that arise from tensions between two different forces; I embraced the possibility that my interview data would generate tensions between what teachers lived, what they reported, and what I perceived and interpreted.

In this spirit, I recorded the first interview on the phone with each teacher just prior to the first observations in March of 2012. This first interview focused on, in general, the teacher's background (see Appendix A), and was organized into themes (Kvale, 1996), seeking information about the teacher's teaching and educational background, and her UA involvement. It also involved coming to know how the teachers conceptualized inquiry- based instruction in their classrooms, how they conducted the LTI, information about their curricula, and about how they used the UA teaching tools in their classrooms. I also asked about their school contexts, which included information about the surrounding neighborhoods, the school focus, the UA involvement in the school (i.e., to what extent other teachers were involved in the UA program), the planning schedules, teaching schedules, and demographic information about their students. Lastly, I asked about the numbers of English Language learners (ELLs) in each classroom and how they thought about teaching science in linguistically diverse classrooms.

The second interview, which took place between the fourth and fifth classroom observations, was an in-person interview conducted in each teacher's classroom (see Appendix B). This interview involved playing two recordings of classroom talk (accompanied by the transcripts) and discussing her reflections on those recordings. The purpose was to ascertain teachers' ideas about students' engagement in whole and small group discussions. I was interested in understanding the teachers' perspectives on student dynamics, to get a sense of their typicality – in as much as we might be able to discern through audiotape – and teachers' ideas about what insights they could share about the discourse data. Another theme of the interview was to capture teachers' thinking about classroom discussion (Kvale, 1996). I wanted to probe their ideas about when to use small and whole group discussions and their reasons for doing so. I also wanted to find out about their thinking about how ELLs tend to participate. This follows my interest in teachers' perspectives about organizing discourse spaces inclusive of students who speak minority languages. Overall, this interview sought information about the teachers' ideas about student engagement.

I conducted the third and last interview with all three teachers in October (see Appendix C). It was difficult to schedule an interview at the end of the school year when teachers were busily packing up their classrooms. This interview was the most open-ended of the three, and I invited teachers to reflect on their study participation, the insights they may have gained since the last interview about the student recordings, and about classroom discourse in general. I also ascertained their reflections on their LTI process, including their ideas about the success of the students' final LTIs, as well as any ideas for changes they would make to how they would conduct the process the next year. Finally, I took notes about ideas to follow up on, and to use as a backup in case the recording equipment failed.

Field notes. I took handwritten field notes for each observation in each teacher's classroom (Emerson, Fretz, & Shaw, 1995). I chose handwritten notes as opposed to my laptop computer to allow me the greatest possible flexibility to move about the classroom, as well as to avoid physically or socially distancing myself further from the students and teachers (Miles & Huberman, 1994). Also, using a notebook provided me the opportunity to draw or make charts of things I saw in a way that a computer could not.

My focus was on things I sensed I would not be able to glean from the recordings: the classroom physical space and organization, where and how students were organized to work, how teachers and students moved about the classroom, how the teacher seemed to interact (in non-verbal ways) with students, the general tenor of the relationships among students, or other typical school kinds of things, like intercom announcements, people coming and going from classrooms, other adults in the room, how science materials were handled and organized, where the teacher tended to stand or how she moved about the classroom, any audio-visual details of the instructional space (e.g., posters on the wall, uses of technology, the dry erase board or smartboard or overhead projection equipment, etc.). I also took note of students' backchannel conversations (Johnstone, 2008) during instruction: when, how, and what they talked about, comments they made to each other or to themselves as teachers were teaching, how they reacted to instructions, and their general eagerness to engage in the tasks. These details helped me flesh out the narratives with details (Emerson, Fretz, & Shaw, 1995).

I used the field notes to write narratives of classroom action (Emerson, Fretz, & Shaw, 1995). After each observation, as soon as possible, I converted my handwritten notes to a typewritten description. On some days, this meant three descriptions of three different classrooms. My notetaking had to be detailed and precise enough to offer clarity about which classroom I was describing. I found that it was remarkably easy to remember details from each classroom when I typed up the notes on the same day. They were each unique from each other, and my presence in each room, with different sets of students, felt different. Therefore, I was able to also fill in the notes with details from my sensory memory how the moments unfolded (Emerson, Fretz, & Shaw, 1995).

Supporting data. The conceptual framework guiding this study presumes that teaching is situated work. As such, the contexts in which teachers work – material, intellectual, historical, social – shape what they do. Each teacher planned her LTIs with the help of numerous curriculum sources. These material resources provide documentation, which contribute to the macro-view of instruction. I describe each of the other resources that I created or collected below.

School-specific curriculum materials. All three teachers planned their units and LTIs with the *New York City or State Benchmarks for Science Inquiry;* and *NYCPS curriculum materials for 7th and 8th grade science, the Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects* (National Governors Association Center for Best Practices, 2012) in mind. They connected these various standards documents to their schoolwide kit-based curricula (such as SEPUP and FOSS). Marilyn and Carrie, who teach at the same school, used the *Science Education for Public Understanding Program* (SEPUP) (www.sepuplhs.org) and the *Full Option Science System* (FOSS) (www.fossweb.com), while Diana used selected materials from the *Project Based Inquiry Science* (PBIS) curriculum (Kolodner, Krajcik, Edelson, Reiser, & Starr, 2009), as well as Urban Advantage curriculum materials that accompanied an extensive case study of the zebra mussel population in the Hudson River, the result of a collaboration between the American Museum of

Natural History and the Carey Institute for Ecosystem Studies (http://www.amnh.org/education/resources/rfl/web/riverecology/). I provide a full description of the teachers' curriculum approaches and of the Hudson River case study in particular, in chapter 4. I did not collect these resources, per se, as teachers were not able to provide copies of books for me. However, the websites for all of the programs provided adequate information. I was able to collect paper copies of student readings on the AMNH/Carey Institute case study that Diana used as they were generated as part of the NSF project that I was working on at the time.

Urban Advantage science inquiry tools. The UA program provides two essential instructional tools for guiding teachers and students in learning through inquiry: the Investigation Design and Development tool (IDD) and the Developing Scientific Explanations Tool (DSET). Both tools are intended to support teachers in guiding their students through the required NYCPS 8^{th} grade exit projects (e.g., long-term inquiry projects). The IDD lays out steps for creating scientifically sound investigations (NRC, 1996), while the DSET assists students in creating evidence-based reasoning from the results of their investigations. I describe each in detail in chapter 3 and provide student samples in chapter 4.

Each tool organizes language and science vocabulary and reasoning according to the standards for science inquiry (NRC, 1996; 2011), and requires students to be proficient in reasoning through reading, talking with others, and writing (NGACBP, 2012; NRC, 2011). Urban Advantage recognizes these tools as literacy tools, as they are also connected to the *Common Core Curriculum for English Language Arts* (NGACBP, 2012) as well as to the *Next Generation Science Standards* (Achieve, Inc., 2013).

Student work. I also collected student work samples for as many lessons as teachers were able to provide. Some artifacts were photocopies of student journal pages, or copies of students' work on daily work (e.g., Do Nows) and graphic organizers. I also obtained digital copies of students' final LTIs, as PowerPoint© documents and typewritten lab reports. I explain and present several examples of these in chapter 4.

Student work samples provide information about the content and inquiry processes from those verbal interactions into the artifacts students are expected to produce. Thus, student work was not intended for describing achievement, but instead to provide additional descriptive data about students' engagement with the discourses, or language, of the classroom community in general, and of science inquiry in particular.

Data Analysis

This study draws from sociolinguistics to guide the interpretive approaches to understanding classroom talk and interaction in science classrooms. Given that much of the work of science involves socializing students into the academic language practices (e.g., structures and social interaction, like argumentation), teachers and students often find themselves negotiating their way toward mastery of the disciplinary language demands (Hakuta & Santos, 2012). Sociolinguistics helps us to understand how language learning unfolds (Jaworski & Coupland, 2008; Johnstone, 2008). In her discussion on sociolinguistics in classroom settings, Florio-Ruane (1987) reminds us that "sociolinguists research what teachers and students need to know to participate in socially-appropriate ways" (p. 186). I take this approach, one that involves teachers helping students to engage in classrooms in "socially-appropriate ways"; that is, in ways that are governed by the normative practices of science discourse (NRC, 2012). Following Florio-Ruane (1980) I ask questions such as: "What is happening, specifically, in the social action that takes place in this particular setting? What do these actions mean? How are the actions organized? How is what is happening… related to happenings at other… levels?

How do the ways everyday life is organized in this setting compare with other ways of organizing social life?" (pp. 186-187).

To answer these questions, I conducted two levels of analysis, one involving a macro-perspective on the context (Erickson & Schultz, 1981) surrounding teachers' work (using interview data, student work, and field notes). I also conducted a micro-analysis (using transcript data of classroom talk, the bulk of my data) to trace patterns of engagement. In this study, I refer to the ethnographic component as the macro-analysis, and the discourse analysis of selected speech events, as the micro-analysis.

Discourse analysis of classroom talk. As a multidisciplinary endeavor, discourse analysis includes an array of strategies for parsing transcript data, some drawing from linguistics (Gee, 2008a; Heath, 1983; Tannen, 2007), from sociology (Sacks, Schegloff, & Jefferson, 1974), or anthropology (Hymes, 1974; Erickson, 2004; Gumperz, 1977).

Following Gee (2008a), I am concerned with the D/discourses in which people communicate in various ways, for various reasons. According to Gee, the lower-case variation, discourse, represents "language-in-use," or the "on site" language we use to "enact activities and identities" (Gee, 2005, p. 7; 2008a). But, in Gee's words,

> To "pull off" being an "X" doing "Y"…. (a lab physicist convincing colleagues that a particular graph supports her ideas), it is not enough to get just the words "right," though that is crucial. It is also necessary to get one's body, clothes, gestures, actions, interaction, symbols, tools, technologies, values, attitudes, beliefs, and emotions "right," as well, and all at the "right" places and times. (p. 7)

In studying the language and communication between teachers and students, I consider both "Discourse" and "discourse." That is, as I explore the various Discourses surrounding this work, I analyze using a macro-analytic approach; whereas, "discourse" calls for a micro-analytic approach (Bloome, et al., 2008; Gee, 2005, 2008a; Johnstone, 2008). However, this study largely attends to issues of small-d discourses (Gee), while I keep the big-D Discourses in mind as I work to understand the larger contexts in which the discourses of classroom interaction take place. Jaworski and Coupland (2006) remind us, "One important facet of discourse analysis is… to show how micro-level social actions realize and give local form to macro-level social structures" (p. 10). As this study takes place within a swirl of science education policy activity, I have also partly attended to another piece of the macro- Discourse, or "social structures," in which this study lies. In the next chapter, I will present some additional contextual factors that make up the Discourse (most notably issues arising in the participants' local teaching contexts). Here I discuss my process for the micro-analysis of the discourse represented in the recordings of teachers' and students' classroom communication about science.

The analyst's job is to determine a parsing scheme that will provide salient descriptive details, understanding that each choice about where and how to parse data is interpretive, and subjective (Johnstone, 2008). Throughout the study, I have been aware of the fact that my interests – as former teacher and as a scholar interested in issues of language in urban classrooms – shape my perceptions when collecting data and my interpretations and analyses (Jaworski & Coupland, 2006). In this light, I present below my rationale and process for parsing the speech data in several different types of transcription coding schemes, and through different ways to "entextualize" or, "to make choices about how to select and delimit chunks out of the flow of talk… making these chunks into texts, and treating them analytically in much the way we have traditionally treated written texts" (Johnstone, 2008, p. 20). In short, I chose a multilayered parsing scheme to gather both macro- and micro-discourse data. My scheme involved several different "slices" of the transcript data.

First, I determined the larger structures that formed in the conversation so that I could later identify and describe the contexts in which smaller discourse moves occurred (Erickson & Schulz, 1981). The first slice of data, then, was to identify the participant structures (Jaworski & Coupland, 2006; Miles & Huberman, 1994; Phillips, 1983), or "culturally learned patterns of conversational rights and obligations" (Florio-Ruane, 1987, p. 190). For example, in the second lesson in Carrie's classroom, in which she asks students to work with their project groups to develop their initial plans for their LTI (which I will outline in detail in chapter 4), I color-coded and labeled each bound participant structure as: W, S, S, W, S, I, S, I, S, I, S, I, S, I, S, S, S, S, S, S, S, S, S, I, S, I, S, W (where W = whole group, S = small group, and I = one-on-one discussion). Or, to put it more simply, we can see that the lesson began with whole group instruction and ended in the same way. The "W" in the fourth position was an announcement made to the whole class during the small group work. The rest of the time, Carrie is moving from group to group, visiting some groups more than once. The "I" structures in this particular case, are moments when an individual student comes to Carrie as she is speaking with a small group. Also, since my gaze is on the teachers in these interactions, I coded this interchange as an "I" because, even though it only lasted for a few seconds – the student may have been asking a simple question – I am interested in tracing Carrie's activity. Though she is still sitting with the small group, her interaction is focused on the individual, even as an interruption. What is important to note here is that the duration of each kind of participation varies. For instance, there are two longer "S" moments in which Carrie sustains the conversation for more than 5 minutes. In other cases, the "S" moments are typically less than one minute long. From here, I was able to code each smaller “S” or “W” case and find patterns of talk within them. That analysis came in the next slice of my data.

Looking first at participant structures allowed me to map the patterns of interaction in each classroom, across classrooms, and over time. For example, I was able to determine when whole group participation was expected of students in each lesson activity, when small groups were used, and how much time students spent participating in each. My presupposition here was that if students participated in several different structures on any given day, they would also be expected to shift their discourse strategies (e.g., expectations about contributing ideas, addressing other speakers, listening, writing, asking question). As we saw in the last example in Carrie’s classroom then, since Carrie made multiple visits to each small group as they worked, we might expect them to know how to shift the conversation for when she arrives and when she leaves the conversation. Gumperz (1974) identified these sometimes subtle cues – such as a teacher’s physical arrival to a table full of students who are steeped in conversation – are called contextualization cues. Research on classroom interaction has long argued that in heterogeneous language communities, such as classrooms, the success or failure of communication oftentimes comes down to the abilities of speakers to identify and appropriately respond to these cues (Florio-Ruane, 1987; Gee, 2008a; Heath, 1983; Hymes, 1974). This is just one of the many fundamental principles of the work of conducting research on language in science classrooms.

Once identified, the larger structures of participation served as contexts for the next smallest slice of data (Erickson & Schulz, 1981), each speaker’s turn (Sacks, Schegloff, & Jefferson, 1974), for instance. A turn-by-turn analysis allows the researcher to map patterns of engagement, as each turn is contingent on the meanings of the adjacent turns (e.g., before and after) (Sacks, Schegloff, & Jefferson, 1974). Therefore, I gave each turn an interpretive code based on the meanings I gleaned from the interaction of those turns with the adjacent turns (Miles & Huberman, 1994) (see Appendix D). Then, I mapped those interpretive codes onto the participant structures to determine the patterns of interaction inside of each participant structure. For example, I shall revisit Carrie's lesson for which I provided the map of participant structures above. In this lesson, Carrie has asked students to work in small groups on their initial plans for their LTI. The interpretive the coding scheme (see Appendix D) allowed me to see that Carrie typically opened the floor with each small group she visited by asking them a "checking in" question, such as "How are you guys doing over here?" I labeled this utterance, "CHECK." This was typically followed by a student response that either was a "student initiated question" (SIQ), like, "For this would it be once if we went [to the zoo] just once?" or a simple report of "good," which received no code in this analysis. This particular utterance, "For this would it be once…." opened the floor to a longer substantive conversation about how to write procedures that produce the "best data." (I present more excerpts from this conversation in Chapters 4 and 5.)

Next, I counted the numbers of occurrences of each code inside of each participant structure. (In this way, I went from one layer to the next, from micro- to macro- and back again. Checking for new patterns each time.) This allowed me to get a sense of the patterns of interactions, and the general nature of those interactions over time. This analysis also helped me to choose several key moments that I would use in even more micro-analysis (Crawford, 2000). Key moments are those exchanges that were either interactionally compelling – a student wrestles with a particularly difficult science concept aloud, or a teacher is demonstrating particularly skilled questioning strategies, etc. – or, were difficult for me to understand, compelling me to look more closely. In other words, this was an iterative process of moving between codes and creating new sets of codes that would allow me other, and sometimes competing, interpretations (Miles & Huberman, 1994).

The third analysis involved parsing the transcript data into even finer segments of talk. A different analytic process informed this parsing. For each key exchange, I divided each speaker's turns into smaller chunks according to the most meaningful clusters of words (Johnstone, 2008). Gee (2005) reminds us that "meaning" in discourse analysis is contingent on the surrounding texts and subtexts, which make up a discourse. Therefore, meaning can also be contested between analysts, who are "reading" the texts and subtexts differently (Ochs, 1979). In as many cases as possible, I parsed the turns according to grammatical and paralinguistic segments. In other words, pauses in speech or grammatical phrases (syntactical cues) provided small bounded units for analysis. For example, the utterance, "Who else had the exact word, food? Can anybody tell me? Raise your hand." Would be parsed into three separate sentences: *Who else had the exact word, food/Can anybody tell me?/Raise your hand.* The pitch change between the ends of one interrogative clause and the beginning of another marked by a question mark serves as a logical boundary. Whereas the sentence, "I want you to be sure that you write your materials and procedures so that… so that if someone else were to try to replicate your investigation they could," may have different boundaries for parsing. In my approach, the sentence would be broken into the following segments:

1 I want you to be sure

2 that you write your materials and procedures

3 so that…

4 so that if someone else

5 were to try to replicate

6 your investigation

7 they could.

Notice that each line represents a single idea or single grammatical phrase (Johnstone, 2008). I parsed according to the different head word they each include: the noun phrase, "someone else" in the first case, and the verb "replicate" in the second. Each phrase bound by a new phrase indicates a different part of speech in this way: … *so that if someone else/were to try to replicate/ your investigation/they could*, includes a conditional (e.g., "if someone"), a verb phrase, a direct object (e.g., your investigation), and a closing conditional.

I conducted this parsing for one complete lesson for each teacher, and recoded each line of transcript according to two new sets of codes. I first coded each line, as I had before, in an interpretive way, looking to see new patterns in the smaller chunks of speech. I also coded each line for instances of science practices and writing practices. I derived these last two coding schemes using standards and practices from the official documents of the *Common Core State Standards in English Language Arts* (NGACBP, 2013) and the *Framework for K-12 Science Education* (NRC, 2012) (See Appendix E). These codes helped me to understand different aspects of my data, as I will discuss below.

Analytic research memos. Equally significant to transcription data were several analytic memos I wrote about different slices of the data (Miles & Huberman, 1994). I shared these memos with my advisor during our weekly meetings, in which we discussed my conjectures and emerging hypotheses, revised those conjectures, and sometimes discovered new ones.

My process for creating and using the memos was iterative and discursively connected to the transcription data. That is, each memo resulted in my seeing the transcript data in different and sometimes contradictory ways. Each week in the fall of 2012, during my analysis phase, I created a new memo that involved creating a different chart or graph of these data, descriptive data about the frequency tables on the types of utterances for each participant structure, or new matrices on which to represent different ways to explore the relationships between themes (Miles & Huberman, 1994).

For example, one memo analyzed a count of the number and types of utterances coded as each of the science practices (see Appendix F) for each teacher for each lesson. Collectively (e.g., across all three teachers), there were 324 utterances about science practices in the 13 observations that were recorded and transcribed.[4] Of these, 120 and 126 utterances about science practices occurred in whole group and small groups respectively. Since these represented the majority of the types of utterances, the analytic writing about these data helped me to make decisions about where to direct my attention for the microanalysis. In other words, I decided that very few science practices were discussed in one-on-one discussions, and those discussions tended to be very short, I knew to focus my further analytic attention to the whole and small group conversations.

In another example, I wanted to understand how the nature of talk across the scope of the LTI, that is in terms of time. Therefore, I produced a matrix with "open-ended" on one axis and "product-oriented" on another. Inside the matrix, I placed utterances of teachers specifically about science practices and processes (NRC, 2012), and noted the patterns that arose. This memo helped me to see the tensions between teachers' talk about science as being between a pull toward the more centralizing – as in the centripetal sense (Bakhtin, 1981) – or product-oriented utterances, and the utterances which push the science discourse outward from the center – in the

[4] Due to technical and scheduling issues, two recordings of teacher talk were lost or not available.

centrifugal sense (Bakhtin, 1981) – or, in other words, those utterances which afforded the students more open-ended writing and thinking tasks. This memo helped to generate a portion of the argument that I will make later in this dissertation.

Still another memo helped me to see how the literacy codes played out across all three teachers' talk. In 435 total utterances coded using the literacy frame (see Appendix E), I was able to determine that for all teachers, observations 3 through 5 – which represented the planning and writing stages of the LTI – included the most talk about writing. This memo helped me inside another perspective that I will present in chapter 5, that teachers' ideas about how to write in science nearly always intertwined with the ways that teachers talked about doing the investigations themselves. Finally, a combination of these and other memos helped me to theorize about a "trajectory of teacher and student engagement" that I discuss in the analysis chapters.

Summary

In sum, these data collection and analyses involved both art and science. These processes challenged and informed every aspect of this work. In fact, it is through these practices that the focus of this dissertation shifted frames from what I originally conceived – from one about the nature and differences between and among participation structures (Phillips, 1983), to one about the trajectory of engagement of long-term investigations. In this way, discourse analysis, though oftentimes is presented as a scientific practice, highlighted by an insistence on systematicity (Johnstone, 2008). But, as I practice it, discourse analysis feels more like an iterative combination of strategies for understanding. It feels kaleidoscopic. Add to this the challenge of conducting a discourse analysis of teachers in classrooms with students and technology and science materials and small group dynamics and the hubbub of the school day, and discourse analysis is far more multicolored than one might expect. This has been my own science inquiry experience.

Chapter 3:

Setting the Stage:

Urban Advantage, the Lead Teachers, and their Classrooms

In this chapter, I present the Urban Advantage professional development program (www.urbanadvantagenyc.org), the context within which this research was conducted. I describe the program's goals, structure, and major teaching tools. Next, I describe each teacher's background, teaching assignments, school, classroom, and students. Lastly, I discuss the similarities and differences amongst and between the teachers to paint a more complex portrait of the context in which this study took place.

Urban Advantage

Urban Advantage (UA) is a professional development program serving New York City public middle school teachers (grades 6-8). Begun in 2004, UA is a partnership between eight science cultural institutions and the New York City Public Schools (NYCPS) to support middle school teachers and their students in conducting long-term science investigations, called “exit projects.”[5] All 8th grade students in NYCPS are required to complete an exit project in which they engage in scientific inquiry through answering questions and developing scientific explanations while using standard scientific practices (NRC, 2012). UA's mission is to answer the call for high-quality inquiry-based teaching, to support the efforts of the district in helping middle school teachers teach through an inquiry stance, as well as developing strategies for writing evidence-based explanations and scientific argumentation.

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[5] In addition to the New York City Public Schools, the science institutions who are a part of the UA program are: the American Museum of Natural History, the Bronx Zoo, the New York Botanical Garden, the New York Hall of Science, the New York Aquarium, the Brooklyn Botanical Garden, the Queens Botanical Garden, and the Staten Island Zoo.

UA takes a situated learning approach to professional development; the program staff assume that learning is contextualized, situated in and among various participants and communities that both use and offer various resources (Cohen, Raudenbush, & Ball, 2003; Wilson et al., 2012). The program views learning as best supported through a broad range of material, professional, and personal resources (Cohen, Raudenbush & Ball, 2003), such as the NYC's cultural institutions, local scientists, parents, and administrators. The program includes six components (Wilson et al., 2012) designed to support teachers, students, parents, administrators in teaching and learning about authentic science inquiry practices (NRC, 2012), including:

1. High-quality professional development for teachers and administrators
2. Classroom materials and equipment that promote scientific inquiry and authentic investigations
3. Access to UA Partner institutions through free school and family field trips
4. Outreach through family events, celebrations of student achievement, and parent coordinator workshops
5. Capacity-building and sustainability structures, including a network of demonstration schools and support for the development of lead teachers
6. Assessment of program goals, student learning, systems of delivery, and outcomes

Largely funded by NYC, schools participate in UA voluntarily. Some schools have a handful of trained UA teachers, while others have required that all staff participate. The three teacher participants in this study teach in schools in which the entire science staff has attended UA programming for at least one year, including the school principals.

In the first year, UA teachers receive 48 hours of PD within three "cycles." Subsequent years involve a series of continuing teacher workshops in which teachers have opportunities to deepen their knowledge of a particular content area (e.g., life science, physical science, earth science) or scientific practices (NRC, 2012). In the first year, Cycle 1 is a two-day workshop that introduces teachers to the UA teaching tools, long-term investigation design, and the various workshop options and scientific investigation types they will choose for Cycles 2 and 3.[6]

During Cycles 2 and 3, teachers conduct long-term investigations firsthand (e.g., field studies, controlled experiments, design experiments, or secondary research). They participate in investigation design, data collection, data analysis, and write up their own exit project (Wilson et al., 2012). For example, teachers who choose to complete Cycles 2 and 3 at the New York Botanical Gardens spend several Saturdays conducting investigations about plants and ecosystems. They gather data on soil quality on the NYBG grounds, using soil thermometers and pH meters, and bring samples back to the lab/classroom space where they test for nitrate and phosphorous levels. They test water quality of the Bronx River. They compare the observations (e.g., measurements) to previous research on relevant variables, including dissolved oxygen, temperature, sediment levels, pH, phosphorous levels, macro and micro-invertebrates living in the river.

By design, the UA PD engages teachers in science experiences that closely emulate the day-to-day work of professional scientists. Through these experiences, questions and decision making processes similar to those of scientists arise from their conversations: Where should we sample? How many samples do we take? How often? Why? What other factors may affect the

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[6] Like many professional development programs, UA's content and structure evolve over time. The description offered here is being revised, but this description accurately represents what the teacher participants experienced at the time of their participation.

results of sampling and of testing soil or water quality? What may impact the accuracy of our data collection? How do I make sense of data that does not align with what I know about ecosystems? Further, participants' decision making and questioning also occurs in teams of colleagues who push each other to scrutinize their own knowledge, to argue for a position, to make scientifically reasonable decisions about the procedures they will enact in collecting and analyzing data. Finally, participating teachers present their investigations – their own exit projects – in formal presentations on the last day of the PD. They have opportunities to field questions from colleagues, and to discuss improvements or next steps in their research. In short, they work as scientists. Although UA does not explicitly tell teachers how they should use these experiences in their classrooms, the UA staff believe that these experiences -- rooted in social constructivist and situated perspectives on learning -- will influence science teaching and help teachers develop similar opportunities for their students.

In addition to experiences in *doing* science, UA also provides time for teachers to take stock in these experiences, to design classroom applications that are specific to their own teaching contexts. At most UA professional development meetings, teachers are given substantial time to gather around tables with colleagues from other schools to discuss how to develop inquiry-rich experiences for their students or to discuss how their classroom efforts are unfolding. Teachers develop long-term investigations in light of their local curriculum and *the National Science Education Standards* (NRC, 1996), as well as the *Framework for K-12 Science Education* (NRC, 2012) and the *Common Core State Standards for English Language Arts and Mathematics* (NGACBP, 2012). Teachers ommit to trying one new idea in their classrooms and reporting back (as well as offering others feedback) about it in the final PD session (usually mid-

March). In this way, throughout Cycles 2 and 3, teachers participate as both learners of science and (learning) teachers of science.

As the long-term investigation (the exit project) that UA hopes teachers will use with their students is central to this effort, here I provide more detail both about that project and the concepts and tools provided to participants to support their classroom efforts.[7]

The exit project. All NYCPS 8th grade students are required to conduct long-term science investigations designed to answer a specific scientific inquiry. One feature of the NYCPS science curriculum is that it differentiates between different types of scientific research and thus there are four types of exit projects: field studies (e.g., collecting data from field observations about the relationships between variables such as water quality and microinvertebrate populations), design studies (e.g., designing and testing a tool to satisfy some specific need or use), secondary research (e.g., investigating and describing relationships between variables taken from large data sets from organizations such as NOAA), or controlled experiments (e.g., fair tests of the relationships between variables of some phenomenon).

The exit project is designed to actively engage students in scientific practices (NRC, 2012) such as writing a researchable question, developing a hypothesis, and designing and carrying out a set of procedures to investigate the relationships between variables, data collection, and constructing scientific explanations that include a claim, evidence, and reasoning.

UA participants are provided with various scaffolds to support their own investigations and those of their students. For poster presentations of exit projects, students and teachers use

[7] Sixth and seventh grade teachers are not required to do an exit project, but they were encouraged to engage their students in long-term investigations. While eighth grade teachers are required to do exit projects, there is considerable variation in how that policy is implemented. Here I describe the program's aspirations, without making claims about how well this model was then transferred into teachers' classrooms.

PowerPoint slides that include: a title, a researchable question, a hypothesis based in background knowledge, procedures, data presented in charts or graphs, and a conclusion based in the evidence presented. In the study I present here, I focus on what happened in three teachers' classrooms as they helped their students engage in long-term investigations over the course of the school year.

UA schools require students to display their projects in an end-of-year science expo at the school. Each UA school then chooses several projects, across grades six through eight, to represent their school at the Annual UA Science Expo at the American Museum of Natural History (AMNH) each June. This event, hosting more than 400 projects across some 120 UA schools, is a highlight of UA (www.urbanadvantagenyc.org). Hundreds of middle schoolers, sheparded by their teachers, and accompanied by their parents, caregivers, sisters and brothers, aunts and uncles, set up posters in the museum's halls and present their findings to the other families, teachers, administrators, and scientists who are milling around the posters. The exit project then, has some importance, especially for students who want to participate in this huge science fair, which is an honor for teachers, students, and their families.

Tools. UA provides several different teaching tools that help to guide students along each step of creating their investigations. These tools help teachers structure students' learning and work, and support the development of a shared scientific vocabulary for investigations (Mikeska et al., 2012; Wilson et al., 2012). One such tool is the Investigation Design Diagram (IDD or, "ID" as UA participants call it), which is a graphic organizer that helps students record the different components of the investigation design: title, question, hypothesis, independent and dependent variables (IV and DV), constants, and levels of the IV (see Figure 3.1).

Investigation Design Diagram (ID)

Title:
Question:
Hypothesis:

Independent Variable:					
Change in independent variable:					
Number of repeated trials:					

Dependent Variable:
Constant variables:

Figure 3.1. Investigation Design Diagram

Meant as a planning tool, the graphic does not provide space for students to record results, write scientific explanations, or to draw conclusions. That work is done with the help of the Developing Scientific Explanations Tool (DSET), another simple graphic organizer that helps teachers to guide students through the process of composing a scientific explanation that involves the claims, evidence, and reasoning involved in their investigation (see Figure 3.2).

In addition to these two tools, UA staff provide others to support teachers. The Exit Project Rubric, for example, structures how teachers assess students' final projects. Teachers also sometimes use it as an instructional device so that students may conduct peer reviews, or in ongoing evaluation of their own projects.

While teachers are free to use these resources as they see fit, these tools generate a particular way of doing -- and of talking about -- scientific inquiry that will become apparent in this study.

Lead Teachers. The UA program recruits and trains teacher leaders across the city to join a professional development team at each cultural (partner) institution (see component 5 above). "Lead teachers" (LTs) are full time middle school science teachers in NYC who commit 96 hours outside of their classroom teaching hours (www.urbanadvantagenyc.org); their role is to assist in designing and delivering the UA professional development program, consulting with teachers individually at each school, and assisting with curriculum development at the partner institutions and UA schools. A year-round position, LTs are paid a small stipend (roughly $4000), commit to working with teachers in schools throughout the school year, and attend teacher leader professional development. UA leaders regard the LTs as vital, integral members of the program.

Developing a Scientific Explanation Tool (DSET)

What is your question?

Support for your explanation

Claim based on the evidence (What is the answer to your question based on your evidence?)	**Evidence (observations/data that answers your question)**	**Scientific Reasoning (why you think this happened based on background resarch)**

Scientific Explanation = Claim + Evidence + Science Reasoning

My claim is <u>(fill in with above claim)</u> because <u>(evidence and science reasoning)</u>

Figure 3.2. The Developing Science Explanations Tool

Teachers become UA lead teachers through a multi-step process. UA staff might approach a particularly enthusiastic or talented UA participant or a UA teacher might approach the UA staff to express his or her interest. Then teachers apply for a position with their chosen science institution. UA staff assess the applications for evidence of science knowledge, teaching experience, full participation in UA, and success in helping students complete exit projects. Prospective LTs also provide examples of student work, and submit a written statement about their vision of high quality professional development. Finalists are interviewed by the UA curriculum director at the chosen institution (i.e., the Bronx Zoo, the Brooklyn Botanical Gardens), and several program staff. Thus, the LTs can be seen as the "cream of the crop," which made them an appropriate population to sample from for this study.

While the three LTs in this study were immersed in UA, they were also immersed in their schools, to which I now turn.

The Lead Teachers, Their Schools, and Their Students

Diana. Diana is a six-year veteran teacher, currently teaching 7th grade science and mathematics at the Middle School for Math and Science (MSMS), a linguistically diverse, mostly Spanish-speaking science-focused middle school.[8] Diana is a White native New Yorker, who knows the community where she teaches. Although she does not live in the neighborhood, she has become connected to the parents and families through her work with UA and as a school leader. Like other UA teachers, she provides as many opportunities as possible for her students to learn science outside of school, organizing field trips to the city's science institutions (supported by the UA program) at the AMNH and New York Botanical Gardens, among others. Diana's connection to UA and the resources it provides is an important piece to her identity. She once said to me, "I don't have a sense of who I would be as a teacher without UA."

Growing up, Diana had no intention of becoming a teacher. As an undergraduate mathematics major, a mentor encouraged her to take coursework in geology. With some skepticism, she did, discovering that she loved it. Within a year, she switched her major to

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[8] All names and places are pseudonyms.

geology and upon graduation enrolled in a Master's program in environmental engineering. There, she got a job working as an intern with an environmental engineer for the NYC Department of Environmental Protection (DEP) doing groundwater research. But she "ended up hating it"; working as a scientist was not as fulfilling as she had hoped: "There wasn't the level of science" that she wanted. She quit the MS program and, because she needed a job, ended up teaching in a pre-school.

Her “accidental” work as a pre-school teacher led to an epiphany that Diana clearly recalls. In one pre-school science unit, she made a scale model of the solar system and mounted it inside the room, even using the classroom bathroom. She realized, "I was getting so technical and so excited about this solar system thing, I was thinking I should probably not be teaching three year olds. Probably..."

So she entered graduate school again, this time to study earth science education at a local college. Another mentor who was teaching at MSMS encouraged her to apply for a job. Although her original plan was to teach high school earth science, teaching with her mentor at a science-focused middle school was an opportunity she could not pass up. During her very first week at MSMS, Diana was encouraged to also enroll in Urban Advantage. UA made an impact on her, as she immediately enrolled in advanced PD sessions, and after two years of teaching experience, UA staff (who recognized her strong content preparation) encouraged her to apply to be a lead teacher. The invitation stood as a testament to Diana's strength as a teacher, as most UA lead teachers have more experience than she does.

As a science leader, Diana coordinates science units and plans -- especially the school-wide science fair -- with the other teachers in her building. In addition to working at her assigned partner institution, Diana’s school-based responsibilities include helping other UA teachers get the materials they need, keep up with the professional development offerings, and supporting any other UA needs teachers voice. All of the MSMS teachers have now been trained in UA, so her school-based responsibilities are few; her colleagues have become independent in their use of the UA tools and teaching investigations.

Diana is highly regarded by her peers and principal. Twice I saw other teachers come into her classroom asking for advice about a lesson plan, or to borrow science materials. On one occasion, I was able to meet the principal, Ms. Wilson, who visited Diana's class during a lesson. Standing at the side of the classroom, Ms. Wilson smiled the entire time. She also interacted with the students, asking them questions, participating in their discussions about preparing Petri dishes to collect bacteria samples from different places in the room. They discussed how to label the four different zones on the Petri dishes so that the students could later compare three different locations to each other in the same Petri dish (one space would become the control, where no bacteria would be collected). Ms. Wilson added that it was important that the students be very precise in their observations, as well as in their descriptions of the locations they choose to collect their bacteria.

The neighborhood surrounding Diana’s school is marked by wide busy streets, narrow storefronts, and high-rise apartment buildings. Most businesses in the neighborhood serve the local Spanish-speaking population and the various other cultures that reside there. The diversity of cultures -- reflected in the conversations overhead on the street and in the music pouring out from storefronts and restaurants -- is everywhere apparent.

Diana’s school is one of NYC's historic school buildings, an impressive three-story brick mid-19th century building that takes up an entire city block and houses both a high school and MSMS. At the entrance, stalwart white columns tower above two long flights of grand concrete stairs that welcome guests from the quiet side street below. While inviting, entering Diana's school is a process. Once past security in the entry, MSMS is located on the second floor, up a set of stairs hidden from view, down another long hallway, through a set of double doors. The school takes up both the east and west wings of the second floor (a relatively small portion of the building). Inconveniently, students must walk down a long corridor in-between the wings, passing through the high school to move from class to class.

The school's demographics reflect the diversity of the NYCPS. About 361 students are enrolled, seventy three percent are Latino/a, 23% African American. The rest are a mix of Caucasian, Asian, and Native American. Classes average on the order of 32 students, and 96% are on free and reduced lunch. Ten percent of the school is Limited English Proficient.

Diana's classroom is on the far end of the east wing, about as far away from the main entrance as anyone can get. The room is relatively small for her 32 vivacious 7th graders. And it is not a science-specific classroom; there is no furniture that would evoke science – no sinks, no storage areas, no special fire- or chemical-resistant tabletops. Just 32 chairs situated around eight small groups of desks pushed together. But science lives in the room regardless. Bins full of science supplies – measuring tools, plastic tubs, planting supplies, etc. – fill the cupboards along one wall, while well-organized racks of resources – handouts, books, magazines – line another. Diana uses a Smart Board to teach science lessons, which allows her to call up websites and interact with documents along with her students. The tools of her practice are everywhere apparent.

The room faces north and is not bright, even with the overhead lights on; the light blue paint exacerbating the room's shadiness. Even the large windows that stretch from the tops of the counters to the tops of the 15' ceilings provide surprisingly minimal light. Sound echoes loudly in the long, narrow room, reverberating against windows and desks, hard floors, and a bank of closet doors on one side of the room. Exuberant middle school voices create an impressive din, but Diana is not lost in the choir. Her presence is strong; she is relatively tall, with a strong presence, and speaks authoritatively, assuredly, and enthusiastically and students can hear her clearly across the room. The audio equipment I used picked up her voice anywhere she was.

MSMS has an air of formality, and Diana's easy-going nature and motherly care of her students' various needs balances this formality well. On one afternoon, for example, I arrive to her classroom during the lunch period. Instead of going outside for the 30-minute break, a small group of students have convened in Diana's classroom to watch a movie and generally "hang out." And while Diana uses this time to grade papers and organize materials for the upcoming science lesson, she socializes with her students, asks one student if she's feeling okay (she had missed school because of illness the day before), and makes inside jokes with others. She is in charge here, and her students know her boundaries; they thoroughly enjoy being in her space.

School uniforms are required (dark blue pants and light blue shirts), and each day students are again reminded of how to wear them. Students call teachers by their formal names – many of Diana's students call her "teacher" or "Ms. S," or simply "miss." Like the other teachers, she does not wear a uniform. A 30-something stylish woman, Diana wears her long dark hair in one easy ponytail, and is always dressed in professional clothing, usually black dress pants, a colorful blouse, and easy black shoes.

The MSMS students are predominantly Spanish-speaking children from many different cultural groups, new immigrants, or children of immigrants. They file into the classroom bringing their schoolyard conversations and frustrations with them, arguing, whispering secrets, plot afterschool rendezvous. They laugh and tease each other, as well as Diana. They ask her for help with things unrelated with school. They eagerly ask her questions about what is on the schedule for the day's activities. They crowd around her at the beginning of class in a tangle of adolescent concern and worry and need. Diana refocuses them instantly, all the while being able to seemingly work through each special request. With the coordination of an experienced waitperson in a popular diner (Rose, 2004), she handles the flurry of teenage needs flawlessly.

Diana's is the only White face in the room. Her class includes a large Spanish-speaking population (a mix of Hispanic and Latino/a students), a small percentage of African American students, students from African countries, and Chinese students. The class in which I observed includes 31 students. Eight were English Language Learners (ELLs), and five are former ELLs (e.g., students who have passed the English proficiency test). The rest are general education students (i.e., those who receive no additional academic support). She teaches science to this class five and one-half hours each week, and one homeroom class a week. She also is responsible for another section of 30 students for mathematics and science (each for five and one-half hours a week). Her students score with 2s and 3s (out of a total rank of 4) on the state test, comparable to the rest of the school’s students. Some have repeated a grade in school, therefore are a year or more older than the other 7th graders.

According to Diana, her students often relate to each other by cultural group: the Mexican students tend to socialize in small insular groups, often only talking (especially in class) to other Mexican peers. She sees this as a way for the students to support one another: some "may only have been here for a short time." Her two Chinese students also tend to want to work together; because one is more proficient in English than the other, she allows this, hoping that their shared language and culture can enhance their learning and confidence. Speaking only minimal Spanish and no other languages than English, Diana calls upon her students to be helpful to one another as often as possible.

As we will see in later examples from Diana's classroom, she is deeply interested in what she is teaching, and works hard to find the best ways to engage her students. She has high expectations of them, yet recognizes when they need additional time or assistance.

Carrie. Carrie is the sole 6th grade teacher at the Science Academy, another small science-focused middle school situated in a neighborhood very different from Diana's. A 10-year veteran, Carrie is a National Board Certified teacher. A young African American New Jersey native, Carrie's energy is infectious. She is a slender, athletic young woman who wears a bright smile, easy clothing (sometimes running shoes), a long straight ponytail, and speaks in enthusiastic bursts. Her colleagues and her students brighten in her presence.

As with Diana, Carrie took an alternative path to teaching. She began college as a neuroscience major, with aspirations to enter medical school. As she was about to take the MCAT, and contemplating whether she was ready for medical school, a mentor encouraged her to join Teach for America (TFA). For Carrie, that first teaching appointment was one of the hardest things she has ever done.

> And I couldn't leave . . . I was like, alright, I should be taking my MCAT now and when my two year commitment is done . . . I could go to med school, and I'm like, "but I can't leave" . . .Until four years ago, I had one foot in the door and one foot out the door, and then it was like, "Carrie, let's be honest with yourself here... you're in here for the long haul, you're not leaving."

After Carrie completed TFA, she began teaching in New York City and after teaching at another middle school for two years, was drawn to teach at the Science Academy (SA), a highperforming school, with most of the students scoring 3s and 4s on the state tests. She has been at SA for seven years.

Like Diana, a mentor encouraged Carrie to sign up for UA, and she has been part of the program since her first year at SA. As lead teacher, Carrie has little responsibility at her own school, because, like Diana, all of her colleagues are also part of UA, including the special education teachers. Thus, at her own school, Carrie mainly helps with ordering supplies from UA, or assists other teachers when they ask for help. Most of her work as a lead teacher occurs at her partner institution, where she assists in planning and delivering the UA professional development throughout the calendar year.

The Science Academy is located in an affluent neighborhood in NYC. It is a culturally diverse neighborhood, hosting many white collar professionals and academic families from different countries. Restaurants, playgrounds, historic parks and buildings, and high-end shopping areas are within a short walk. The school is housed on the upper two floors of a six-story building on a quiet one-lane side street (an elementary school inhabits the first four floors). If one did not know the school is there, it would be easy to pass by without noticing it. Just one small sign perched above the school's double doors announces its presence. Across the street is the school's playground, a paved courtyard with several basketball areas, enclosed in a high fence.

Once inside the building, SA students rush by me on the stairs, seeming unaffected by the intense cardiovascular workout entailed in climbing five flights of stairs. (Teachers take the stairs much more slowly.) Once through the doors, the school is bustling with pre-teen energy. On many of my visits, I arrived during passing time, where students stream through the hallways talking, laughing, boys and girls teasing each other from a distance. Girls stand gossiping in large clumps by one locker; boys walk three abreast, talking loudly of sports, of a particular teacher, of yesterday's science class.

This is a highly selective science school, and students are selected for their academic standing based on entrance exams, state exam scores, and elementary school grades. Three hundred and eighty six students are enrolled at SA; just under 13% are Latino/a/Hispanic, 4.4% African American, 17.6% Asian, and 64% Caucasian. Sixteen percent of them are on Free and Reduced Lunch; 0.3% are LEP. The students are among the academically elite of the New York schools, often competing for acceptance into the city's best high schools. They are keenly interested in academics, and seem happy to be at school. When the teachers arrive at their doors, students crowd around them, asking questions three at a time. Teachers are called by their first names, come and go from classrooms, and move along the hallway as smoothly and unassumingly as their students. The community seems welcoming, students know that teachers are always available, doors are always open.

The students' sense of autonomy is fostered at SA. Even during lunch hours, several students leave the building and walk to the neighborhood's delis or restaurants for lunch. Many carry cell phones, which are not confiscated by the security officials, although students are not allowed to use them in class. I saw no incidents where a teacher had to ask a student to put away his or her phone, and noticed no subversive texting during class.

According to Carrie, these students are under great pressure to perform, and she senses competition running through their classroom interactions. The pressure to get good grades and to test well in 7th grade, leading to acceptance into the city's best high schools, sometimes challenges the teaching staff to balance the students' social and academic needs. Students worry about grades often. And I heard Carrie on occasion encouraging her students not to ask about how to get the highest score on an assignment. Instead, she redirects their attention toward learning concepts. Sometimes this is met with students' grunts of disapproval, and even more hearty quests for information about performance expectations.

Carrie's classroom is located on the 5th floor. Eight tables are squeezed into the small long rectangular room, leaving little walking room in-between. The room brims with science materials: an incubator, plastic storage tubs, test tubes, books and magazines, meter sticks, computers, planting materials. Student work hangs on the walls, as do classroom-generated posters acting as reminders about how to think through the scientific process, or how to be a good citizen. Carrie's workspace is not clearly marked, but there are tables with her belongings on them throughout the room: an audio-visual cart in the center, a large lab table with curriculum supplies, a small cart at the front that houses Carrie’s teaching supplies for the day, a chair in the corner that holds her lunch and other bags. The tools of her trade are everywhere.

Marilyn. Marilyn is an 18-year teaching veteran from Trinidad who teaches 7th grade at SA with Carrie. A heavy Trinidadian accent punctuates her speech, lilting, expressive. Of the three teachers in this study, she is the only one with recognizably accented speech. A 40-something woman and short-statured, she is confident, energetic, and warm; she commands attention and respect of her students. She is committed to pushing her students to stretch themselves academically, and has a no-nonsense sensibility about her. When I asked her about my visits and about bringing recording equipment into her classroom, she responded with, "You are welcome to come here any time. I am too old and have done this for too long to worry about how others perceive me. I am not a perfect teacher by any means, but I am always working hard to give my students what they need."

Unlike Diana and Carrie, Marilyn did not begin her career as a practicing scientist. She trained as a teacher in Trinidad, where she taught high school biology before coming to New York in 2001 during a large recruitment effort by the NYC schools.

Like Carrie, she cites her first position in her first school as difficult, mostly because of her long commute from home, but also because she felt that the staff was not as supportive as she had hoped. She enjoyed her students, but was looking for collaborative colleagues. After a year at the school, she transferred to another school, but soon learned that the school was being phased out. This prompted her to conduct extensive research to find the school that would suit her. Marilyn applied for a transfer to SA because she was impressed with the curriculum, the students' academic achievement, and the location, which suited her commuting needs.

But her move to SA was not straightforward. At first, she was unsure about the fit: "I am a Caribbean Black teacher and this is not necessarily the most diverse... environment here at SA... and then we're also in [neighborhood name], so I was like, what would this Trinidadian teacher do here?" She decided to interview, but she took some time to decide to come to SA because she wanted to "make sure this was a place where I would fit in." She was comforted by finding out that her principal was also from Trinidad, that the students at SA were much like the students she had had in Trinidad, that they were invested in their work, and formed close bonds among each other and to her. She was looking for a supportive teaching and learning community, and SA proved to be it.

Like Carrie, Marilyn came to UA after being encouraged by another teacher at SA who had been involved in years past. She reports learning a lot from UA, especially how to do a long-term investigation. UA has been an important professional development experience for her, in that it changed her teaching practice dramatically. Currently, she is the SA science department chair, works on science curriculum at SA, and works at her UA institution to deliver PD programs to other NYC teachers.

Marilyn's classroom is next to Carrie's and though they teach different grades, they collaborate often. One of their goals is to have students learn a similar way of talking about science when they move from one grade to another. In this way, when the 6th graders come to Marilyn's classroom, she already knows the kinds of science experiences they have had, and can work from there.

Like Diana's and Carrie's classrooms, Marilyn's classroom is full of science supplies. A large plant lab takes up one corner, laptop computer carts and books in another, an incubator and bins and fish tanks, bags of planting supplies, boxes of measuring tools. There are bins with student notebooks and journals on one countertop. And handmade class posters fill the walls. Three large hexagonal sink stations are mounted into the floor, lined up down the center of the room. These represent the only other physical evidence that this is a science-specific classroom. The student tables are arranged in groups of four to six, and can be moved around the room to accommodate several different configurations. This is an active space, filled with the buzz of 7th graders working and negotiating, arguing, teasing, laughing, flirting.

There are 33 7th grade students in Marilyn's classroom. They are a diverse mix of students, culturally, linguistically, and academically. As in Carrie's class, students speak a variety of languages at home, such as Spanish, Chinese, Russian, but they do not currently receive language services at school. A few students have Individualized Educational Plans (IEPs) for special education services, and Marilyn works closely with a special education teacher to plan science lessons and appropriate interventions for them.

Marilyn talks fondly about her students, describing them as warm, energetic, and highly competitive. Since 7th grade test scores and academic grades are used to determine their high school entrance eligibility, she too recognizes the extra pressure that is placed on her students, from family, parents, other teachers, as well as the school. She does not expect to be able to combat that competitiveness, but instead sees herself as a teacher who can help them to learn as much as they can while supporting their particular developmental needs:

> So it's not only doing their best, 'cause their parents are like “You need to get 95s and above,” but they're also working on, you know, that prep for the test for specialized high school, so you know, sometimes we try to be mindful of the fact that they're going through so much as well as all the normal things that come around with puberty.

According to Marilyn, another characteristic of her students is that they are helpful to each other, accepting and open to students who need special accommodations. While they are also understandably influenced by peer pressure to feel otherwise, SA students appear to be genuinely interested in each others' well-being. For example, during one visit, a student praises another student who usually struggles when he contributes a great idea for their group project. The student leader who offered the praise, turned the moment into a game, offering special (imaginary) "points" to the student for being "brilliant." Others in the group followed suit; they too agreed that the idea is brilliant, playing along by distributing points when someone else offered a good idea. At ease with one another, Marilyn’s students also contributed to my own sense of ease.

Summary

While the study participants teach in different contexts, with all the attendant social and cultural differences in the communities in which they teach, they share similarities. As UA lead teachers, having the same professional development training, they approach scientific investigations in much the same way. They use the UA tools throughout the year, especially during the investigation that leads to the school science expo project. Students work in small groups, and are expected to talk to one another and participate fully in whole group conversations. All three adapt the UA teaching tools (e.g., the IDD, DSET and Exit Project Rubric) to meet their students' specific learning needs.

The starkest differences between the two schools relate to socio-economic factors and student achievement. Diana's school is located in a low-income neighborhood where Spanish is the predominant language, and students typically score 2s and 3s on the New York standardized exams. A majority of Diana's students speak Spanish and other languages, and several have received ELL services in the past. In contrast, Carrie and Marilyn's school is located in a neighborhood with white collar professionals and academics, where English is the dominant language (and other languages are spoken at home), and where students score 3s and 4s on the NY exams, only a few of those students having ever received ELL services in the past. Diana and Carrie, both raised in the New York area, were trained as scientists before choosing to teach, and each had entered the teaching profession through non-traditional means. But Marilyn was trained as a science teacher in Trinidad, and had not previously worked as a scientist.

Chapter 4:

Engaging Science Practices in Long-term Investigations

In chapter three I presented each teacher and the structure of her long-term investigation. In this chapter, I describe how teachers engage students in particular science practices during the LTIs (Achieve, Inc., 2013). Recently, the science education community has sought clearer and more uniform ideas about what it means to “do” science – or to engage in scientific “inquiry” in P-12 classrooms, arriving at eight practices which "emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice" (NRC, 2011, p. 30). These include:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Engaging the science practices involves multiple kinds of investigations. The NGSS (Achieve, Inc., 2013) states that "at all levels, [students] should engage in investigations that range from those structured by the teacher—in order to expose an issue or question that they would be unlikely to explore on their own (e.g., measuring specific properties of materials)—to those that emerge from students’ own questions" (NRC, 2011, p. 61).

These ideas come to life in Diana, Carrie, and Marilyn's classrooms, as each developed LTIs that engaged students' questions, as well as those that they would "be unlikely to explore on their own." For example, Diana introduced students to a secondary research project on the Hudson River ecosystem - a topic (and an investigation design) that they were unlikely to study on their own, while Marilyn provided opportunities for students to develop their own questions using the most suitable investigation design. Carrie, on the other hand, created an LTI in which students had some choice about topics and investigation types, but those choices were constrained to among a few possibilities. Across all three teachers, unless students' families were particularly interested in science, it is unlikely that the students would have had opportunities to engage in such inquiries outside of school.

In this chapter, I focus my analysis on two specific practices most observed across all three classrooms: Practice 3: planning and carrying out investigations and Practice 8: obtaining, evaluating, and sharing information, which comprised 75 percent of all of the utterances for all fourteen observations.[9] In other words, teachers talked about these two practices most often than any others during the LTI. For this reason, I nominate these two practices as significant to these teachers' processes for engaging their students in the LTIs. It is also important to note, however, that all other practices were present, but together comprised less than 25 percent of the total teacher utterances about science practices.

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[9] Using the codes for utterances of science practices (as defined by the NRC, 2011), I identified 324 total practice-based utterances across all lesson observations. Of those, 96 teacher utterances (or 30%) were about planning and carrying out investigations, and 144 utterances (or 45%) were about obtaining, evaluating, and sharing information. I coded each practice as a combination of their component parts. That is "planning and carrying out investigations" was coded as two different practices, all but 6 of which were about "planning" specifically. Similarly, the practice, "obtaining, evaluating, and sharing information," 28 utterances were about obtaining information, 27 about evaluating information, and 89 of those utterances about sharing information.

The purpose of this chapter, then, is to describe and explain the ways in which Diana, Carrie, and Marilyn engaged their students in these two practices. I use the term "engagement" to describe how teachers helped students interact with content or scientific practices. In my analysis, engagement was also marked in the micro-analysis of discourse using Tannen's (2007) and Schegloff's (2007) markers of engagement. I will present these markers in the discussions of the transcripts themselves. Broadly speaking, engagement also means involvement in science discourse (Gee, 2008; Lemke, 1990). In this chapter, I show students in scientific discourse as they engage in science practices and use the various instructional and other tools (such as video) teachers use to initiate, support, and sustain such engagement.

Planning Long-term Investigations

Planning a long-term investigation involves multiple conversations over multiple teaching sessions, encompassing a broad range of skills. According to the NGSS, planning entails "...identify[ing] independent and dependent variables and controls... [which] tools are needed to do the obtaining, how measurements will be recorded, and how many data are needed to support a claim" (Achieve, Inc., 2013, Appendix F).[10] In the following discussion, I show how the teachers address all of the aspects of planning according to this definition. To lend clarity to this discussion, I show examples of planning within two sub-categories: understanding variables and working with data.

For instance, I show how Diana provides opportunities for her students to learn about the variables involved in studying the Hudson River ecosystem database. She guides students to understand the tools scientists use to gather the river data so that they can apply those same

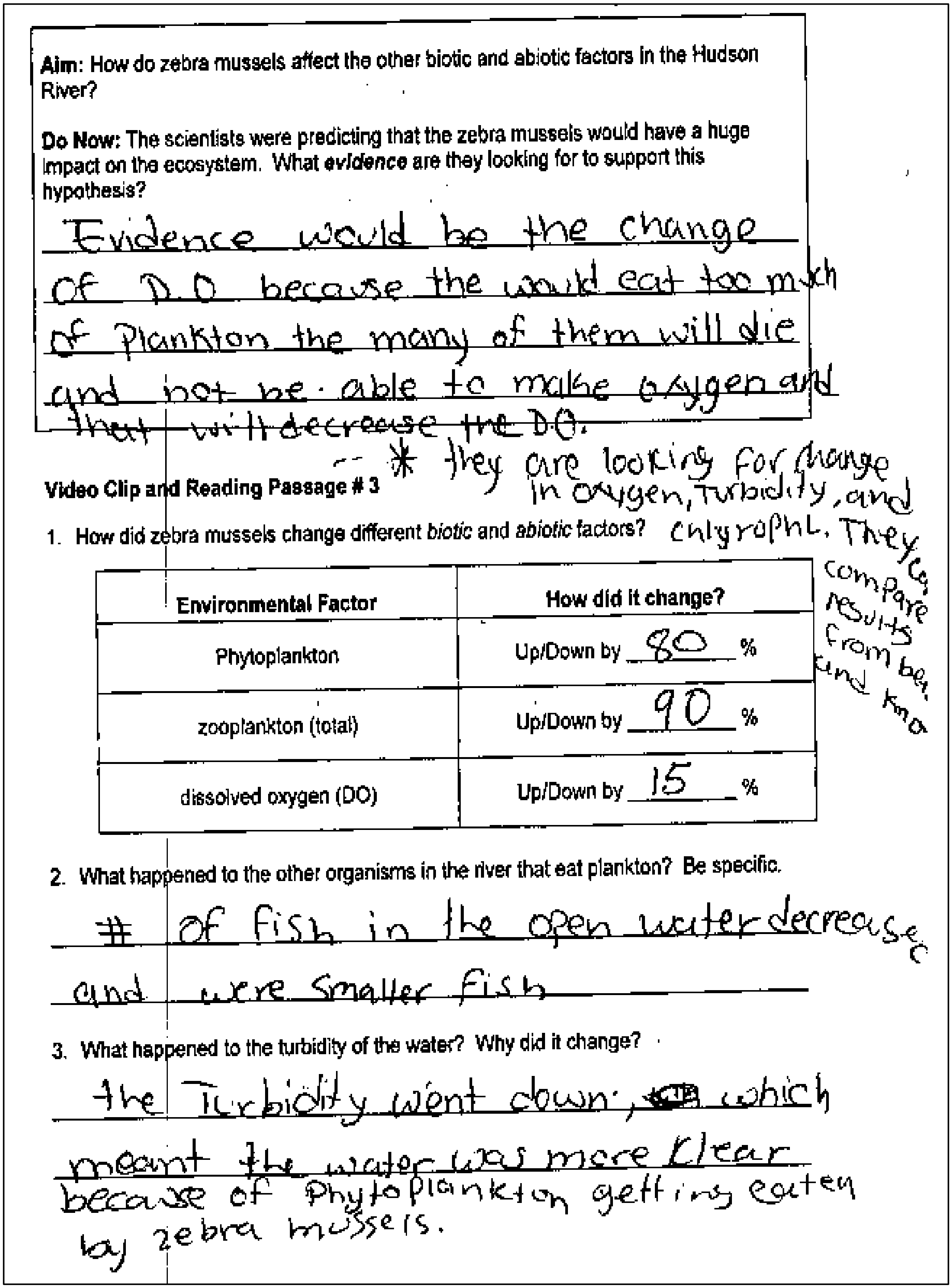
[10] See link to online appendix http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf

strategies in their own plans. I use examples from Carrie's classroom to demonstrate what happens when teachers ask their students to make choices about how to gather data, and "how many data are needed to support a claim." With excerpts from Marilyn's classroom, I provide evidence that shows how Marilyn helped students make decisions about how to record their measurements. Finally, I note how each time teachers engage a practice, they do so with reference to, and using the support of, a textual learning tool of their own design: a graphic organizer, a Do Now sheet, or science journals. I show how these textual tools are also interwoven into the ways teachers taught and engaged their students in science practices.

Understanding the Relationships Between Variables

Students shuffle in to Diana's 7th grade science classroom, take the day's Do Now sheet (see figure 4.1) from the table in the back of the room as they walk by. Pencil sharpening, paper filing, chairs squealing across the floor, the students get settled in to their routine. It is the beginning of their planning for their study on the zebra mussels' impact on the Hudson River ecosystem. The activity affords them to the chance to apply what they know about ecosystem variables to design their own inquiry.

Students in Diana's classroom are conducting a secondary research project using data from a study of the Hudson River ecosystem. As a participant and now lead teacher of UA, Diana has learned how to develop an LTI using secondary research strategies (Mikeska, et al., 2012). Diana launched the unit by contextualizing the research scientists conducted on the river, looking closely at variables the scientists studied (e.g., dissoved oxygen, temperature) and data collection (e.g., how scientists collect data on the variables, how and when they measure dissolved oxygen) in order to make a plan for their own study.



Aim: How do zebra mussels affect the other biotic and abiotic factors in the Hudson River?

Do Now: The scientists were predicting that the zebra mussels would have a huge impact on the ecosystem. What ***evidence*** are they looking for to support this hypothesis?

Evidence would be the change of D.O because the would eat too much of Plankton the many of them will die and not be able to make oxygen and ~~that will decrease the D.O.~~

-- * they are looking for change in oxygen, Turbidity, and chlyrophL. They compare results from be and kno

Video Clip and Reading Passage # 3

1. How did zebra mussels change different *biotic* and *abiotic* factors?

Environmental Factor	How did it change?
Phytoplankton	Up/Down by 80 %
zooplankton (total)	Up/Down by 90 %
dissolved oxygen (DO)	Up/Down by 15 %

2. What happened to the other organisms in the river that eat plankton? Be specific.

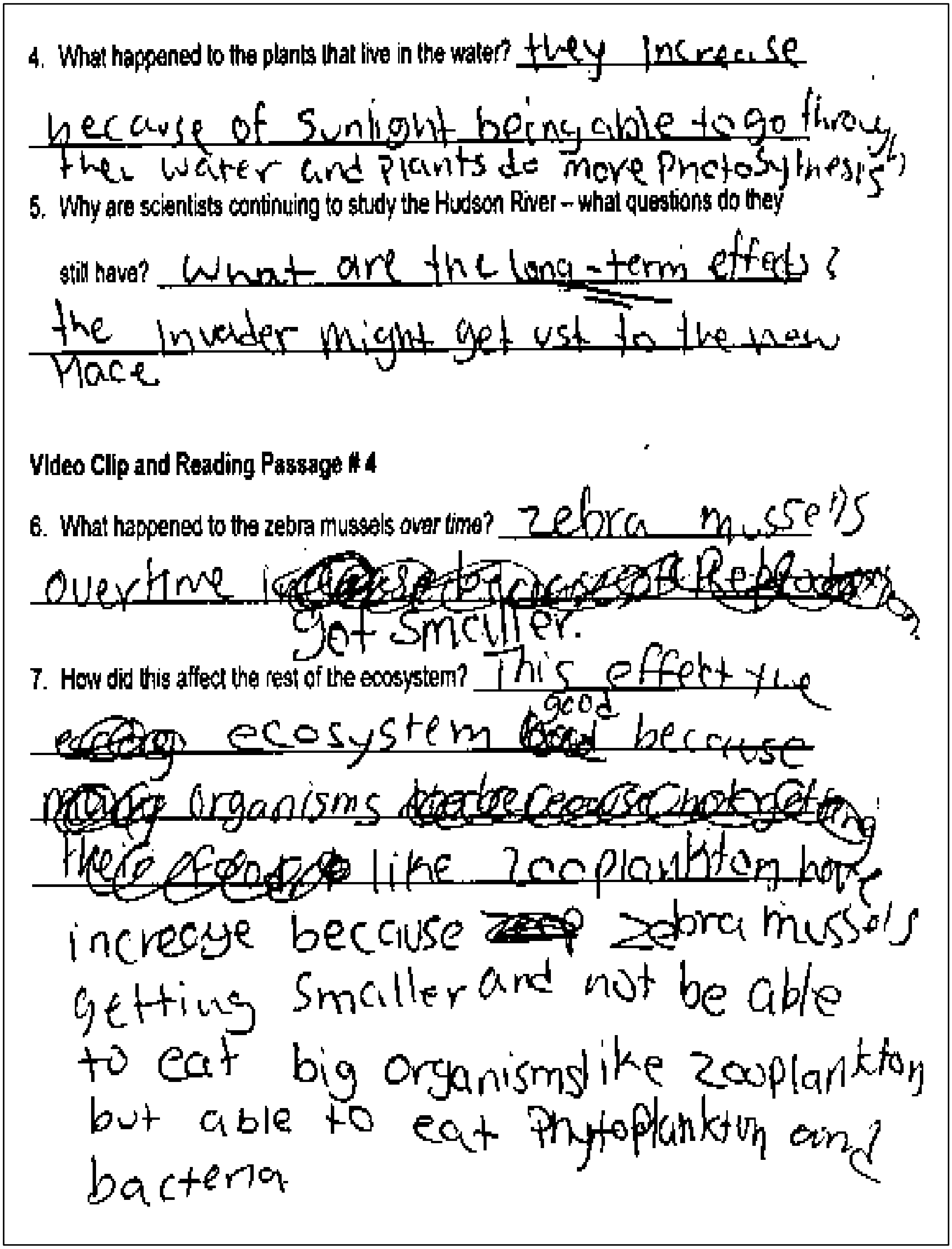
# of fish in the open water decrease and were smaller fish

3. What happened to the turbidity of the water? Why did it change?

the Turbidity went down, which meant the water was more Clear because of Phytoplankton getting eaten by zebra mussels.

Figure 4.1. Do Now Handout from Diana's Classroom (pages 1 and 2 of 3)

(Figure 4.1 Cont'd.)



4. What happened to the plants that live in the water? they increase because of sunlight being able to go throug the water and plants do more photosynthesis

5. Why are scientists continuing to study the Hudson River – what questions do they still have? What are the long-term effects? the invader might get ust to the new place

Video Clip and Reading Passage # 4

6. What happened to the zebra mussels *over time*? zebra mussels overtime got smaller.

7. How did this affect the rest of the ecosystem? This effect the ecosystem good because organisms like zooplankton have increase because zebra mussels getting smaller and not be able to eat big organisms like zooplankton but able to eat phytoplankton and bacteria

Figure 4.1. Do Now Handout from Diana's Classroom Cont'd. (pages 1 and 2 of 3)

Diana opens one conversation by asking students to respond to the question at the top of the page: "Scientists were predicting that the zebra mussels would have a huge impact on the ecosystem. What **evidence** are they looking for to support this hypothesis?" Students hesitate to respond, so Diana recasts the question: "How do I know that the changes are from the zebra mussels? Couldn't they be from anything else in the river?" With this question, she offers another way to interpret the question, specifically, the meaning for the term "evidence," and prompts students to consider each variable (oxygen, temperature, turbidity, etc.) in relationship to how the zebra mussel survives in its new ecosystem (the Hudson River). Adrienne is one of the first students to contribute an answer.

1 Adrienne: ((citing her own answer on her Do Now)) Okay. I said that they're looking for changes in the oxygen the turbidity and the chlorophyll.

2 Diana: ((writing on board)) They, are, looking, for, changes.. in what?

3 Adrienne: I said oxygen turbidity and chlorophyll.

4 Diana: Oxygen, turbidity, and what?

5 Adrienne: Chlorophyll.

6 Diana: ((writing for 2 more seconds)) Alright. So, how is that going to support the hypothesis? I agree with you that they ARE looking for measurements of oxygen they ARE looking for measurements in turbidity, and they ARE looking for measures in Chlorophyll. How is that going to tell us whether or not the zebra mussels had an impact?

7 Adrienne: 'Cause they could compare to the information they had before. And the one of um.. the mussels the zebra mussels came and they noticed the changes and see what's the um impact.

This interchange demonstrates how knowledge of the relationships between variables can help students understand how to provide a causal explanation for scientific phenomena (NRC, 2012). Diana asks them to explain how to know whether the zebra mussels caused the changes in the other organisms in the river. Adrienne provides a list of variables (organisms) in the river, but does not explain the causal link. So, Diana uses repetition to draw attention to the idea of causality (Schegloff, 2007). For example, Diana's speech pattern here is "they ARE looking for X variable" in each of her statements in line 6. And each time she does, the point gets made that explaining variables does not necessarily explain the inference she is asking them to make. After Diana's response, Adrienne answers Diana's question accurately and more fully. She states that in order to prove that the zebra mussels have a direct impact on the other variables, the scientists have to compare changes from before and after the zebra mussels arrived in the river (line 7).

But the conversation does not end there. Diana then helps her students uncover each other relationship one-by-one. In another much longer exchange, she asks, "Why did the turbidity change?" Jason offers that turbidity might change because zebra mussels eat plankton so there will not be as many in the water, and thus the water will become more clear. When she asks about the effects of chlorophyll, Kendra attempts a partial answer, "It's a type of phytoplankton." Manuel then says, correctly, that "phytoplankton have chlorophyll." Diana accepts each answer, and extends their ideas as, "we find chlorophyll in phytoplankton." She finishes the connection: chlorophyll is in phytoplankton, and therefore the relationship will be similar to that of the turbidity question from above. As the zebra mussels eat plankton, the chlorophyll numbers decrease. Diana points to the board and writes and underlines the word chlorophyll. When Diana asks about how turbidity is affected, Andrea says, "because the zebra mussels eat all of the phytoplankton." Other students yell from the back of the room: "It [the water] got more clear," "It filtered," and "more sunlight went through." All of their answers are correct. And each time, Diana responds by restating the relationship aloud and writing on the board, adding that less phytoplankton means less turbidity, greater photosynthesis, and writes on the board, "the amount of rooted plants (adding an arrow pointed upward) goes up" (for the example of chlorophyll).

In this example, Diana asks students to respond in writing to a question that asks about the relationships between variables. She solicits their ideas during the whole group discussion and records their thinking on the board. As she does, students copy ideas into their notes. Diana demonstrates that part of the work of helping students to learn how to plan an LTI involves their understanding of the relationships between variables (NRC, 2012). And one way to build that understanding is through joint negotiation and making sense of variables through discussions of phenomena they study firsthand (NRC, 2007). In other words, students do not simply answer the questions on the Do Now sheet and move on without remark; the form itself becomes the guide for the larger discussion about variables. Diana continually returns to it, recording students' ideas on the board so that they can enter them on to the Do Now handout.

And Diana provides multiple ways for students to identify the relationships. For example, she shifts students' attention from the discussion of the first question on the Do Now to the graph from the student reading (see figure 4.2). She encourages them to use what they know about graphs from mathematics class (which Diana also teaches), and points out that she is looking for a general interpretation of the data (NRC, 2007).[11]

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[11] Looking at data is an example of another science practice, "analyzing and interpreting data" that I do not take up specifically in this chapter. However, this part of the discussion was coded as evidence for interpreting and analyzing data as well as "planning and carrying out investigations" (Achieve, Inc., 2013).

Soon after examining the graph, Terrence offers that the graph represented chlorophyll and zebra mussels. Diana then asks students to think about the chlorophyll rates before the zebra mussels arrived in the river (marked by the vertical line near 1992) and what happened afterward. When she asks them to explain what they know about chlorophyll, Manuel, who has answered many of her questions, confidently states, "it's a chemical used in photosynthesis." They talk about the relationships among the zebra mussels (ZMs) and the phytoplankton numbers from before and after the ZM invasion, too. She links this to the chlorophyll numbers, in that the number of phytoplankton are also dependent upon the amount of chlorophyll in the water, that the phytoplankton use chlorophyll, so that if there is less chlorophyll after 1992, there are less phytoplankton. The key relationships are how the zebra mussel affected the chlorophyll numbers and the amount of phytoplankton in the water.

In these examples, Diana used two different textual tools to support her students' emerging ideas about the relationships between variables: the Do Now pages, and the graph and accompanying reading. Students would later apply these relationships to writing researchable questions and hypotheses (NRC, 2007).

Likewise, in the following exchange, Marilyn and three of her students -- Maddy, Jacob, and Caroline -- wrestle with identifying and understanding variables as they launch their plan. Marilyn's LTI is more open-ended than Diana’s in that students may choose the topics (and therefore the relevant variables) under the broader theme of oceanography. In Marilyn’s classroom, students worked for the last marking period of the school year to develop their LTIs. Most worked independently in and out of class time. Marilyn supported their work through a series of mini-lessons in the beginning of the school year that covered the scientific process and practices.

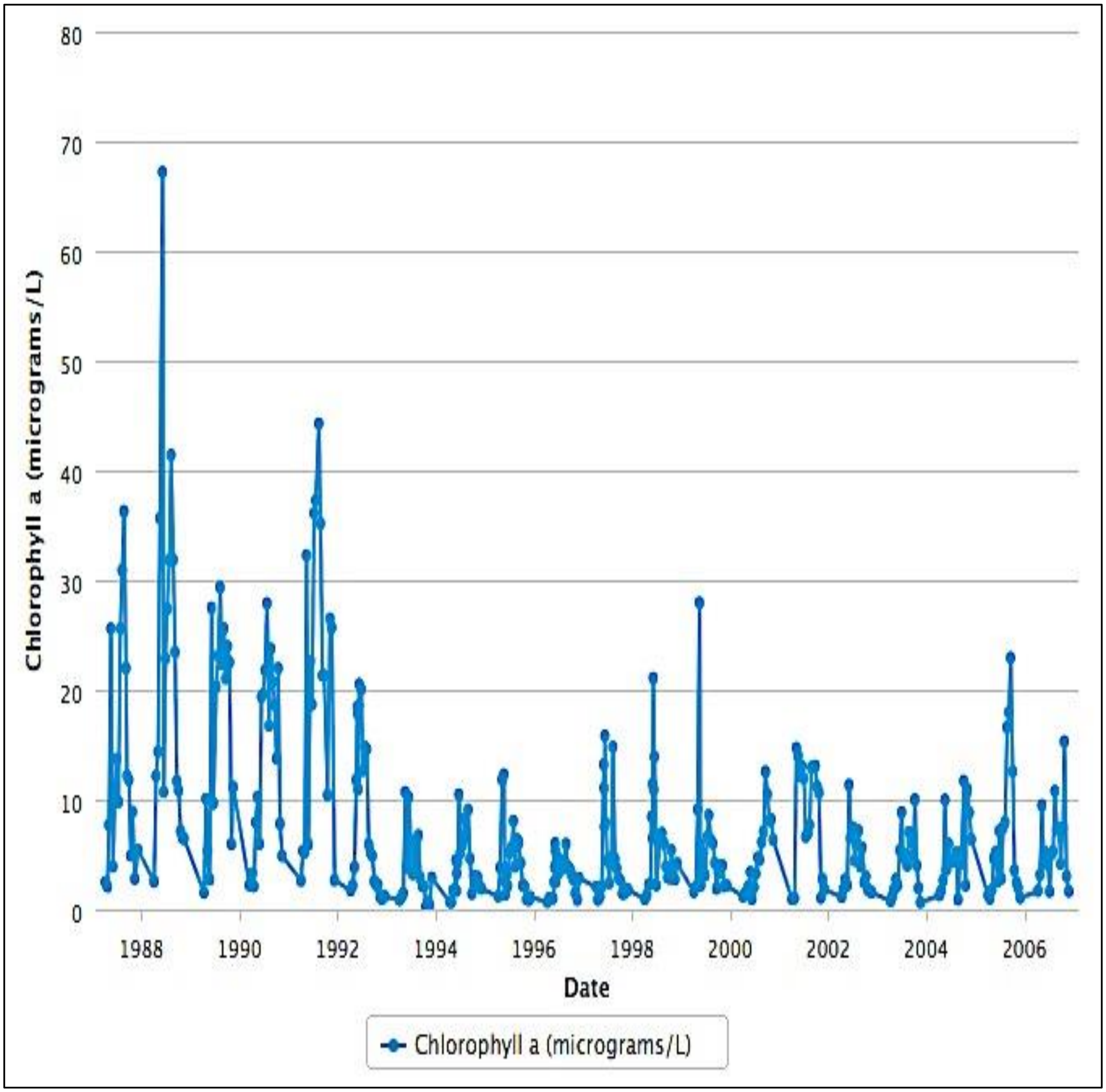


Figure 4.2. A graph of chlorophyll amounts over time (For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation.

During the final LTI, Marilyn supported student work by conferring with them regularly in class and providing short lessons which reviewed the concepts taught at the beginning of the school year.

The following excerpt comes from a class period in which students are finishing their investigation designs and using materials from around the classroom to test out how data collection process will proceed. Steeped in the task, students are working in small groups, scattered around the classroom collecting and testing materials, reading information on websites, emailing scientists at UA institutions (museums and zoos affiliated with UA), revising plans, and negotiating with each other about next steps.

In the following interchange, three of Marilyn’s students, Maddy, Jacob, and Caroline, have designed a simulation of the effects of wind on wave height in the ocean. They are using an electric fan to stand in for the wind, and a long, shallow plastic tub with water in it to stand in for the ocean. As they talk, they find that they are also interested in knowing whether salt or fresh water has a bearing on wave height. Marilyn helps them to untangle the variables they want to study.

1 Maddy: 'Cause we have the fan on low, medium and high and then the salt and fresh water.

2 Jacob: So like we can make like, it's kind of like a tree. Like, it goes off into the salt water and the fresh water and then the low medium and high=

3 Maddy: =high low and medium for salt and then and then we do high low and medium for fresh=

4 Marilyn: =for the fresh. Okay. That's fine.

5 Jacob: That's two independent variables, right?

6 Marilyn: Well... what is your independent variable again?

7 Jacob: I guess it would be the wind speed.

8 Marilyn: Okay.

9 Jacob: But then we..

10 Marilyn: But but but the water itself is not going to be a variable.

11 Jacob: But.. it would be the setting the setting of the fan.

12 Marilyn: It's now going to be. You would say the effect of wind speed on different.. water.. or different types of water. Or fresh and water...

13 Jacob: But then we have the wave height too.

14 Marilyn: On the wave heights of two different types of water.

15 Maddy: Also we're using tap water for fresh water. Is that okay?

16 Jacob: Naw, it's fine.

In this exchange, Marilyn listens carefully as students describe their current research plan: that they are going to use a fan, set at three different speeds, to explore the effects of wind speed on wave height. In line 4, Marilyn latches on to Maddy's idea of fresh water. Tannen (2007) argues that latching is a marker of engagement, that when a speaker repeats the last phrase or word of another speaker, they are focused on that speaker. Marilyn asks for clarification in line 6, "What is your independent variable again?" Here, she's checking on their procedure, making sure that they can explain the variables they have nominated. After clarifying their variables, Marilyn provides the language for their title, "The effects of wind speed on wave height of two different types of water."

One fundamental difference in the examples from Diana and Marilyn's classrooms is that students were doing different types of investigations. For example, in Diana's classroom, students were conducting a secondary research project in which the independent variable was chosen for them. On the other hand, in Marilyn's classroom, students could choose their own variables as long as they were under the theme of oceanography.

Considering Data

Discussions about variables eventually lead to plans for working with data. That is, once students identify the variables they want to investigate, they move into making a plan for collecting data on those variables (NRC, 2012). Through the LTI, teachers engage students in making decisions and solving problems about data collection (Driver et al., 1994; Michaels, Shouse, & Schweingruber, 2008; NRC, 2012). Such "problems" may be the available tools for collecting adequate and accurate data, time, or access to materials, especially in schools, where material resources are typically in short supply. Many of the students' decisions about how to investigate their questions depends on not only their own knowledge of the problem space, but also the resources available (Driver et al., 1994). In the following discussion, I present several examples of how teachers and their students considered the data collection methods they would employ.

Decisions about when and how to collect data. In Carrie's classroom, students discussed the investigations they had conducted earlier in the school year to inform their current LTI designs. Specifically, they evaluated how to collect data that would more accurately answer their questions in the second attempts. In the following excerpt from a whole group conversation, Vicki, identifies a problem she had the first time she and her group attempted to gather data on gorilla social behaviors at a local zoo.

1 Vicki: Well, it was sort of like a problem that my group had was that um, we have like eight different that we could check off and some of them were a bit vague.

2 Carrie: MMMMMM!!!

3 Vicki: So like they would go under this category now be more specific kind of thing?

4 Carrie: Excellent! So making sure when you fill out your ethogram, that you have specific descriptions.. of behaviors. ((three second pause while she writes on the board.)) Excellent. So you know exACTly what you're looking for.

This exchange not only shows students using their prior experiences to inform their plans (e.g., "a problem my group had was"), it shows them reasoning about how to collect the data (e.g., use specific descriptions of behavior). Earlier in the school year, students learned how to use the ethogram – a standard tool for animal behavior studies – to gather their data at the zoo. To properly use the ethogram, students decide the specific behaviors they plan to observe, and define what counts and does not count as those behaviors. Students also make decisions about how often and when to observe specific behaviors.

In the following exchange, Carrie's students continue talking in their whole group conversation about changes they make to the investigation design.

1 Alex: Well, I think that we didn't well, we didn't collect enough data because ((unclear)).. go earlier in the morning so.

2 Carrie: Okay. So more visits. Making sure you got enough data to draw a good conclusion. Excellent. Vicki?

3 Vicki: Umm.. what I had in my head was looking at what animal 'cause there were two animals there so it was hard to see which animal we were studying.

4 Carrie: Hmmm.

5 Vicki: And uh, we could improve that by having 'cause we have four people in the group, we could have two people watching and shouting out what they're doing and the other two people recording the time and behavior?

6 Carrie: Excellent! So splitting up those observation jobs if you're doing an animal behavior project, good.

Here we see Carrie naming for her students the specific scientific ideas she wants them to learn. For example, she states "making sure you got enough data to draw a good conclusion." With this, Carrie reflects back to the students what Alex offered in the first line: "we didn't collect enough data" and extends that idea with the phrase "… to draw a good conclusion." O'Connor and Michaels (1993) identify this discourse move as "revoicing." Cazden (2001) states that revoicing in the classroom serves two functions: it "rebroadcasts" [the ideas] back to the bigger group, often reformulating it in the process" (p. 90). One value with reviocing is the ability of the teacher to then "extract the essential core of previous student utterances that are hard to hear because of the disfluencies typical of exploratory talk when speakers are thinking out ideas as they speak" (p. 91).

Further, the revoicings are also "reconceptualizations," "a fusing of the teacher's words, register, or knowledge with the original intent of the student" and "conferring on (or attributing to) that student a stance with respect to the topic under discussion, a stance the student may only dimly be aware of" (p. 91). Revoicing also functions to "not only position students in relationship to content but in relationship to each other" (p. 91). As Cazden (2001) states, "revoicings can be one strategy for building both an ever-increasing stock of common knowledge and an ever-more-powerful community of learners" (p. 91). Thus, revoicing can be a useful especially in the context of the LTI, in which students and teachers ideally work in a community of science learners, which operates with specific language competencies such as specialized vocabulary, phrasing, and reasoning, etc. (Gee, 2008; Lemke, 1990; NRC, 2012).

Decisions about collecting data occur in reference to a specific data collection tool - such as an ethogram, a chart, or notebook. As teachers developed the LTIs as small group projects, they also created opportunities for students to collaboratively make important decisions about the best data collection methods.

Decisions about how many data support a claim. Teachers provide opportunities through the LTI for students to participate in conversations about how many data are needed to answer their questions and support their claims. For example, Carrie's students consider how the data they collect will help them to make defensible claims about animal behavior (NRC, 2012). This is particularly true for the group I highlight below, who are relying on one trip to the local zoo to get all of the necessary data, making the planning process especially important. In fact, with limited resources in schools, students generally do not have the luxury of revising their plans and collecting data more than once. Here, Carrie discusses the kinds of data the group will need to adequately describe gorilla social behavior with limited time and resources. The discussion opens with Maddy, a student in Carrie's classroom, asking about how often she and her teammates should go to the zoo to observe gorilla behavior.

1 Maddy: For this would it be one if we just went once?

2 Carrie: ((reading student work)) "The effect of time of day on gorilla social behavior."

3 Maddy: So if we do it twice=

4 Carrie: =So if you go once, I would make sure=

5 Maddy: =So twice per IV=

6 Carrie: =that you do it for a longer time, um=

7 Allison: ((student in background))

8 =So, I would say twice=

9 Carrie: =in the morning and the afternoon.

10 Maddy: So, we go twice and we then just do it at 12, 1:30, 3.

11 Allison: About two times on each day.

12 Maddy: And then we average out the data.

13 Carrie: Sounds good. Now, who did gorillas before?

14 Allison: Me.

15 Carrie: And what was your IV before?

16 Allison: It was um.. like, um...

17 Natalie: ((in background)).. grooming behavior.

18 Maddy: Actually it was.. time of day=

19 Carrie: =was it time of day?=

20 Maddy: =time of day on gorilla grooming behavior=

21 Carrie: =Because you might be able to bring in some of the data from before.

22 Natalie: ((unclear))

23 Carrie: Good. Now are these the same times as you used before?

24 Allison: No. We only did it twice and=

25 Natalie: =and we did it at 11:30 and at 2:00=

26 Maddy: ((in background)) What time? 11:30 and=

27 Allison: =I think it should be::... 3 times because you get more productive data.

28 Carrie: So...

29 Maddy: So we have more to work with.

30 Carrie: Excellent. Okay. So I like that you're making this one, you're like, "no, we need more data," which are some of those improvements that we talked about. So good. No questions? We're all set? Make sure you're talking and everyone's on the same page.

This group is particularly concerned with getting data during several times of the day, hypothesizing that gorilla social behavior will change throughout the day, and they want to describe those changes. They consider which times of day would yield "the best data." Their previous experience informed their choice to make more observations this time around, three times instead of two.

Here, Carrie asks clarifying questions and allows her students to have space and time to talk through their concerns with minimal interruption. The students are intensely engaged, taking turns in rapid fire fashion, demonstrated by the multiple times speakers latched (signaled in the transcript by the equals sign) onto one another's turns (Schegloff, 2007; Tannen, 2007). Carrie's role here is as a less-central speaker than is typical in most classrooms (Mehan, 1974). Carrie does not interject. Her most significant contribution to this conversation is at the end, when she summarizes and revoices what the students accomplished. She names their idea of making more observations as "an improvement," thus supporting the idea that collecting more data is better. Students are engaged in conversations about data collection and making early decisions about their procedures (plan) that would yield "the best data."

Considering data collection tools. Teachers also discuss with students appropriate data collection tools, another key aspect of planning an investigation (Achieve, 2013; NRC, 2007). For example, using the video case study (with the accompanying readings and Do Now tool) to guide their understanding of secondary research, Diana asks, "In the video, the scientists mentioned that the Secchi disk didn't go down very far before it disappeared in the water. What does this mean about the turbidity in the water?"[12] They discuss how the scientists stop measuring when they cannot see the disk in the water anymore, which allows them to get a measurement of the phytoplankton. Students mention that scientists are measuring how "murky" the water is, and Diana leads them to use the scientific word, "turbidity." She reasons, "once we can say it means there's high turbidity, we can say the water looks murky, why does the water look murky?" The interweaving of the everyday and scientific (Warren, Ogonowski, & Pothier, 2005) combine to help student meaning making – here, about the notion of turbidity – in describing the relationships between variables as well as how the scientists take specific measurements using specific tools.

Problem solving around science tools is also an element in Marilyn's classroom. Similar to examples from Carrie and Diana's classrooms, Marilyn's classroom is abuzz with lively talk and exploration among students. During one observation, students were working in teams to refine their investigation plans, using feedback they received from Marilyn's teacher's assistant. Students are moving about the room to ask advice of each other, gather materials, test those materials, and make final decisions about their written procedures. In writing these procedures, they test several kinds of materials. They try out measuring devices like scales, thermometers, and graduated cylinders. Some ask about using the classroom supply of plastic bins to simulate the ocean. Another group asks about using the incubator for their exploration of algae, and

[12] A Secchi Disk is a small flat round disk connected to a rope marked at each meter. The disk has four sections alternatively colored black and white. When it it lowered into the water, scientists use the meter markings on the rope to determine when the disk cannot be seen anymore. This distance is the Secchi depth, a measurement of turbidity, or how clear the water is. Clarity is then described by Secchi depth and the amount of organisms found in a particular volume of water.

sources of light available in the school. The group in the following example is asking about the aquatic conditions under which algae survive best. The conversation between Marilyn and three of her students, Sam, Casey, and Ellie, involves their decision about how to make sure that they transfer equal amounts of algae into cups with different volumes of water.

1 Sam: But can I ask a question?

2 Marilyn: Mm-hmm.

3 Sam: Um this algae? We need to divide it into cups.

4 Marilyn: Mm-hmm.

5 Casey: And then we need certain amounts for each cup. So do you have any kinds of tweezers that are tiny tiny that we could use to get the algae out of the tank?

6 Marilyn: I have tweezers but I'm not sure how well that would work. I think what you should do, the best thing to do at that point in time I would say is to shake it up and then hopefully by then it's sort of evenly distributed and then pour. Because there is no other way that you're going to be able to divide it, like, pull it out and divide it equally.

7 Ellie: Can we use a beaker for...

8 Marilyn: ((unclear))

9 Ellie: You mean like certain amounts and like... a.. uh.. larger amount into one cup and smaller amount into another cup

10 Marilyn: Did you want.. are you dividing it up into equal volumes? Is that what you were saying where you wanted=

11 Casey and Ellie: =Yeah ((unclear. background noise))

12 Marilyn: So let's say if you put like 5 mL in the first cup and then 10 mL in the second cup and then.. but just make sure if you're doing that that you shake it up so that hopefully yeah so that hopefully.. alright, there are no guarantees but that hopefully it would be evenly distributed. Okay?

While this excerpt is about the use of tools, it is also very much about problem solving (NRC, 2007). Using tweezers and samples of organisms engages both Marilyn and her students in a series of decisions about their planning for data collection. Here, Marilyn and her students rely on their knowledge of how algae behave in a sample of water, how much of the sample they will need for each cup, and how many samples they need. Getting an equal amount of algae in each sample is important to their fair test, and deciding on a reliable technique is a challenge. But they are equally unsure about the best technique for dividing the algae samples equally. Marilyn offers her best advice, though unsure herself whether it will yield the best results. This is a part of the challenge LTIs, as teachers sometimes have to trust the ambiguities in investigation design, given that we enter into authentic investigations without a priori ideas about the results.

For instance, in line 6 Marilyn says, "I have tweezers but I am not sure how well that will work." With this, she is thinking alongside her students, attempting to make the decisions with them, not for them and positioning herself as their learning partner, not as an all knowing expert. Later, they decide that they will use a different kind of sorting technique: stirring the sample in the water to get an even distribution of the algae before pouring into the different cups. This demonstrates how teachers and students work together in an authentic task using their knowledge of the tools of science to design the most sound data collection method (NRC, 2007; NRC, 2012).

In the next sample, Carrie is leading her students in a whole group conversation about how to refine their data collection methods from the first time they conducted their trebuchet projects. This time, students are to use what they learned in the previous iteration of the project to make revisions to the data collection methods. In the following, Carrie is asking students about the challenges of conducting the projects, and to imagine solutions to those challenges. The first response a student gives comes from his previous experience with the techniques and tools they used for measuring distance.

1 Carrie: Alright let's go to trebuchet people so that we are fair. You guys ALL have done a trebuchet project.. what were some challenges? There definitely were some challenges this was our first time doing it. What were some challenges and how do we plan to improve upon them? Excellent! Alright Cameron start us off!

2 Cameron: Well, our table disagreed about ((unclear)).

3 Carrie: Ah.. so deciding how to measure distance. Deciding how DV is measured. Alright. I know people are arguing is it where it hits? Is it where it rolls to? You guys have to decide those things ahead of time very good. Ginny?

In thinking about the difficulties of measurement, the students consider the role of error in design and execution of the plan.

4 Ginny: Um, like tying strings or...

5 Carrie: That was one of THE most difficult things, something as simple as just tying strings. And they kept coming loose and kept coming off and the load kept coming out. So that's something that you guys... ((to herself as

she writes on the board)) Ty... ((back to class)) need to think about ahead of time. Go for it, Wendy?

Next, Wendy links to this idea and gives another example of error.

6 Wendy: Um how well you did the launches?

7 Carrie: What do you mean by "how well"?

8 Wendy: Just like sometimes if.. if the.. sometimes we did good launches that went far and we'd have like some flawed launches like we'd mess up and it wouldn't go.

9 Carrie: Okay and what were some of the things that possibly could have messed up the launch?

10 Wendy: Um..well..the.. person launching it ((laughs))

11 Carrie: ((laughs, other kids laugh)) Okay so maybe some human error in there. So ((writing)) making sure launches are consistent. I saw lots of hands up back there. Let's see Vicki?

With this, Carrie revoices Wendy's idea as human error, and adds in the idea of consistency of each trial (launch) (NRC, 2012). The conversation continues with Vicki adding in the idea of the trebuchet design itself. The trebuchet project was a design investigation, which involves an iterative process of design, test, and redesign (NRC, 2007; NRC, 2012).

12 Vicki: Um.. how you set up your trebu..

13 Carrie: Yeah, what do you mean?

14 Vicki: Sometimes you ((unclear)) under it and you have the load and it doesn't fly far and it hits the ground. ((unclear)) that's why it's hard to decide where it landed.

15 Carrie: Alright. Going back to where it landed and deciding where to measure from. And making sure that um.. the launches are started every time the same way. Trevor?

16 Trent: Um.. make sure um.. there's no one in your way when you launch it 'cause there was a lot of human interference.

17 Carrie: Ah, make sure the launch path is clear. ((writing)) Excellent. Alright.

Carrie once again using revoicing and pressing for further explanation as ways to engage students in the discourse of science (Cazden, 2001; Gee, 2008; Windschitl, Thompson, & Braaten, 2012). In all of these moves, Carrie affirms students' ideas and intuitions about solutions to the problems they experienced in the first trebuchet investigation, and she confirms and recasts for students the scientific habits of mind (NRC, 2012) and the ways of talking and being as scientists in discourse in the practice of planning (Achieve, Inc., 2013; Gee, 2008; NRC, 2012).

From here, students will capture their plans to a "considerations sheet," a tool Carrie designed for her work in the LTI in response to the difficulty she observed in students' organizational skills and attention to details in planning (see figure 4.3). Carrie uses the considerations sheet as a scaffold for organizing the specific details of the project plan.

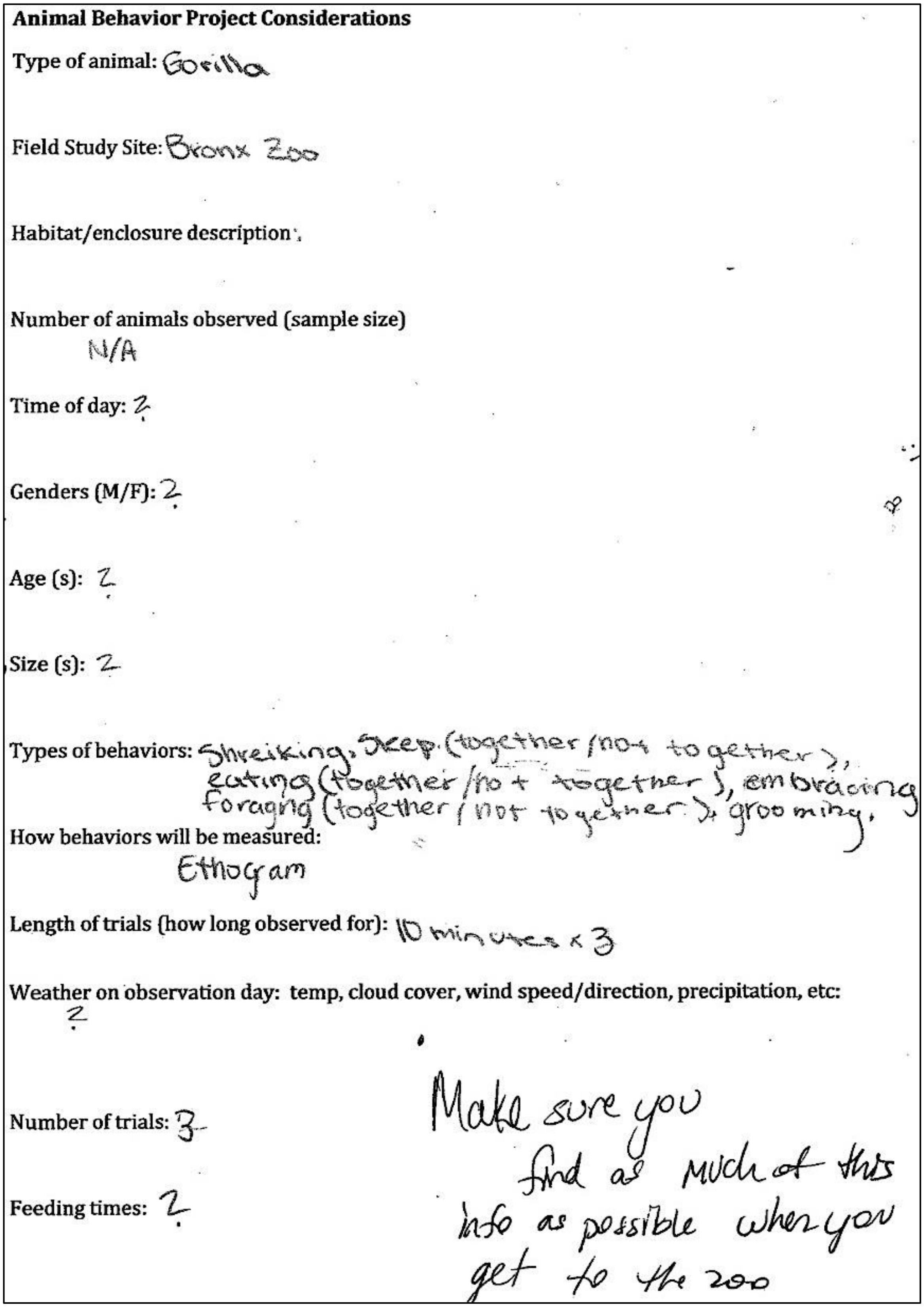
These excerpts show how teachers generate discourse through the task of engaging students in their own plans and revisions to their investigations (NRC, 2007; Gee, 2008). Instead of the more traditional IRE discourse pattern, Carrie asks students to draw upon previous experience to think about their planning process in the next LTI. One experience informs another. They are contextually dependent, involving students in the higher-order thinking and metacognitive processes required of scientific practice (NRC, 2007).

Obtaining, Evaluating, and Communicating Information

Across all three classrooms, students and teachers engaged in several conversations that demonstrate the practice "obtaining, evaluating, and communicating information" (Achieve, Inc., 2013). According to the NGSS (2013),

> Being literate in science and engineering requires the ability to read and understand their literatures. Science and engineering are ways of knowing that are represented and communicated by words, diagrams, charts, graphs, images, symbols, and mathematics. Reading, interpreting, and producing text are fundamental practices of science in particular, and they constitute at least half of engineers' and scientists' total working time. (p. 74)

Teachers in these classrooms are providing opportunities to become "literate in science." As I noted earlier, almost half (45%) of the teachers' utterances across all observations were dedicated to working with information. They read texts, watch videos, write emails to scientists, write lab reports, observation notes, talk with classmates about findings, offer peer reviews of work, develop charts, use mathematics, and so on.



Animal Behavior Project Considerations

Type of animal: Gorilla

Field Study Site: Bronx Zoo

Habitat/enclosure description:

Number of animals observed (sample size)
N/A

Time of day: ?

Genders (M/F): ?

Age (s): ?

Size (s): ?

Types of behaviors: Shreiking, sleep (together/not together), eating (together/not together), embracing foraging (together/not together), grooming.

How behaviors will be measured:
Ethogram

Length of trials (how long observed for): 10 minutes x 3

Weather on observation day: temp, cloud cover, wind speed/direction, precipitation, etc:
?

Number of trials: 3

Feeding times: ?

Make sure you find as much of this info as possible when you get to the zoo

Figure 4.3. Carrie's animal behavior project considerations sheet

In my coding of the transcripts of these discussions, I treated each element (obtaining, evaluating, and communicating) separately to find patterns across teachers for each (Miles & Huberman, 1994). Exchanges about obtaining and communicating occurred more often than evaluating information. I also observed that developing these practices was an iterative process, following The NRC's (2007) descriptions of scientists' work. In other words, teachers and students engaged in all three elements of this practice - obtaining, evaluating, and communicating - throughout the LTI, and not in any particular order. In the following discussion, I provide examples and analysis of teachers engaging students in this practice through transcripts of discussion as well as samples of various textual tools.

Opportunities to Obtain Information

Obtaining information, or doing background research, occurs across the LTI. Teachers engage students in background research at the beginning of the LTI in order to develop content knowledge. They do research to understand how variables are connected to each other as they learn about the specific study's phenomena. And they use several different kinds of texts (written and audio-visual) as they develop their own investigation designs. Students also do research to support their claims after data collection. In general, in these teachers' classrooms, the LTI proceeds in a dialogic fashion, one that involves an interweaving of texts which are used to provide information all along the way.

For example, Diana used several tools to help students to gather information about their variables. Using the Do Now handout, Diana asked students to watch and take note about information in a series of videos from the Carey Institute case study. Several background readings also accompanied the videos. Students also had access to the interactive database provided by the Carey Institute and the AMNH.[13] Informational text played a role in all phases of the work.

For example, in the excerpt that follows, students are getting ready to watch the second of four case study videos of the Hudson River study. In Diana's classroom, the students have begun thinking about their projects and have selected the variables they would like to investigate. (I showed a few examples of these lessons in the previous section.) Here, they are using the background information to develop a deeper understanding of the scientists' work and of the data collection process. Seeing the scientists at work and hearing their explanations about their processes provides necessary background information for conducting secondary research, one in which the data are not one's own (Wilson et al., 2012). The excerpt opens with Diana transitioning a whole group conversation into viewing the video.

1 Diana: Now we're going to find out what the scien- We're gonna get the most current information.

2 Video: "We are at the Hudson River at ((unclear)) on the North Side of the river and we're collecting zebra mussels in order to know their population... right here, fully-loaded... so here's the rock and you can see that there are some older zebra mussels on it these larger guys, which are a few years old. And then you can see all these small ones that are attached on here, these all settled out last August. So what we've been noticing is ah, a few years ago that they were mostly large and then we saw a few small ones. And so now what we're seeing is that we don't see much survival between

[13] See http://www.amnh.org/education/resources/rfl/web/riverecology/

June and August of the large ones. And we'll see that there's more small ones currently.

3 Diana: ((pausing the video on an image of the zebra mussels attached to rock)) So what does that mean? What happened to the zebra mussels over time? Allen?

4 Allen: They started to die.

5 Diana: They started dying. What happened? The ones that aren't dead, what happened to them?

6 Charles: They're getting smaller.

7 Diana: Yes. Charles, raise your hand.

8 Charles: They're getting smaller.

9 Diana: They got.. smaller..

10 ((a student says something over Diana that I can't hear.))

11 Diana: She's showing us.. right, if you look, you can actually see it. Look at the SIZE of the zebra mussels in this picture here and look at the size of them there ((comparing two sizes of mussels that have collected on the rock)).

Here, students watched and listened to the Carey scientist on the video explain how the scientists knew that the size of the zebra mussel had changed over time. In the video, the scientists are on a boat on the river, and show a rock they had pulled from deep in the water. The rock has attached to it several small and some larger zebra mussels. They explain that the larger ones are a few years old, and that the smaller individuals settled onto the rock just months before.

Diana stops the video to ask the students to make meaning of the video text (NRC, 2012). With this, she provides them an opportunity to reason about what happened to the zebra mussels over time. With Diana's help, the students infer through this video - which counts as a textual tool in this study - that zebra mussels were also affected by their new habitat. Diana helps them to see that changes in their size happen over time. I present this as an example of obtaining information because it shows how information can come in the form of written or visual texts. It also shows how students have opportunities to learn content as well as process from studying the scientists' work through the case study videos and accompanying readings.

Another example of obtaining information comes from Carrie's classroom. Here, students are putting their final touches on the display boards just a few days in advance of the school science fair. Carrie is circulating among the students, giving feedback and direction. The focus of the conversation on this day is about how to make the most professional looking display board that includes the key investigation information. In the example below, students are now in the final "presentation" phase of the LTI in which students prepare their artifacts - here, tri-fold display boards - for a formal presentation. In three teachers' schools, students present their projects at the school science fair, and each gave opportunities like this for their students to complete their display boards in class.

In the following exchange, we see how Carrie challenges her students to return to the background information they were to gather earlier in the marking period, so that they can include this information as support for the claims they want to make about trebuchets. In this moment, Carrie reads their work before allowing them to glue the text to their display board. She notes missing information.

1 Carrie: ((back to group)) Okay you have resources. Okay. Make sure you guys put your names here. And then let's break this up by doing like this. [3 seconds] Okay?

2 Garrett: I think I lost maybe some of the info so...

3 [10 seconds]

4 Carrie: But you guys ne::ed some background info you don't have any scientific background info.

5 Garrett: Yeah, we're...

6 Carrie: That's all that's all history of the trebuchet. But that doesn't tell me anything about length of string counterweights, anything.

7 Alex: ...((unclear)) 'cause any time we looked up background information on trebuchets, um, it just gave the history.

8 Carrie: [2 seconds pause] That's not okay. That means you don't have any data to support your hypothesis or excuse me scientific, reasoning. And we what did we learn about when we did trebuchets earlier this year?

9 Alex: That, trebuchets were...

10 Carrie: What was the scientific.. vocab that we learned? [2 seconds] Do you remember?

11 Alex: U::mm...

12 Carrie: You guys have to be the experts on this. And right now you're not sounding like an expert. When WE studied trebuchets in class what were the scientific words that we learned?

13 Brad: Ah...

14 Garrett: ((unclear))

15 Carrie: No. That's a PART of it.

16 Alex: Potential energy.

17 Carrie: And?

18 Garrett: Kinetic energy.

19 Carrie: I don't see ANY of this in your background research and that's what we did in class and THIS time you should have gone above and beyond THAT. Okay? So I would go back. And check that at LEAST you have something about potential and kinetic energy in there.

I coded this excerpt as "obtaining" because Carrie refers specifically to the students' use of science resources to support their claims. As shown here, discussions about obtaining information occur throughout the LTI, but even in the final stages of preparing the display board, teachers sometimes refer to previous moments when students were obtaining information about their variables. Sometimes those conversations lead to students having to make last minute revisions based on how they communicated that information.

Students gather information at the beginning of the investigation as they are learning about variables - as in the first example from Diana's classroom - and they obtained information as they were making changes to their final lab reports as in the last example from Carrie's classroom. Also in Carrie's classroom, one group of students watched online videos of lion behaviors during the design phase so that they could more clearly define the behaviors they expected to see at the zoo, so they could accurately record them on their ethograms. I also observed students in Marilyn's classroom gathering information as they were designing their investigations. They researched variables on websites and used their cell phones to contact local businesses about the materials they would need for their projects. In sum, obtaining information occurred throughout the LTI, and became an integral part of the students' work as I observed students interacting with several different kinds of texts and media sources to support their understanding and refine their plans regardless of the task of the day (i.e., revising a lab report, writing investigation procedures, gathering data).

Opportunities to Evaluate Information

As with obtaining information, evaluation occurs throughout the LTI process. In its description of this practice, the NRC (2012) states,

> Being a critical consumer of science and the products of engineering, whether as a lay citizen or a practicing scientist or an engineer, also requires the ability to read or view reports about science in the press or on the Internet and to recognize the salient science, identify sources of error and methodological flaws, and distinguish observations from inferences, arguments from explanations, and claims from evidence. All of these are constructs learned from engaging in a critical discourse around texts. (p. 75)

The practice of evaluating information is iterative. In fact, the NRC (2012) places evaluation at the center of the "three spheres of activity for scientists and engineers" (p. 45). In this view, evaluation informs and is informed by all other activity and is the cornerstone of critical science activity.

Likewise, in these teachers' classrooms, evaluation occurred throughout the LTI and in no particular order. In these classrooms, students, like scientists, evaluate the information they gather for various reasons. They evaluate information for its validity and clarity. And they evaluate the information of their peers based on the language conventions used in the scientific community (Latour & Woolgar, 1986; Lemke, 1990). Students evaluate textual information along the process, from evaluating the best information for use in supporting claims, to peer evaluation of reports prior to the final presentations.

In the following exchange, for example, Carrie’s students are learning the best ways to present their LTIs for the school science fair. Using former students' projects as fodder for discussions about not only project quality but also the information and its organization, students talk about the display boards in small teams and write notes in their journals for use later as they evaluate and plan their own boards (see figure 4.5). In the following excerpt, Carrie's students are in small groups, each with a display board to evaluate. Carrie stops by Sandra’s and Andrew's table.

1 Carrie: ((to another group)) So what's good about this one?

2 Sandra: Well, they have all the information.

3 Carrie: All the info's here is it in the right order?

4 Sandra: No.

5 Andrew: What if you take the um...

6 Carrie: What's out of order?

7 Sandra: U::um... the graphs..

8 Andrew: It's in the right order.

9 Carrie: Does it flow like a lab report?

10 Sandra: No.

11 Carrie: Up and down, and then like a newspaper across?

12 Sandra: ((unclear))... it goes up and down and then you have to go back up.

13 Carrie: But, that's the newspaper part.

14 Sandra: And they're missing a question.

15 Andrew: What's their question?

16 Sandra: It's in the title.

17 Carrie: So they say the title but they don't say the question. Okay.

18 Sandra: But isn't that, isn't the title the question?

19 Carrie: It's just a rephrasing.

20 Sandra: The question is, "what is..." ((unclear))

Here, Carrie has asked students to respond to a number of elements she expects them to include on their display boards. They must organize the information so that it reads "like a newspaper" down three separate columns. They also must state their question in a particular way, using the UA model, "What is the effect of X [independent variable] on X [dependent variable]." Students have noted that this particular display shows the right orientation of text, but that their title - which is closely related to their question - is missing.

As groups evaluate the displays, they include their notes in their notebooks (see figure 4.4). Notebooks like these were used throughout the LTIs among all teachers. In Carrie's classroom, students responded to each day's Do Now prompt in their notebooks. Below is an example of a Do Now response from a student's notebook from the above lesson about evaluating the information represented on the students' project display boards.

Notice that the student organized the notebook page according to the two Do Now tasks: what was good and what needed to be changed. The notebook page shows the interactions with text and was another space for students to practice reviewing the language expectations as members of a scientific learning community (NRC, 2007; Lemke, 1990).

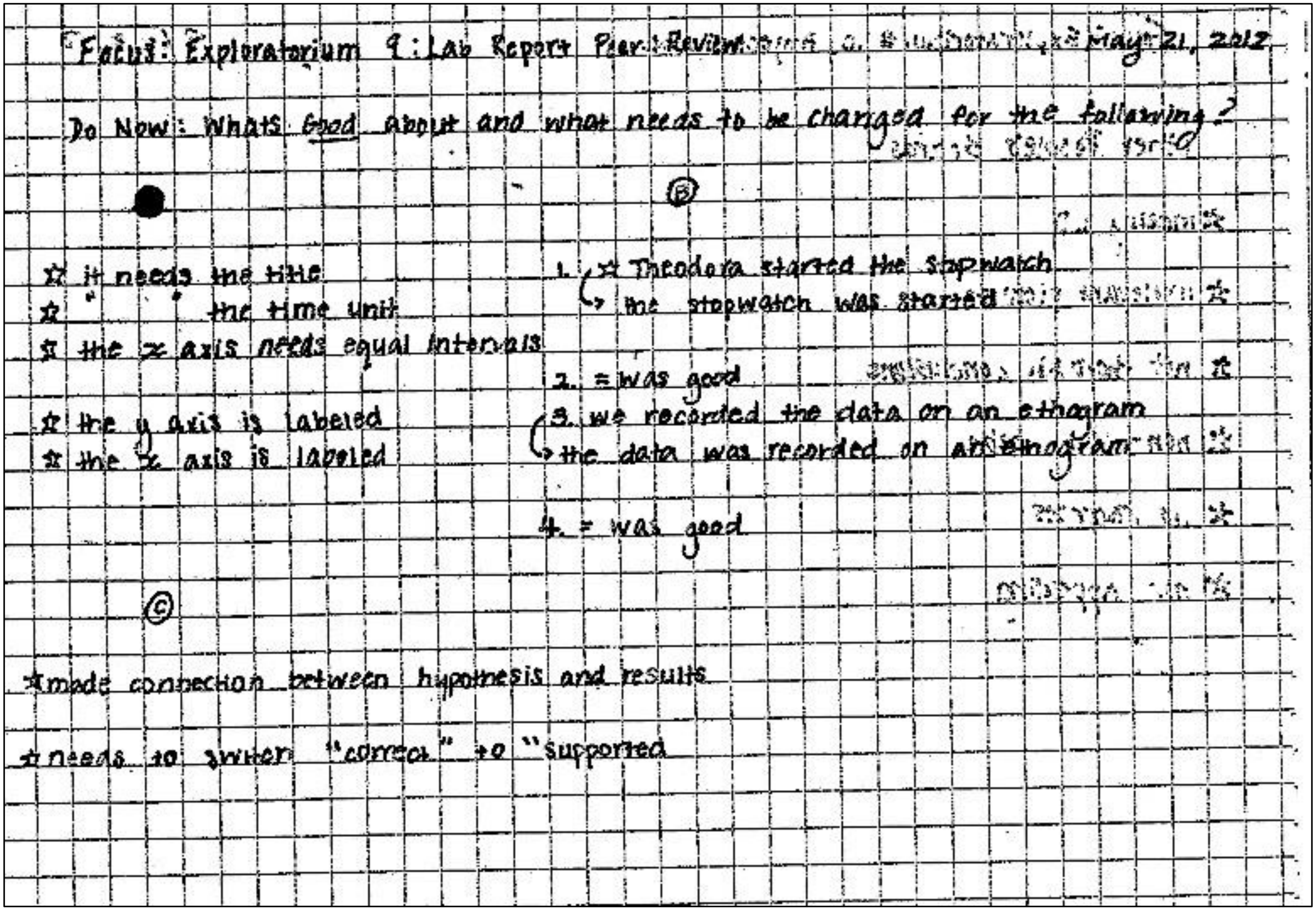


Figure 4.4. Student journal page from Do Now for peer review of lab report (see Appendix A on page 214 for translation of text)

Opportunities to Communicate Information

According to the NRC (2012), "communicating in written or spoken form is another fundamental practice of science; it requires scientists to describe observations precisely, clarify their thinking, and justify their arguments" (p. 74). Teachers also engaged their students in several opportunities to communicate information throughout the LTI. They communicated in emails to local scientists, presented ideas to peers, developed formal lab reports for the final LTI project, and gave oral presentations to parents and students at the science fair. During my observations, students most often communicated formally in writing. Their informal communications were most often spoken, as parts of discussions in class. Regardless of the modality, along the way teachers provided scaffolding – in the forms of discussions and textual tools – for learning and practicing the formal written and spoken conventions that are a part of doing science (Latour & Woolgar, 1986; Lee, Quinn, & Valdes, 2013; Lemke, 1990; NRC, 2012). While I address the ideas of writing and talk in the next two chapters, I discuss how teachers use writing and talk in the context of learning to develop the practice of communication.

In the following example, Carrie is moving about the classroom as her students are working on revising their lab reports. Their lab reports will eventually accompany their science fair projects, and comprise a major part of the project grade for the LTI. A student calls Carrie over to her table, asking for advice about her writing.

1 Maddy: So over here, do I have to write the behaviors in my hypothesis?

2 Carrie: No, you can describe it here ((referring to a section in the lab report)).

3 Maddy: Oh, I have to move my hypothesis...

4 Carrie: So you can work on finding more background info on what behaviors gorillas exhibit. So is there you know feeding behavior. Are there grooming behaviors, social, like specific behaviors that you guys could possibly see when you go to the zoo.

5 Maddy: So do I need to add most of my hypothesis... ((unclear)) I mean I do I know I do, but I mean like specific...

6 Carrie: So you guys ((reading, unclear)).. So why do you think being a close, ancestor genetically, that's what you're getting at here right? Why do you think being a close ancestor genetically, would make them, more likely to be active.. or....

7 Maddy: So like humans are most interactive ...((unclear)) So... ((unclear))

8 Carrie: And that's what you need. So...

9 Maddy: Should I change my hypothesis?

10 Carrie: Yes. You want to have some science supporting what you're thinking. Okay?

In the beginning of this interchange, Maddy asks Carrie for advice about how to write about the animal behaviors in her hypothesis (lines 1 and 3). But as Carrie reads her work, she notices that this group needs more background information to support their rationale for hypothesizing that "being more active" is a human trait that we can logically attach to gorilla behavior because of genetic similarity. So, she redirects this conversation. Carrie presses them for more information. Windschitl, Thompson, and Braaten (2012) identify "pressing" as a key discourse move that experienced teachers use in helping students to engage in scientific discourse practices. Pressing involves asking a follow up question that "presses" students to provide more information to support or explain their ideas. According to Windschitl, Thompson, and Braaten, pressing helps develop scientific reasoning among students and helps all learners become more skilled in participating in the discourse of science. Here, Carrie presses Maddy and her group to write a hypothesis using background information. I provide this exchange as an example of communicating information because writing a hypothesis is one of the conventions of doing science.

And in other moments, communicating information is about how to use one's spoken and written language to develop ideas in scientifically formal ways. In the following example, Diana helps a small group of students to develop their titles for their final projects so that they learn to follow the conventions of the UA program and scientific discourse (Lemke, 1990; Gee, 2008).

1 Diana: ((to another group)) You have a title on your sheet. "The effect of zebra mussels on... "

2 Marlyse: Turbidity.

3 Diana: Turbidity. In the Hudson River. Or tot... you could say, tot. You could say ...

4 ((to Adrienne, who is across the room)) Adrienne you need to decide as a group whether you want to say Total Suspended Solids, or if you want to say "Turbidity." Talk to your group.

5 ((to this group)) Because zebra mussels eat the plankton. So there will be less plankton. Or le- how how how do YOU want to say it?

6 Marlyse: Like that.

7 Diana: So there will be a decrease or there will be less or there will be fewer. Or, that's why we think it will go down. You figure out how you wanna say it.

Notable in this exchange is the idea that Diana provides for them formalized language scaffolds, such as using the correct terminology ("turbidity" for example), yet also supports students in expressing their ideas in their own way.

Sometimes teachers attend to the writing conventions and are concerned with surface features like organization and conventions such as indentation. While I explore the ideas of writing in the next chapter more fully, I mention this here to show how teachers use talk as a way to engage students in ideas that will later translate into writing, in their ways of engaging the practice of communication.

1 Jonathan: We just, my conclusion is taking up the whole page but we thought that ... ((unclear))

2 Carrie: And your paragraphs aren't indented so it's like we can easily tell it looks like a LO::T of text. So it looks like.. you have a very thorough conclusion but see how like, I can tell kinda here 'cause there's, a space here..

3 Jonathan: Uh-huh.

4 Carrie: ...but it's not indented. So that, it doesn't look so... so the first, part of every paragraph, indent it, so it breaks it up. So it's not like... people can tell where a new idea or a new section of a conclusion begins.

5 Jonathan: If we indented it... but if we indented it, I felt like it's too many words..

6 Carrie: Well, lay it out I don't think you'll have any room for indenting and ((laughs)) a space. But an indent will help to break it up.

Here Carrie reminds Jonathan that communicating in science also includes attending to all of the details of formal writing conventions, such as making paragraph indentations. Though a relatively trivial example, teachers throughout the study had similar conversations with students. Carrie, Marilyn, and Diana's students were engaged in conversations about even the seemingly small ideas about communication in science, that the details matter, that formal science language involves precision of conventions as well as investigative precision (Lemke, 1990; NRC, 2012).

In another example of opportunities to communicate information in science, Diana's students learn the syntactical conventions of science discourse. In the following, students are using the Do Now form to help them organize their thinking, and Diana sits with small groups to help refine their language use. The discussion begins with Cameron reading aloud the text at the top of the page (see figure 4.6).

1 Cameron: Okay.. ((giggles))

2 [reading] "How do you think the Hudson River ecosystem is being affected by zebra mussels? Use what you have learned to make a prediction that... how... your independent variable could be changing the... or dependent variable. Use your science knowledge about the variable you choose and about the ... of the river (?)"[14]

3 Diana: Okay so everyone's gonna start the same way. Because everyone has the same what? Everyone has the same what?

4 Students ((in unison)): Variable!

5 Diana: INdependent variable. Because that's what's changing the ecosystem. We wanna know, how do zebra mussels affect phytoplankton, how do zebra

[14] The ellipses in this transcription of Cameron's reading represent places where the recorder was not able to pick up his voice. Though the text he is reading is included in figure 4.6, I left the transcription as is. Without a clear recording, it is possible that the text may not have been an accurate representation of what he read or how he read it.

mussels affect the water, the fish the shallow water, how do zebra mussels affect copepods, how do zebra mussels affect turbidity, and so on. So everyone has a different question but it's all gonna start with, "If ... " what?

6 Cameron: If the scientists stopped studying=

7 Diana: =No. What independent variable here? I just said it, the independent variable is=

8 Students: =Zebra mussels=

9 Diana: =Zeb- IF zebra mussels are introduced into the ecosystem, right, or you could say, if the zebra mussels=

10 Students: =Went up.

11 Diana: Increase or the amount of zebra mussels in the ecosystem increases.. IF the amount of zebra mussels in the Hudson River ecosystem, INcreases... you could say it another way, you could say, if zebra mussels increases it's pretty simple you could say if zebra mussels are introduced into the ecosystem.. reproduced.

12 Marlyse: How about if zebra mussels in the Hudson River increase...

13 Student: ((student asks a question.))

14 Diana: No. Figure out a way to say it on your own. You don't as long as you say something about zebra mussels increasing, this is where you write your prediction. What do you think is gonna happen when you look at the phytoplankton, or you look at copepods, et cetera and so on and so on and so on. So you have to make a prediction about your variable. So, this is where you make your prediction about your dependent variables. This is

where independent variable goes. Here's the dependent variable. And in ALL these lines you have lots of space there, fill in the whole thing please.

This interchange involves Diana in helping students to learn the formal science conventions of communicating the relationships between the IV and the DV and writing a hypothesis. Diana begins by telling them that they are "all gonna start the same way," that the first part of their hypothesis will include the independent variable, which is the same for everyone: zebra mussels. In her next utterance (line 5), she uses repetition (Tannen, 2007) to emphasize the notion that the students will then set that independent variable against their dependent variables. Cameron takes a turn at trying on the convention, but he uses the wrong phrase. Rather than saying, "The effects of zebra mussels on..." he links back to an earlier conversation in which Diana was asking students to finish the sentence, "if the scientists stopped studying..." Diana attempts to repair (Schegloff, 2007) that mistake by restating how to express the relationships between the variables. In line 5, she states "We wanna know, how do zebra mussels affect phytoplankton, how do zebra mussels affect the water..." And Marlyse makes an attempt at starting the phrase on her own, "How about if zebra mussels in the Hudson River increase..." A student then interrupts Marlyse, asking (presumably) if all students need to write their hypothesis in the same way.

Diana then redirects the students. She repeats the phrase (in line 14), which functions to provide emphasis, that there is a regular pattern to this language, that students should use the first part of the phrase - which doesn't change - and simply add their own dependent variable at the end. In her last utterance (line 14), Diana then adds that students will add their prediction about what they think will happen to the dependent variable if the zebra mussel population increases. This is the hypothesis they are to write.

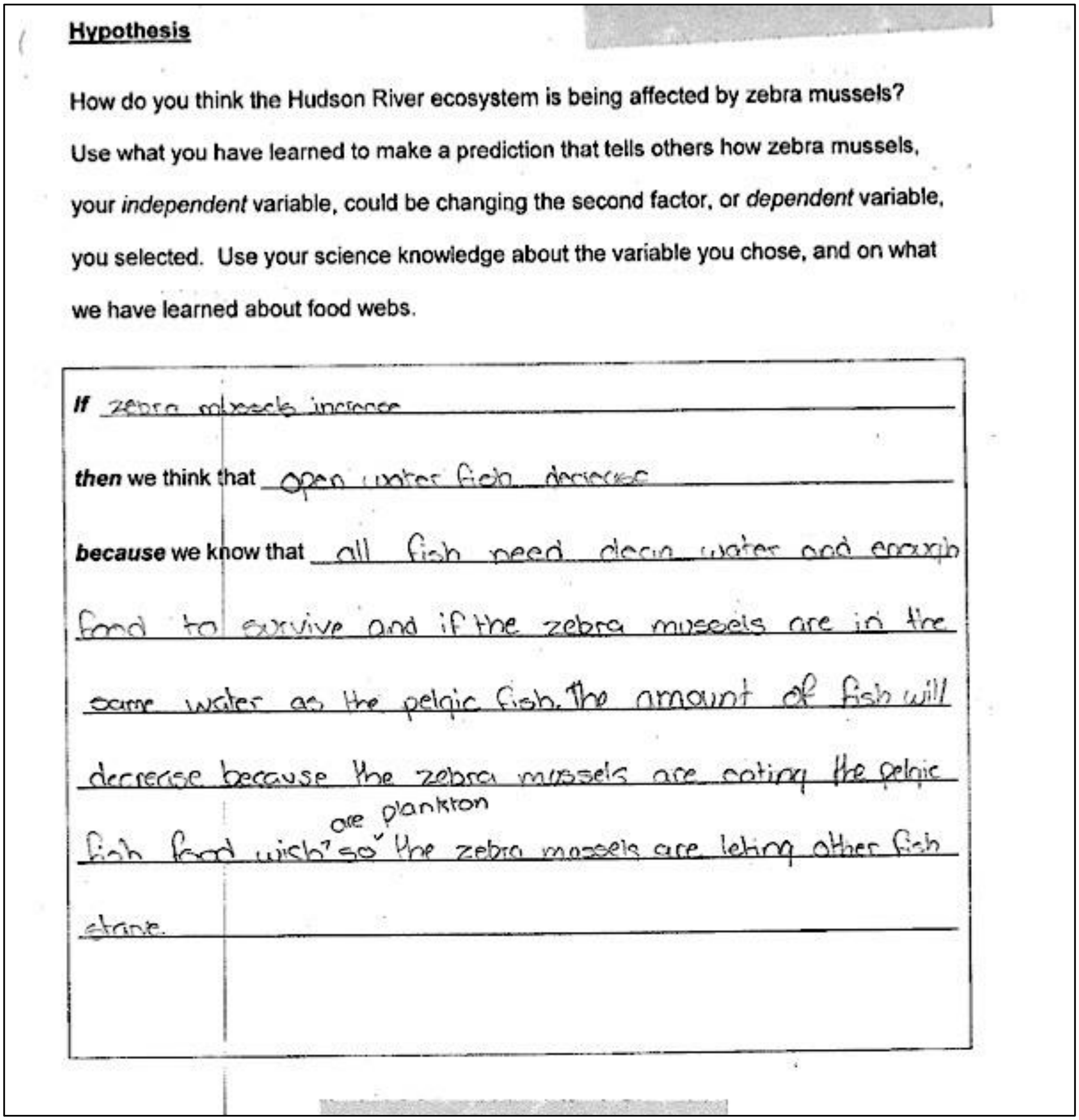
Students then work in teams to develop the hypothesis. Diana provides the Do Now form to scaffold each segment of the hypothesis (see figure 4.5). The students have the responsibility to compose the hypothesis based on their collective knowledge, using the language pattern Diana modeled for her students in the conversation and presents again in text form on the Do Now handout. In other words, this tool, and Diana's teaching of the tool, provides students another opportunity to learn how to communicate information - in this case, the hypothesis - scientifically.

This student example demonstrates that the conversations Diana held with students earlier in the LTI about understanding the relationships between the variables (discussed earlier in this chapter) appear here in the written product.

These interchanges between the teachers and their students and the resulting writing illustrate the complexity of language work in science (Achieve, Inc., 2013; Lemke, 1990; NRC, 2012). Compiling, evaluating, and finally compressing that knowledge into a clear communication about scientific principles is multilayered work. Through the LTI, teachers provide opportunities for students to both learn and practice the formal discourse of science in authentic contexts, in the day-to-day work of designing, conducting, and communicating a scientific investigation over an extended period of time. They use other textual resources too, like the Do Now or considerations sheets, or graphs and charts, or science notebooks, to provide students spaces to record, and then later use, their new scientific knowledge.

Summary

Teaching the practices is a generative, demanding, language intensive pedagogical move. What I have attempted to demonstrate here is that tools cannot be used in isolation, nor can students work completely independently with the tools without careful guidance of the teacher.



Hypothesis

How do you think the Hudson River ecosystem is being affected by zebra mussels? Use what you have learned to make a prediction that tells others how zebra mussels, your *independent* variable, could be changing the second factor, or *dependent* variable, you selected. Use your science knowledge about the variable you chose, and on what we have learned about food webs.

If zebra mussels increase

then we think that open water fish decrease

because we know that all fish need clean water and enough food to survive and if the zebra mussels are in the same water as the pelgic fish the amount of fish will decrease because the zebra mussels are eating the pelgic fish food wich are plankton so the zebra mussels are leting other fish starve.

Figure 4.5. Hypothesis Page from Do Now from Diana's Classroom

Each example of the teachers engaging students in each practice demonstrates that the teacher plays an important role in translating, naming, revoicing, and providing multiple opportunities for students to engage these practices in whole group as well as small group formats.

The work of the LTI, regardless of the structure or investigation type, requires teachers to develop strategies for guiding students through each phase of the work. One way that teachers guide the students is through the use of several different kinds of textual tools such as Do Now sheets, the IDD, considerations sheets, journals, readings, and videos. Teachers stick close to the process alongside their students. They move in and out of direct instruction and more open-ended conversations. Much of their instruction happens in the natural interactions, in the improvisational moments of talk with students, in responding to their needs, their questions, their knowledge.

In this chapter, I present examples of teachers engaging students in just two of the eight science practices (Achieve, Inc., 2013). I presented these two practices because I observed teachers helping students to plan their investigations and work with information (obtaining, evaluating and communicating) more often than the ways they interacted around other practices. However, the other practices were present, and interwoven throughout the process as well. For example, I observed teachers asking students to develop arguments using their background knowledge and experiences in order to develop their investigation designs (practice numbers six and seven above). And all students were required to provide scientific reasoning in the final laboratory reports and science fair projects (practice number seven).

All three teachers used several instructional tools (i.e., the IDD, Do Now, considerations sheets) to organize, through writing, students' emergent understanding of science practices and content. But, the written work did not always come about individually, as a result of quiet contemplation; instead, it was constructed in the context of classroom discussion (Bakhtin, 1981, 1986; Bazerman, 2004; Leander & Prior, 2004; Latour & Woolgar, 1986; Street, 1984; Vygotsky, 1986). Leander and Prior (2004) explain: "writing, speaking, and embodied activity co-evolve and interact in a specific strip of interaction" (p. 226). Similarly, Latour and Woolgar (1986) illustrate how texts are instantiations of the social activity of scientists' work, at the same time that they also drive such work. Here I consider how teachers in this study used written tools to support students' "embodied activity" as they engaged in LTIs, where students and teachers talked and generated new texts as the LTI evolved.

Further, the LTI is not scripted work that inherently results in students' doing science. Teachers have an important role to play. Here, Diana, Carrie, and Marilyn sustain the work with their students through on-going conversation focused on their moment-to-moment learning needs. For example, Carrie helps students write a hypothesis more clearly in one moment, and then moves to another group to help them understand their variables. Diana helps two students clarify how to express their variables in one moment, and in another, she helps students understand how to write their hypothesis. In a single class period, teachers working in small groups with students may have many different kinds of conversations, all focused on different points along the process: from writing a question, to using measurement tools appropriately, to making decisions about how to best measure a variable, when to collect data, etc. In other words, these teachers orchestrate their students' involvement in the LTI process responsively. That is, in response to students' needs at any given moment (Gallas, 1995). This work is not dictated by the page number in a textbook or any one standard item in a list of curriculum goals.

These teachers use the UA textual tools and language to scaffold their students' needs, to shape the interactions among students, and between the students and their own projects. For example, when Carrie listens carefully to her students grapple with decisions about when to go to the zoo to gather data on gorilla behavior, she not only guides them to make decisions as science colleagues, as partners, she helps them to make critical decisions about how best to collect data.

She does this through pressing them to explain their ideas, she draws from them (through questioning) their reasoning for their investigation design. She guides them to find the most efficient use of their time given the materials and the constraints she knows are accessible to them (e.g., one trip to the zoo to collect all data, their emerging understandings about how to define observable animal behavior, how to make a claim based on the data they are likely to collect). The teachers' roles during the process of the LTI, how they sustain the work, and push students toward knowledge of content and of practices, are central to this work. I shall show, in even further detail, how these roles play out in subsequent chapters.

Chapter 5

Language as a Tool

Now that I have considered the basic structures of long-term investigations, the science practices that teachers engage, and touched on teachers' roles in the LTI, I delve inside. What particular things are teachers doing in the moment-to-moment interactions? I attempt to answer these questions by looking at the spoken language (talk) in these classrooms as teachers engaged students in the LTI.

Why language? Wells (1994) reminds us that, talk "makes [a contribution] to the activities in which students engage in the "lived-in-world" of the classroom, the actual structures of participation, and the function that talk performs – along with other semiotic systems – in mediating the goals of these activities" (p. 2). Further, recent calls for science education to pay close attention to the practices that teachers engage in science classrooms makes language, and the discourse of science, a key concern (Hakuta & Santos, 2012; Nagy & Townsend, 2012; NRC, 2012), especially in classrooms that serve students from minority language communities (Hakuta & Santos, 2012). Hakuta and Santos have argued that NGSS and CCSS "raise the bar for learning, call for increased language capacities in combination with increased content sophistication, and call for a high level of discourse in classrooms across all subject areas" (p. i).

This chapter's purpose, then, is to drill further into language, into the generative and receptive nature of talk in science classrooms where students are conducting long-term investigations (Nagy & Townsend, 2012; Wells, 1994). My use of the phrase "language as a tool" derives from sociocultural theory, which explains how spoken and written language, as primary components of discourse, are socially constructed by those who participate in discourse

(Gee, 2008a).[15] In his summary of Cole (1994), Mercer (2008) states, "drawing on a strong tradition in sociocultural theory, language is the 'tool of tools'; it allows us both to intervene in social action to shape and direct it and also to represent that action and the world in which it occurs in a 'theory of experience'" (p. 100). Similarly, Nagy and Townsend (2012) adopted a tool metaphor in thinking about how words work in language: "being able to use an item of academic vocabulary means being able to use it in the service of the functions of academic language" (p. 96). In other words, words *do* things.

In this chapter, I bring together the analysis of science practice that I conducted in chapter four with language by exploring how the language of science – embedded within the activity of scientific practice – becomes a tool that students can learn to employ to both develop and communicate ideas in scientific investigations. Research on disciplinary literacy shows that students can appropriate the language of a discipline in the context of practicing (e.g., discussing and being actively engaged in) that discipline (Gallas, 1995; Gee, 2008a; Hull & Moje, 2012; Moje, 2008; Nagy & Townsend, 2012; Snow, 2008).

In this chapter, I hope to show how language – the spoken and written words, and the conversations they create – is a tool, like a wrench or a Phillips-head screwdriver (Nagy & Townsend, 2012) teachers use in their LTIs. I hope to show, through micro-analysis, the different dimensions involved when teachers and students employ, negotiate, and learn to use the LTI language.

I begin by describing how teachers use language to engage students in the practices of scientific investigation (NRC, 2012) along three dimensions: vocabulary (lexical), talking about

[15] Although there are also other components that make up discourse -- semiotic or paralinguistic tools like body language or written or visual texts (Gee, 2008), for example – those are not the focus of this analysis.

science language (syntactic/grammatical and semantic), and in writing (which also considers the lexical, syntactic, and semantic dimensions).

Learning Disciplinary Vocabulary

Learning an academic language like science entails learning to use words as one learns to use a specific tool. We do not live our days solely using academic language(s) (there are many), but having such language(s) available to us provides us with greater opportunities to participate in multiple language (and social) communities. Nagy and Townsend (2012) relate, "Learning academic language is not learning new words to do the same thing that one could have done with other words; it is learning to do new things with language and acquiring new tools for these new purposes" (p. 93).

Recent research on disciplinary vocabulary development suggests that vocabulary – or specific technical words -- cannot be separated from the contexts in which it is used (Gee, 2008a, Nagy & Townsend, 2012; Snow, 2008). Not only are the meanings of words inherently inseparable from their contexts, but students learn new vocabulary within the context of authentic discussion (e.g., a small group discussion with other students) within a larger meaningful context (e.g., a LTI) (Lindfors, 1987; Nagy & Townsend, 2012; Snow, 2008). Consider several examples of the ways Diana, Carrie, and Marilyn engaged in talk about science vocabulary.

Getting to "trachea." First, let's return to Diana's classroom. Here, Diana conducts a whole group discussion, early in her LTI process, in which she solicits students' answers to the question, "What are the parts of the respiratory system?" This is a part of a Do Now exercise, intended to review terms before they begin building models of the respiratory system later in the class period. Ariel is the first student to respond.

Ariel: Your windpipe.
Diana: Windpipe.. um.. I don't disagree with you.
There's a word I'm gonna put down,
a new vocabulary word for today and it starts with a T and it's the, the=
Sam: =Trachea.
Diana: The yeah. ((laughs)) That's how I want I'd rather you put it on there.
Trachea is a funny word to spell, so look at how I'm spelling it.
T-R-A-C-H..
Sam: E-A.
Stacey: E-A. ((said simultaneously with S before))
Diana: E-A. ((laughs)) Raise your hand if you had trachea. Very nice.
Or if you had like..
Sam: Can I put throat?
Diana: Throat. Yeah well throat you gotta be careful
'cause when you think of your throat
sometimes you think of your digestive system,
right 'cause both food and the air, going through here.
So trachea is a way to distinguish the part that that,
I guess air goes through.

Here we see Diana and her students in negotiation of terms. Students provide terms, starting with "windpipe" and with Diana carefully nudging them along, they move toward the scientific term, "trachea." Diana announces there's "a new vocabulary word," and before she can say it, Sam yells it aloud (line 5), partly surprising Diana, making her laugh (line 6). She explicitly tells the class that this is a term she prefers that they use (line 6). She identifies it as "a funny word to spell." Students also copy the word into their own notes.

Then Sam inserts a question, "Can I put throat?" (in place of trachea) (line 13). Diana explains the distinction between throat as a more general term for the area surrounding the trachea and esophagus (a part of the digestive system) and trachea as the specific organ in the respiratory system, their focus of study for the day (lines 14 through 19). Students do not take this idea any further after Diana's last utterance (in line 19), and the conversation moves on to listing other parts of the respiratory system.

While Diana explicitly teaches the scientific term for "windpipe," she also takes up her students' contributions (e.g., "windpipe" and "throat") as resources for fine-tuning the terms she wants them to learn (Warren, Ballenger, Ogonowski, & Rosebery, 2001; Snow, 2008). This is a moment of negotiation and meaning making in the context of a discussion designed to prepare students to build models (the second practice in the NRC framework) (Warren, et al., 2001; NRC, 2011). This exchange is also multimodal (e.g., using talk and text interchangeably), and depends on the social negotiation between Diana and her students (Nagy & Townsend, 2012). Research has provided numerous examples of this sort, providing a reason to believe that this approach is fruitful, especially for students who speak minority languages (Gee, 2008a, Nagy & Townsend, 2012; Rosebery & Warren, 2008).

But there is something else noteworthy about this exchange. Let's zoom in on the last few lines of this exchange, in which Sam inserts his question about the word "throat" (line 13). After Diana provides the term she prefers, Sam asks (line 4) if he can use the word "throat" in place of "trachea." Diana clarifies for him the distinctions between the throat – which includes several organs, some of which are not a part of the respiratory system – and the trachea, which is a specific name for one organ located in the same area we call the "throat."

But this moment involves more than a curious student. Sam's question, confidently inserted even after Diana provides her preferred term, expands the discussion, prompts Diana into a spontaneous explanation. She provides an answer (lines 14 through 19) (e.g., "you have to be careful…") about how to explain "trachea" as the more precise term.

Sam's exploration of other possible terms (i.e., "throat") is an example of what Rosebery, Ogonowski, DiShino, and Warren (2010) argue is the heterogeneity of language use among students in culturally and linguistically diverse classrooms. They go on to suggest that this hetereogeneity is a resource for teachers and students. Here, his honest question has the potential to push everyone's learning, because it prompts Diana to be more clear and to consider alternative terms (Rosebery, et al., 2010). This moment also provides a glimpse into how murky the linguistic waters are for teachers and students, that words may not always be clear until we are given opportunities to wrestle with them alongside others (Gee, 2008b; Rosebery, et al., 2010).

My own little language. I now turn to a longer excerpt that involves an entirely different sort of conversation about vocabulary. I have broken this excerpt into four sections, each according to the natural shift the conversation (Erickson, 2004; Gee, 2007); these shifts define successive conversational turns in which speakers refine their understanding of a particular technical term.

Marilyn's students, early in their LTI, were working in "expert groups" to read articles and share what they learned about various weathering processes. Marilyn has just arrived to a group to check on their progress and the conversation begins with Jamie responding to Marilyn, who asks about how their note-taking is coming along.

1 Jamie: Um. When I did it, I kinda got ((unclear)) because a lot of the words
2 I really didn't understand.
3 Marilyn: Oh yes, and this is one of the things I was telling you yesterday,
4 that our vocabulary for this is really tough.
5 Jamie: So, Margaret's ((another student)) kind of helping me kind of break it down and like put it into more like, my own little language so that's a great idea for like [word], hydration, ((provides two more terms))
6 Marilyn: So, he's named a whole lot of different things there... what are those?
7 Keith: There's just different forms of chemicals.
8 Marilyn: Different forms of chemicals.
9 Keith: And all the processes in which chemical weathering happens.
10 Marilyn: Okay.
11 Keith: Chemical.. and then you can sub.. into which chemical processes are happening, there's oxidation, carbonization, ((lists a few more)).

In the opening of this conversation (Schegloff, 2007), Jamie explicitly identifies vocabulary as a challenge toward understanding the assigned reading. Marilyn supports Jamie by recasting in lines three and four, saying, "our vocabulary for this is really tough." They establish their mutual understanding. And now, with everyone in the know, the work begins. Jamie and Keith drive this segment, identifying what is difficult for them (e.g., the terms), identifying what they have done so far (e.g., put them into his "own little language"), and naming what they do know so far (e.g., terms like "hydration"). Marilyn interjects with one clarifying question, “What are those?” (line 8), pressing the boys to move from the specific terms to the general category (e.g., chemicals). The conversation continues as Marilyn and students shift the conversation into an explanation of “oxidation.”

12 Marilyn: Okay, who wants to explain oxidation for me?
13 Jamie: ((unclear))
14 Marilyn: So what do you think? Who can explain oxidation?
15 Margaret: We didn't get that much..
16 Marilyn: You didn't get that much on it. Okay, so you just spoke about... you just spoke. So how about her?
17 Vicki: ((raises her hand to speak))
18 Marilyn: Ah.. okay.. Vicki, thank you=
19 Vicki: =Well, I said that it made rocks like smoother?
20 Marilyn: Made rocks smoother, but what's happening.. in the rock..
21 'cause I'm not sure it actually makes rocks smoother so much,
22 it's actually a very familiar chemical reaction
23 except that you may not know it by the term oxidation,
24 you may know it by something else.

This segment begins with Marilyn’s direct question, “Who can explain oxidation for me?” It takes a few turns and hedges (e.g., “we didn’t get that much on it”), before a student attempts an answer (line 24). And when Vicki does respond with “Well, I said that it made rocks like smoother?” her statement includes a rising tone at the end, as if asking a question (Johnstone, 2008; Tannen, 2007). This indicates Vicki’s hesitation about her answer. Vicki provides the result of this particular weathering process, but does not explain the process.

Marilyn gently nudges with, “I’m not sure it makes rocks smoother so much… you may know it by something else.” This signals that Marilyn will provide a hint next (Schegloff, 2007). But before she does, Alex takes the opportunity to add his explanation to the table, as we will see in the next segment.

25 Alex: I know what it is, but..
26 if I can say more about it,
27 it's when the compound oxygen reacts to ((unclear)) electrons,
28 it makes the rock unstable which makes it collapse?
29 Marilyn: Which makes it.. now..
30 Alex: ((something about softness))
31 Marilyn: Now, you tend to get this sort of reddish-brown substance,
32 being.. ((Margaret guesses)) exactly.
33 Vicki: ((to Margaret)) What did you say?
34 Marilyn: You want to say it again a little louder?
35 Margaret: It's like it's.. it's like it's rusting.
36 Marilyn: It's like it's rusting. And some of our rocks will actually contain iron in it.
37 Vicki: The Statue of Liberty. It got oxidized.

Here, Alex begins explaining the process of oxidation – even asking for more time to “say more about it” (line 31). He uses highly technical language: “when the compound oxygen reacts to …. electrons” Marilyn responds in line 34 “which makes it… now,” hinting that she wants students to name the end result – rusting -- which is the word she hinted at in the above sequence that students “may already know.” She gives the next more specific clue in line 36 with “now you get this reddish-brown substance.” And with this, Margaret explains that the process of oxidation results in rusting (line 40).

Here, Marilyn effectively helps students to use their everyday language to make a connection to the formal variation on a specialized word (Gee, 2008b; Snow, 2008). And Vicki provides her own device for remembering the term (line 42), ruminating that since the Statue of Liberty appears rusty, “it got oxidized.”

Throughout this exchange, Marilyn provides small supports for her students as they attempt their own explanations. Their talk about vocabulary moves back and forth between teacher and student ideas, moving from identifying a difficult term, to explaining it, to putting it into the context of everyday knowledge (e.g., rusting). While it is true that Marilyn provided the goal, to explain the word “oxidation,” the students participate in nearly equal measure in this discussion. They responded to each of Marilyn’s moves with full answers, attempts at scientific-sounding language, timid guesses, as well as confident leaps. Each time, Marilyn supported and pushed.

But what were Marilyn’s discursive moves and why do they matter here? Recall in the first section, she shows alignment with the student who opens the conversation (Schegloff, 2007). In other words, she shows that she is in agreement with Jamie (line 1), who observes that the vocabulary is difficult. She then inserts a proposal (Schegloff, 2007) that they explore one of the difficult words in their reading, “oxidation.” Then she notices that students, while using highly technical language to explain the process, are relying on the written text to tell them what they need to know. Marilyn attempts another shift by suggesting that they “know [the term] by another name” effectively asking them to rely on their everyday experience as a resource (Rosebery, Warren, & Conant, 1992; Warren, Ogonowski, & Pothier, 2005).

Weird words. In this next example, we return to Diana's classroom. This time, Diana's students have completed a short activity in which they were to explore how the diaphragm feels when they breathe. This short exchange comes from a whole group conversation to help students understand how the diaphragm works. As in the first example, this excerpt is from the lesson on the organs in the respiratory system, in which she teaches about "trachea." However, this time, Diana takes an extra moment to teach the word "diaphragm." This excerpt begins with Diana demonstrating the same activity that the students had just completed. She stands at the front of the room with both hands just below her ribcage, where she can feel her diaphragm expand and contract as she breathes deeply, in and out. Students are watching, some imitating her at their seats, as waves of breathing and giggling move across the room.

1 Diana: So when you breathe in, ((demonstrates taking a breath))
2 it actually feels like it gets bigger. Right? That's correct.
3 And when you breathe out ((breathes out)) it almost feels like it gets smaller.
4 So if we go back to our Do Now, there's a muscle, that we're missing.
5 And remember when I said leave a blank?
6 Students: ((two boys say simultaneously)) Yes.
7 Diana: The word is diaphragm.
8 And look at how I'm spelling it. ((writing on the Smart Board))
9 It's a weird weird word.
10 And your diaphragm is the muscle.. underneath...
11 and you guys will be able to read a little bit about it
12 and it'll be part of your model..

Though the transcript only reveals Diana's talk, students are interacting with her non-verbally: some continue to test how their own diaphragms work, others laugh, still others write notes. And many have their eyes squarely on Diana.

This example illustrates another type of move that teachers used when teaching vocabulary, one that involved an investigation experience out of which new vocabulary comes. Here, Diana takes a moment to connect a physical experience with its word. In a sense, this moment mirrors the one reported by Rosebery, Ballenger, Ogonowski, and Rosebery (2001) in which a student understands the growth of a pumpkin seed by enacting the growth physically, he "interanimates" it. Rosebery and her colleagues demonstrate how students make connections to concepts through active interanimation. Diana's students do the same thing here. Although this time, Diana directs the embodiment, the students create their own variations on that as they observe that they "get dizzy" when they breathe deeply in this way, or feel their "ribs going in and out" or their "diaphragm going up and down." In this way, Diana supports students' own ways with words and active embodiment resources to both visualize the term and make conceptual connections (Heath, 1983; Warren, Ballenger, Ogonowski, & Rosebery, 2001).

"**Food" or "nutrients?"** We stay in Diana's classroom for the last example of vocabulary work. This exchange comes from the bacteria lesson (see chapter 4) in which Diana asks the students to name under what conditions bacteria survive, writing answers on their Do Now sheets, and sharing them with the class. This excerpt begins with Diana responding to a student who provides the first answer: "water."

1 Diana: Water. Okay. Raise your hand if your group also said water.
2 Did any-, any other group say water? No?
3 Okay, some bacteria need water, yeah.

4 Alright, um, who else wants to share something your group talked about?

5 Andrew, what did your group say? One thing.

6 Andrew: Um, people agreed that um... ((unclear))

7 Diana: Okay. Food.

8 Alright, raise your hand, if you had the exact wo::rd, "food."

9 Okay. Raise your hand if you said, 'nutrients.'

10 Students: ((yells out in the background)) I put it on the side!

11 Diana: Sh... okay, so I'm gonna put, -slash- nutrients.

12 ((writing student answers on the board))

Though brief, again we see Diana making explicit moves toward specificity (Lemke, 1990; Snow, 2008). As she takes ideas from the class, she asks students if they agree or disagree with the idea. She records their ideas on the projection of the Do Now sheet on the Smart Board as students write answers in their own Do Now print outs (see chapter 4).

In line seven, Diana responds to Andrew who, though we cannot hear his entire answer, presumably adds the word "food" to the list. Diana asks if others wrote the "exact word." Then, she introduces the word "nutrients." But this time, she does not announce it as a vocabulary word, simply writing "nutrients" beside the word "food" on the board. She says nothing more about this explicitly in this conversation, and moves on to soliciting more student answers.

However, I paused on this moment for two reasons. First, it demonstrates how teachers differentiate between levels of abstraction or specificity in science language. As Snow (2008) explains, one difficulty with learning science vocabulary is that, as students move from elementary to high school, they are expected to use more sophisticated -- and abstract terms. She outlines a system of classifying words into three different categories, or tiers (Beck et al., 2002 cited in Snow, 2008). Tier one words are those that students who grow up in most any English-speaking community would already know, such as “plant,” “water,” or “fish.” Tier two words are those that are “encountered in academic discourse but are not specific to any particular field or discipline” (Snow, 2008), such as “compare” or “characterize.” Or, they can be less common forms of tier one words such as "growth" instead of "grow", or "differentiation" instead of "different". Tier three words are those that are highly technical and abstract and used only in a science context, such as, "electromagnetic" or "oxidation" or "photosynthesis." Tier two words are said to be the most difficult for students to learn because they are less likely to be taught explicitly, their meanings are complex and sometimes abstract, and they occur in casual conversation (Snow, 2008).

Snow’s ideas are illustrated in this example. Diana replaces the word "food" with "nutrients,” moving from a tier one word to tier two or three.[16] But instead of replacing one word with the other, she writes them side-by-side (line 11).

This discursive move brings me to my second reason for including this example. As Diana writes the words next to each other, she effectively positions them as equal in meaning at the same time that it honors Andrew’s answer, as well as other students who said they wrote “food” (Warren, Ogonowski, & Pothier, 2005). Though the subtext of her question (e.g., “okay raise your hand if you said ‘nutrients’…. okay I’m gonna put, slash, nutrients”) suggests that one word is preferred over the other, she stops to recognize that these words may be interchangeable, but that Andrew provided an opportunity for Diana to point out these subtle differences between

[16] Snow (2008) also notes that some words are difficult to place in a category and may actually be appropriate to place in both tier two and tier three, such as “nutrients,” which may be used in casual conversation among some groups more often than others, but that may also be a scientifically-technical word, depending on the grade level. For example, “nutrients” would not feel like a technical word to a 12th grader in advanced biology, but for a younger student, it might be completely new.

words. This moment is reminiscent of the moment when Sam asked “Can I put throat?” These are moments that Diana did not squander, moments in which a student presents her with an opportunity to explore vocabulary and meaning making with her students.

In these examples, we see several strategies that teachers use to help students learn scientific vocabulary. They draw students’ attention to vocabulary that they know is challenging, and push students to use the resources around them, material and experiential, in acquiring these new words, so that later they can become tools in their communication about science. Teachers draw on students’ ways with words to help them to make connections to specific scientific terms (Heath, 1983; Rosebery & Warren, 2000; Rosebery, Ogonowski, DiShino, & Warren, 2010). They clarify the distinctions between words that students may use in their everyday language that have different meanings in science (Lemke, 1990; Gee, 2008a; Rosebery & Warren, 2008; Snow, 2008). They take opportunities to clarify meaning through recognizing the subtle differences between terms, to focus on helping students add new things to their linguistic toolboxes. And what did these tools afford students and the teacher?

Talking About Science

In addition to focusing on specific words, teachers also taught how to use various other conventions for "talking science" (Lemke, 1990). In this section, I describe the strategies teachers and their students used to learn about and use multi-word, phraseological (Bakhtin, 1986) constructions of scientific language – which includes the lexical, syntactic, and semantic dimensions – and discourse (Gee, 2008a). With the examples that follow, I hope to show two different patterns with respect to teachers’ use of and teaching about language during the LTI. First, I explore how teachers explicitly taught the language they would later expect students to use both in classroom conversation and in writing. Second, I demonstrate how the LTI provided a context for learning the language of science (Rosebery, Warren, & Conant, 1992).

Learning LTI conventions. Recall that at different times in the school year, teachers launched the LTI with instruction about the science practices and ways to think, talk, and write about the scientific process (NRC, 2012). As teachers and students moved into planning for the LTI, they applied the language in class discussions concerning the investigations, including talking about variables, writing scientific questions, writing a hypothesis, and deciding how to collect data. I now turn to several examples of those language forms (e.g., the grammatical and syntactic conventions).

In one 50-minute whole group discussion, Diana guides her students through understanding the IDD. It is her first time teaching the textual learning tool, and she uses the bacteria activity (see chapter 4) to teach students how to navigate and understand the tool. The excerpt illuminates how Diana and Marlyse talked about the formal language conventions that teachers teach through the IDD. Later, I will show how this same language is repeated throughout the LTI, in different forms, for different purposes.

At the beginning of the lesson, Diana asks students to respond to questions on the Do Now (see Figure 4.1), where students list what they knew about the conditions under which bacteria live. The back side of the IDD is for filling in information in advance of beginning the data collection for the bacteria investigation. Here, Diana moves the discussion from talk about bacteria to the question that they will write, using the specific language she wants them to use (Gee, 2008a; Lemke, 1990; Nagy & Townsend, 2012). Diana is at the front of the classroom, writing on the board as she talks. She expects the students to copy the information on their IDD as she writes.

1 Diana: So the first part of our question is, "how.. does.. location... affect.."
2 and we're not actually gonna say "dirty"
3 what are we re::ally looking at in this investigation?

Diana opens with how to write the scientific question with very specific language: “How does location affect…” She pauses briefly here to allow students to catch up with their notetaking. After a few moments, she continues:

4 Diana: ((we’re not)) really saying dirty,
5 we're saying where is really, there are the most bacteria in the classroom.
6 So, "How does location affect..." who thinks they know how to say it now?
7 What should we say?
8 "The amount.. of.. bacteria" ((writing)) "that... is growing.. or that will grow."
9 So under DEpendent variable what do I write for DEpendent variable?
10 Student: ((unclear))
11 Diana: ((writing and talking simultaneously)) Is growing.. or will grow..
12 so you put it in your own words, yeah.
13 Yeah, the amount of bacteria.
14 How much bacteria. ((writing))
15 And I'm going to put in parentheses our vocabulary word,
16 "number of colonies of bacteria".. "number.. of colonies.. of.. bacteria." ((writing on the board))

After the students have completed writing their question, they title the LTI. Here is a small excerpt from the "how to write a title" segment of the conversation.

1 Diana: Alright. So we don't have a title.
2 So, we want our title, the title of an investigation a scientific investigation
3 is almost like having a question,
4 but instead of having a question mark at the end of it,
5 you just say it as a statement.
6 And instead of saying the work "affect", we're gonna talk about the word.. "effect."
7 Alright, this is that affect-effect thing that can be really confusing sometimes.
8 So, the title, we're gonna say the title is, [writing]
9 The effect.. of.. and what's the the INdependent variable,
10 you wanna say the independent variable first..

In this last segment of the conversation, Diana teaches that the title of the project is going to build from the question, that it is "almost like having a question, but… you just say it as a statement" (lines 4 and 5). She then notes that there is a difference between the words "affect" and "effect." Diana is writing as she explains these ideas, which partly explains the pauses and repetitions in her speech. Also, students are writing the same information on their IDDs. She begins the sentence construction as, "The effect of…" and reminds students that the first phrase in the sentence includes the independent variable. The rest of the lesson moves in a similar way, in which she leads the students to write the title as, "The effect of location on the number of colonies of bacteria." This becomes the title all the students will use.

Later, in the same conversation, Diana moves on to teaching about the dependent variable, another new term. Here, Diana and Marlyse (a few students chime in as well) discuss what they know about the conditions under which bacteria will live, and apply what they know to a video they saw previously about people who become ill after eating foods that had not been properly stored at a picnic. Marlyse opens the discussion by offering the example, and Diana takes it up, as an entry into teaching about variables. The excerpt begins with Diana asking Marlyse to remind the class about the dependent variable.

1 Diana: Marlyse, what did I just say?

2 Marlyse: You said that the dependent variable is the number of people that got sick ((at the picnic in the video)).

3 Diana: Yeah, it's a little more, I tried to give it to you a little more subtly.

4 Stacie: It's the measurement.

5 Diana: Yeah.. you guys, Stacie can you repeat it again?

6 Stacie: It's the measurement.

7 Diana: Okay, so it's what.. you.. measure ((as she's writing the answer on the board)).

8 So if the dependent variable is what you mea::sure.

9 It's the one you measure 'cause it's the dependent variable, ON what you're investigating.

10 So, the INdependent variable is the other one,

11 does anyone remember what the OTHER one is?

12 I know Stacie knows... does anyone else besides STAcie know?

13 What's the De... what the INdependent one then? Yeah. ((points to student))

14 Taren: One that somebody changes.

15 Diana: It's the one that YOU get to change.

16 So, you change some stuff, and then you MEAsure.

17 What do you measure?

18 Geoffrey: ((unclear))

19 Diana: Your DEpendent variable is what you're gonna measure.

Diana asks her students to complete a Do Now which asks the question, "How do we apply what we learned about bacteria to an investigation in which we culture bacteria? What conditions are favorable for bacteria growth?" As students answer her questions, Diana writes the ideas on the board while students are writing these same answers on their handouts.

While it may appear as though this exchange is a traditional example of the IRE (Mehan, 1979) pattern of classroom interaction, there's more that's going on here that we cannot hear. While the transcript – a limited portrait of a noisy, busy classroom -- might paint the picture of a lifeless marching back-and-forth between teacher and student, students verbally and non-verbally interact with Diana during the discussion. Students talk in the background, offer up answers without being called on. They write, read, agree with each other and Diana, or not. The students call out-of-turn, often in a call-and-response manner (Adger, Wolfram, & Christian, 2007); she consistently, and in good humor, reminds students to raise hands to take their turn in speaking.

Here, guided largely by the IDD, Diana's teaching unfolds in a careful march through the elements of the IDD (e.g., the question, the title, the independent and dependent variables) and the common language she will expect students to use in subsequent lesson – most importantly, the final LTI.

Applying the LTI conventions. Teachers not only guide students to learn the language of investigation design, they later ask students to apply that language as they work in teams to design investigations. In other words, the language they have learned in early lessons about the IDD, considerations sheets, or the Do Nows, for example, is useful for later learning and communication in science (Wells, 1994).

One example occurred in Marilyn's class, where students are arranged in their LTI groups, writing their procedures and making a list of the materials they will need for their investigations. They are scattered throughout the classroom, huddled over computers and books and various science materials that Marilyn keeps accessible for them. There is a vibrant buzz in the room as groups excitedly work on their plans, moving around the room gathering materials, rummaging through cupboards for tools, exploring the plant lab to plan how to use the space, gathering water in aquariums. Students smoothly shift between writing, revising, and exploring.

Marilyn circulates, spending about two minutes with each group. Her general approach is to check in on the progress of groups and keep them on task. Occasionally students reach out to her, asking for help.

On this particular day, Jacob called Marilyn over to his table, while the other members of his group (four other boys), listened in. Their investigation title is, "The effect of light quantities on the growth of the Euglenoid algae." We hear how they negotiate their investigation design based on their anticipation of these variables.

1 Jacob: We're trying to figure out 'cause we can't really use the incubator
2 'cause of the light situation and air, really, we'll figure that out.

3 But then if we can't use light, the grow lab's actually gonna work for us

4 'cause it's like 5 degrees higher than the perfect...

5 Marilyn: That's good! And then you'll get your light...

6 Jacob: And then.. is there way is there like a while light bulb, like white. light light bulbs? Like some are...

7 Marilyn: They have bulbs that they mix in light?

8 Jacob: Yeah.

9 Marilyn: I'm not sure you can get smaller ones but fluorescent ones...

10 Jacob: Alright yeah like that well can animals grow from that like, is that makes them...

11 Marilyn: That makes them um, like regular light? It could.

12 Jacob: Because we can't use the incu- that light ...

13 that's not hot enough or cold enough we don't have like a range of temperatures there.

14 So we need other spaces like the incubator but then, we missed somebody...

15 trying to figure out like our cold situation.

16 Is there like a really cold cold space in school?

17 Marilyn: In this place?

18 Jacob: That will keep it alive?

19 The fridge I'm pretty sure is too cold.. the temperature...

20 'cause then we'd have like a wild range.

21 Marilyn: Now, these are the limitations that you're coming up with now that

are pretty good for coming up with
before you actually start writing up your materials and procedures,
so you know what sorts of things could happen.
Jacob: So like, we have it to the, not to the extremes.

Jacob, the group's unofficial spokesperson, opens the exchange asking Marilyn for help in finding the right equipment to use while the group plans. He grapples with the decision about what kinds of lights to use since they all emit heat and he and his colleagues want to control for heat. Jacob speaks at the formal register that is expected of him. He reasons that they need an appropriate light source that will not result in the "extreme range" of temperatures that he fears would come from using the light sources in the classroom. He considers the variable (light) as it relates to heat production, and worries about which light sources would be best to use in this investigation.

As Jacob helps his group think through their plan, he applies his knowledge of science content (e.g., heat and light), using the idea of a "range" or "extreme" to describe how to narrow down variables to ensure that they conduct a fair test. Jacob demonstrates that he knows – either intuitively or through experience – that investigation design and decisions about materials and other resources (i.e., a cold place in the school) are not arbitrary decisions, but depend on a host of understandings about the phenomena one is exploring (Lemke, 1990; NRC, 2011).

Though subtle, Marilyn's role in this exchange is noteworthy. In the broadest sense, Marilyn provides Jacob (and his group mates) an opportunity to practice his (their) science knowledge (Gee, 2008a; Snow, 2008). In this student-centered exchange (Crawford, 2000), Marilyn's role is to offer support of the students' ideas, and to attempt to problem solve alongside the group. Marilyn does not impose her own ideas; rather, she answers Jacob's questions honestly, offering up suggestions for other light sources (e.g., like "fluorescent").

Looking even more closely, Marilyn provides a sounding board for Jacob's thought process. He opens with exploratory talk in line one. Exploratory talk, according to Cazden (2001), is speaking "without the answers fully intact" (p. 170). His engagement with Marilyn demonstrates that he is interested in Marilyn's feedback. He shows her his knowledge of the investigation process through his alignment moves (Goffman, 1981; Schegloff, 2007) with Marilyn in lines 8-18. He latches onto Marilyn's speech in line eight where he says "... it makes them..." and Marilyn responds with, "... that makes them um, like regular light? It could." Marilyn finishes Jacob's sentence for him, showing that she is listening, and engaged in what he is saying (Tannen, 2007).

Later, Jacob does not directly take up her advice about light sources; rather, he moves on to another question about where to find a cold space in the school (lines 9-15). Marilyn's last line recasts, in a meta-level (Cazden, 2000; Gee, 2008a), what Jacob is doing with his thinking (lines 19-22). Jacob's last line (line 23), "So like, we have it to the not to the extremes," is another chance for him to demonstrate to Marilyn that he understands some of the subtleties of investigation design (e.g., to have consistent intervals – however they are measured – between levels of the IV). It shows alignment (Goffman, 1981) with Marilyn and her knowledge about his choice to be careful about temperature. In this exchange, in other words – through latching, alignment, and recasting – they show that they are sharing in the problem solving task, Jacob taking the lead, Marilyn in the supporting role.

Now let's turn to Carrie's classroom, which offers another variation on talk about planning, and applying the science language students have learned in previous lessons. As in the last exchange between Marilyn and her students, Carrie has asked her students to sit with their project groups to determine their plan for the LTI. Carrie's role is to move from group to group and check in on their progress and answer any questions. As in Marilyn's classroom, the entire class is engaged in their projects, moving about the room, collecting materials, and writing together. They are arranged in table groups of about four students apiece, some standing, hovering, some sitting. We hear several different kinds of negotiations across the room: students arguing about methods they should use to measure things, some students excitedly exchanging ideas about their projects, several taking notes for the group as they talk. There are laptop computers, journals, and colored markers strewn about the tables.

Students are hunting down additional information online about where to find materials at stores in their neighborhood. And yes, some student groups argue. They argue about who is doing the most work, who is being the most unhelpful, and whose turn it is to take notes. And yet, they are also remarkably resourceful and confident. They email the Urban Advantage scientists at partner institutions (e.g., the Bronx Zoo, the New York Hall of Science) for additional information about specific animals in the exhibits, or for background information about the physics of trebuchets. This is a high-energy hour, and students are focused on completing the planning sheet that Carrie requires.

In the following exchange, Carrie is checking in with one small group as they begin planning their LTIs. Here, the students are designing a field investigation about gorilla social behavior. They are trying to decide how they can measure the time of day when gorillas are likely to be the most social at the local zoo, and to mark what kinds of social behaviors they expect to see during different times of the day. One student had done this investigation earlier in the school year, and wanted to explore her data in a different way. Carrie and two girls in this group, Maddy and Allison, decide on how often and when they should visit the zoo to collect their data.

31 Carrie: Alright checking back in, any questions?

32 Maddy: For this would it be one if we just went once?

33 Carrie: ((reading student work)) "The effect of time of day on gorilla social behavior."

34 Maddy: So if we do it twice=

35 Carrie: =So if you go once, I would make sure=

36 Maddy: =So twice per IV=

37 Carrie: =that you do it for a longer time, um=

38 Allison: ((student in background))

39 =So, I would say twice=

40 Carrie: =in the morning and the afternoon.

41 Maddy: So, we go twice and we then just do it at 12, 1:30, 3.

42 Allison: About two times on each day.

43 Maddy: And then we average out the data.

44 Carrie: Sounds good. Now, who did gorillas before?

45 Allison: Me.

46 Carrie: And what was your IV before?

47 Allison: It was um.. like, um...

48 Natalie: ((in background)).. grooming behavior.

49 Maddy: Actually it was... time of day=

50 Carrie: =was it time of day?=

51 Maddy: =time of day on gorilla grooming behavior=

52 Carrie: =Because you might be able to bring in some of the data from before.

53 Natalie: ((unclear))

54 Carrie: Good. Now are these the same times as you used before?

55 Allison: No. We only did it twice and=

56 Natalie: =and we did it at 11:30 and at 2:00=

57 Maddy: ((in background)) What time? 11:30 and=

58 Allison: =I think it should be::... 3 times because you get more productive data.

59 Carrie: So...

60 Maddy: So we have more to work with.

61 Carrie: Excellent. Okay.

62 So I like that you're making this one, you're like, "no, we need more data,"

63 which are some of those improvements that we talked about.

64 So good. No questions? We're all set? Make sure you're talking and everyone's on the same page.

This exchange begins with Maddy asking Carrie for help in choosing how many times they should make observations at the zoo in one day. As Carrie relates to me in an interview, the students' acknowledgement that more trials means better data is admirable, but in this particular field study, there would not be a significant difference between taking notes at 12 p.m., or 1:30 p.m. However, Carrie supports their efforts to find ways to get more data. But getting there takes some negotiation on their part.

The students and Carrie enact several specific discourse patterns that both position the speakers as in and out of alignment (Schegloff, 2007). Both Maddy and Allison interrupt Carrie.

The pair of utterances in lines 3 (by Carrie) and line 4 (by Maddy) are not in alignment. In line 3, Carrie reads what the girls have written, attempts to assess where they are in their work. Just as she finishes her reading, Maddy begins to answer her own question from line 2 ("So if we did it twice?").

Carrie then begins to answer, as her utterances and Maddy's intertwine, but are not true responses to each other (lines 5 through 9). Inside of these turns, Carrie has a complete thought, her only piece of advice in this exchange, "So if you go once, I would make sure that you do it for a longer time, um, in the morning and the afternoon," that is broken into three segments, by by Maddy and Allison's overlapping (Tannen, 2007). Once begun as disagreement, they both come to agreement near the end of that segment in lines 10 and 11. These utterances work to align speakers to each other, bringing their ideas into agreement (Schegloff, 2007). They fall out of alignment again when Carrie asks them what their IV was in the previous investigation (lines 15 through 20) (Schegloff, 2007).

Then, in lines 16 through 20, Allison, Natalie, and Maddy overlap each other as they attempt to answer Carrie's question about who investigated this topic earlier in the year. It was Allison's project in the fall, but Natalie and Maddy attempt to answer her question. In fact, Maddy corrected the two other students in lines 18 and 20: "actually it was time of day…. time of day on gorilla social behavior."

Carrie listens as Maddy and Natalie wrestle with the appropriate number of visits. She interjects softly, "so…" (line 28) which redirects the discussion toward finalizing their answer to Carrie's original question. Notice how Maddy latches onto Carrie beginning her answer with "so…" This indicates that Maddy is in tune with Carrie's move toward bringing the conversation to a close (Schegloff, 2007)). Carrie praises them in the end, revoicing (line 31) what she has just heard them say -- "So I like that you're making this one, you're like, "no, we need more data," -- and explicitly connects this moment to what she had taught earlier in the day, how to make improvements in the plan. After this utterance, Carrie moves to another group, and the girls get back to writing their decisions in their considerations sheets (see Figure 4.9).

With her students' overlapping talk and occasional misalignment – mostly through excitement, as I interpret it – throughout this exchange, Carrie remains task-driven. She persists in asking questions of the group to keep them moving forward with their plan. And her last statement in lines 31 and 32 operate in much the same ways as Marilyn's from the last exchange.

In short, Carrie and the students use several discourse moves to negotiate a solution to potential obstacles toward a scientifically sound plan: overlapping talk, alignment, latching, revoicing, refocusing (e.g., Carrie's task-driven statements). These moves demonstrate how all the teacher and students alike rely on a shared knowledge about investigation design, and apply that knowledge in making important decisions about their investigation. Their fluid exchange about planning a sound field study results in a successful plan in short time.

Here I have attempted to show how the teachers engage students in multiple opportunities to discuss and learn about the "phraseological" (Bakhtin, 1986) aspects of science language, the lexical (vocabulary) and the syntactic forms that combine to make scientific discourse. In the following section, we see how the verbal interactions about science language transfer into writing.

Writing Science

The written work is also a noteworthy aspect of the LTI. As I mentioned in chapter 4, teachers engaged students in the practice of communicating information, and I showed several examples of teachers' attention to students' writing. The written includes – in fact, it cannot be separated from – the first two aspects I presented thus far: vocabulary and talking about science. In the following discussion, I present how teachers guide students in writing using a combination of lexical, syntactic, and the semantic forms they learn as they proceed in the LTI.

The first example is from another moment in Carrie's classroom, the day their projects are to be finished. Here, students are working on their final project presentation boards, cutting and trimming and gluing and arranging their printed PowerPoint© slides onto the tri-fold display boards. The school science fair is in three days, and this is their final class period to put on the finishing touches. Carrie is touching base with each group, some more than once in this 90-minute period. In this following exchange, Carrie reads what a small group has printed. Before they are allowed to glue anything to their boards, she has asked them to get permission (e.g., a final check) from her.

1 Carrie: So the verbal summary is just a summary of the numbers.
2 Gina : No I don't know why I said "verbal summary"
3 I kind of might change this.
4 Carrie: Yeah, so what's in here is kind of a conclusion, which is why it's over here.
5 So this title is misle::ading.
6 Gina : I know I was gonna fix that.
7 Carrie: And you don't have to put this up top
8 'cause you guys already have that here.
9 Gina : Mmm-hmm.
10 Carrie: Okay? So make sure you have conclusion like...
11 Gina : And the verbal summary can just be here?

12 Carrie: Right. So if there is a.. mmm…

13 I guess you will have to reprint it. But yeah, and then…

14 Gina : You know I can just do this...

15 Carrie: For what? But it's not a verbal summary is what I'm saying.

16 The verbal summary is...

17 Gina : Yeah.

18 Carrie: ...doesn't interpret. And YOU interpreted.

19 Gina : Yeah.

20 Carrie: So the verbal summary is just like "In the morning this happened this many times."

21 You know, "in the afternoon..." so the verbal is literally just a summary.

22 You've done. This is conclusion.

23 So make sure that, you print a new one where this isn't on there. But...

24 Gina : Yeah.

25 Carrie: ... so far, very good!

This exchange begins with Carrie re-teaching (line 1) about how to write a "verbal summary," a term Carrie uses to describe the data summary. She points out students that, instead of writing a verbal summary – which simply includes a written (e.g., verbal) description of the data, the students have written conclusion, which includes interpretation (lines 15 through 18). Carrie revoices (O'Connor & Michaels, 1993) what a verbal summary might sound like (lines 20 through 21), with the phrase "in the morning this happened many times." She encourages them to go back and reprint this page after revisions.

This brief discussion also involves ideas about organization in writing. In lines seven through 11, both Gina and Carrie talk about where the verbal summary should be placed on the project board. Though Carrie tries to remind Gina that what she has written is not, in fact, a summary, but a conclusion, they talk about where to place the item on the board.

In the next example, Diana leads students in a similar kind of lesson about writing. Students prepare PowerPoint slides that will later be attached to their display boards, while Diana consults with small groups and individuals, helping them to finalize their writing. In this exchange, Diana comes to a small group, lead by Stefanie, who asks Diana for help. It appears that she is still looking for help in understanding how to express the DV in her project since she has a choice about whether to use the term "turbidity" or "total suspended solids."

1 Diana: ((to student who asks for Diana's help from across the room))
2 What? You're stuck? Show me where you're stuck.
3 Stefanie: DV and constants.
4 Diana: Beautiful.
5 Stefanie: Well, DV is uh...
6 Diana: DV is...
7 Stefanie: TSS.
8 Diana: Very good and make sure in the actual report please right,
9 don't write TSS. What are you gonna write for the real thing?
10 Stefanie: Turbidity?
11 Diana: You could write turbidity. Or you could write ...
12 later on you could say that turbidity is measured by.. Total.. what's the "S"?

13 Stefanie: Solid?

14 Diana: SusPENded Solids.

15 Stefanie: Solids ((overlapping with Diana))

16 Diana: Mussels is spelled wrong, honey.

17 Um, you leave this blank, good. DV is the turbidity.

18 And constant is on the board.

Here, Stefanie's project is to determine the effects of the zebra mussels on the amount of total suspended solids (TSS), or turbidity, in the Hudson River. In this exchange, we hear that Stefanie has learned the formal science language (Nagy & Townsend, 2012; NRC, 2011) – that turbidity is expressed in terms of TSS. But, she checks in with Diana about how to express this idea in writing. As they discuss – or make decisions about – word choice, Diana makes it clear that it does matter which word Stefanie chooses to use. If she uses the term "turbidity," she would have to write in her report that turbidity is measured in terms of total suspended solids (TSS). The difference matters here. In the end, Diana makes it clear that turbidity is their DV (line 17). This is not just a discussion about how to write something, it is a discussion about word choice, about vocabulary, that word choice matters in science (Gee, 2008a; Lemke, 1990; Nagy & Townsend, 2012; Moje, 2008; Shanahan & Shanahan, 2008).

As I showed in earlier examples of vocabulary and in talking about the language of science, teachers are also concerned with issues of specificity in writing. As in the next few brief examples, the IDD and the teachers' ideas about inquiry have helped them to develop a set of expected patterns in writing about the LTI. Those expected patterns form the rules of a particular genre (Bakhtin, 1986), that they then work to develop with students.

Marilyn too explicitly discussed writing science with her students. She explains writing a procedure, as part of a whole-group lesson during the beginning phase of the LTI:

> and then the procedures which are basically a step-by-step procedure, including your materials, um, written in enough detail to repeat the investigation, and that details seem consistent with the project over all, so re::ally important when you're writing your hypothesis is that some someone should be able, to do or replicate your investigation, and get similar results.

At another moment, Marilyn provided her students with an example of how to be specific in writing about procedures:

> You're gonna tweak this, so don't worry but you want to be more specific so like if you know how many you're how much you're gonna mix already, and then you can actually take the data from there okay like we have to mix two cups of our ocean salt material with five cups of water or whatever start writing it down like that, just don't say "mix the salt water," 'cause nobody's gonna know how much.

We saw other examples of specificity in Diana's concern about the word choice between "place" and "location." We heard her as she asked her students to be specific about writing TSS or "Total Suspended Solids" during planning (see chapter four). We heard Carrie insert ideas about specificity when she asked a small group of boys studying trebuchets to include information about potential and kinetic energy in their lab report (see chapter 4). Examples of teachers' concerns about specificity ran throughout their conversations with students, as they pushed students to use the language strategies that were a part of science (Lemke, 1990; Moje, 2008; NRC, 2011; Shanahan & Shanahan, 2008).

Teachers also were concerned with syntactical, or grammatical, conventions in science writing (Gee, 2008a; Lemke, 1990). In the next exchange, Marilyn is consulting with a group who asked her if, in writing their procedures, they should use the passive voice and past tense. (Since I saw this in many students' work, and in a discussion in Carrie's classroom, I surmise that using the passive voice and past tense is a common practice among the science teachers at the school.) Here, a student initiates the conversation:

1 Gina: I mean ((student name)) had something written down
2 but they were really incomplete.
3 Callie: ((interjecting)) Are we supposed to change this to past tense?
4 Marilyn: Pretty much, you can...
5 Gina: Like if you say "we added"... it's like...
6 Um, "10mL of X was added to..."
7 Marilyn: ((to another student in background)) Okay 12 cups were added to....

Notice that students direct this interchange. In fact, Marilyn speaks twice, and in very brief segments. Gina and Callie have acquired the language conventions Marilyn has taught – that scientists write the report of what they did in past tense and using passive voice.

In the next example, Marilyn discusses issues of language in the final writing of the lab report with another small group. She begins by reading what they have written, then providing an example.

> Alright. "The effect.. o::f.. the different amounts of light.. on algae growth... like was observed." You understand what I mean? So take a look at how we've said this. "In the investigation the effect of the, different amounts of light on algae growth was observed." And then you can continue like that.

As in the last excerpt, Marilyn supports a particular grammatical convention through modeling – or revoicing how she expects it to sound (O'Connor & Michaels, 1993).

Carrie also tackles issues of genre during a whole group discussion about how to write the LTI report. In a whole group lesson, her students evaluate an anonymous student's work, giving ideas about how to improve it. Carrie writes their ideas on the board. With almost every example Carrie provided, students noticed that the titles or questions were worded "incorrectly." As Carrie wrote their ideas on the board, she stated them aloud. Statements like, "Is this the way you write a title for a project?" or "that's a question" or "the hypothesis is missing a because statement" permeate the conversation.

In sum, Diana, Carrie, and Marilyn engaged students in learning and applying scientific language through focusing on vocabulary, the language of science investigation, and writing. While teaching vocabulary, teachers began by teaching the vocabulary explicitly, then, they drew from students' prior experiences to make meanings of difficult or new vocabulary; they engaged students in experiences that would generate new and alternative vocabulary; and they helped students use several other resources (including peers) in learning new vocabulary (Nagy & Townsend, 2012; Snow, 2008).

Teachers taught the specific language conventions of science prior to expecting students to use it in an LTI. Teachers modeled the specific phrases that are written on the IDD, providing – for example – sentence starters for the scientific question, "What is the effect of the IV on the DV?" while students wrote them in their notes. They taught about how to phrase the hypothesis, and they talked about how students should express their ideas about the independent and dependent variables. Teachers and students also applied their knowledge about the science discourse in authentic conversations about their investigation plans. In these conversations, teachers were no longer the directors of the conversations, providing explicit instruction about the investigations, but active listeners as they offered support to the students as they talked through their plans. In each teacher's classroom, students used the vocabulary and syntactic constructions effectively, so that the focus of the conversation was no longer on the language, but on the science practices at hand.

Lastly, in teaching their students how to write in science, teachers focused on concerns over specificity (similar to their efforts with vocabulary). They were also concerned with particular conventions, particularly in instances where teachers were teaching about how to use the IDD and new vocabulary. In all of these cases, teachers pressed students toward final drafts, giving suggestions for revisions, and offering thoughts about what a final draft ought to look like.

The Micro View of Tool Use

In this chapter, I presented a micro level analysis of language, to illustrate how language is also a tool for engagement. In the above examples, we saw teachers teaching students about specific disciplinary vocabulary (the lexical dimension of language), as well as about longer phrases or conventions or the "grammar" of the LTI. Lastly, we saw examples of teachers teaching students about (some) aspects of writing in science. But what does all of this work do? Let's consider my second research question: What is the role of language in the LTI? In attempting to answer that question, I begin with Wells' statement (1994) from above:

> What we must attend to… in order to understand the role of talk in the classroom, is not so much the talk per se, as the contribution it makes to the activities in which students engage in the "lived-in-world" of the classroom, the actual structures of participation, and

the function that talk performs – along with other semiotic systems – in mediating the goals of these activities.

Before I move into the specifics, let's first consider Wells' statement and how these ideas are situated in the context of this particular study. First, I would like to add that in this study – and as presented in this chapter – writing has a role in developing students' participation in the LTI and more broadly, in the discourse of science. In this way, when I say "language" I mean talk (as Wells discusses here) as well as writing – the "other semiotic systems" – as micro-instantiations of the discourse of science. Wells considers tools as "mediating activity." As a tool, language is "constituative of the task" at hand, that is, it "is used to mediate the achievement of the goal of action" (Wells, 1994, p. 15).

What teachers created were entry points into the discourse and practices of science, guided by the material tools, the shared language, and time. Let's consider the science practice "analyzing and interpreting data." If this is our macro frame, bound by the science reform document and a part of the Discourse of science education, then, the micro practice – which may, for our purposes at the moment, be construed as a teaching practice – is illustrated in Diana's choices about how to help her students into the classroom discourse (here I mean small-d discourse) of looking at the data. If looking at the data on a graph about the Hudson River ecosystem is the activity, then the conversation about that data, the language that Diana leads her students to use, and the language that they employ as they make meaning of the graph, is a part of the micro aspect of language. In other words, the graph, to which the teacher and students' attention is focused, mediates their conversation about it. Diana asks specific questions about the graph, inviting each student in. Each invitation is a discourse move that involves – indeed requires – students to use particular pieces of the language.

Let's layer the three aspects of language I presented in this chapter: vocabulary, syntactic (or grammatical) constructions, and writing. In the example of joint meaning making of the graph about the zebra mussel data, Diana asks the students to use particular vocabulary. She is not teaching them new vocabulary, they are now asked to use it (as a tool) to communicate some aspect of their understanding about the graph. Such vocabulary might be: "axis," "independent" and "dependent variable," "temperature," "zooplankton," and "zebra mussel." They use the words "increase" and "decrease" as operational words that describe the natural world that is represented in the graph – that the graph is a semiotic tool that represents a phenomenon, the relationship between temperature and copepod populations in the river as a result of the zebra mussel population. These are terms she taught in the context of discussing the elements of the ecosystem (Gee, 2008b, Hakuta & Santos, 2012.)

At the level of the syntactic construction, students engage in talk that closely mirrors the constructions of the formal discourse of science. They draw relationships between variables, as in, "the level of the temperature increased because the plankton levels decreased." Gumperz (1977) would call this meso- level as important to creating the interpretive frames within which speakers operate. That is, conversations are made up of collections of words, put together in strings of phrases (or utterances (Bakhtin, 1986)) which speakers trade in turns as they respond to one another.

In science classrooms – and in these UA classrooms in particular – the larger purpose is to develop scientific discourse in order to convey meaning. But there is a lot that happens between the words themselves and how they combine to address or fit into, or create, the larger purpose. Teachers and students (interlocutors) interact verbally, through writing and through talk, according to particular social norms of the context in which they find themselves. Each moment of talk between people is constiuent of that context. Here, the context is partly comprised of the teachers' UA training, ideologies about how science ought to be taught, as well as their understandings about their students. The context also includes such things as the curriculum materials – or material tools, as I discussed in chapter 4 – and the other material resources that are available, such as computers, cell phones, other adult experts, and science cultural institutions around the city (Cohen, Raudenbush, & Ball, 2003; Wilson et al., 2012).

Chapter 6

Warp and Woof:

Intertwined Micro and Macro Contexts

For Diana, Carrie, and Marilyn, textual tools provide a structure for working across the arc of the long-term investigation. This structure unfolded in three different forms relative to various factors: the teachers' local teaching contexts (i.e., the school, neighborhood, grade level, curriculum, and UA connections); the teachers' ideas about science practices, content, student learning needs; as well as the teachers' own science inquiry teaching practices (recall chapter three). We have also seen that the work of the LTI involves activity that occurs in the discursive – or micro -- spaces through talk (as shown in chapter five).

My goal here has been to portray both an overarching macro structure -- the curriculum materials (and other organizational structures) – as one context in which teachers and students interact and the micro structures, or the moment-to-moment interactions, that produce another kind of context. Following Erickson and Shultz (1981), here I consider context as "constituted by what people are doing and were and when they are doing it" (p. 148). Thus, the macro and the micro constitute different, related contexts.

In this chapter, I argue that the micro and macro contexts come together across the arc of the LTI, illustrating this interdependence with two cases of teacher practice. Throughout, I draw upon the theoretical concepts of intertextuality and heteroglossia (Bakhtin, 1981) to describe the complex, dynamic nature of teaching the LTI with middle school students in linguistically diverse classrooms.

A Bakhtinian Conception of Learning the Discourse and Practices of Science

In chapter four, I described how Diana, Carrie, and Marilyn used various textual tools – the IDD, the considerations sheet, the DSET, the fact boxes, etc. – to engage students in the LTI. Diana used several different Do Now tools to explicitly teach about the biotic and abiotic elements of the Hudson River ecosystem. Carrie helped students plan the details of their LTIs using the considerations sheets. And using fact boxes sheets helped Marilyn discuss with her students what content knowledge they were going to use to support their conclusions.

Teachers used the tools across the various science practices, particularly in designing their investigations, as well as in gathering, organizing, assessing, and presenting scientific information (NRC, 2012). For example, Diana used the IDD and her Do Now handouts to help students to design their investigations. Recall that the IDD included space for students to write their title, the research question, a hypothesis, and to record their independent, dependent, and constant variables (see Figure 3.2). I conceptualize the LTI as having a particular arc, or storyline, that involves the interrelationships between the textual tools, science practices, and their use over time (see Figure 6.1). The diagonal arrow represents time, and the various texts that teachers used throughout the LTI are included on the line, in general order of appearance.

Note that this is a collective list of the tools Diana, Carrie, and Marilyn used. Each teacher used the IDD, the DSET, and rubrics, but not all used the other tools. For example, the Do Now is listed first because teachers used it daily, and was most often the first tool teachers used in each lesson, creating the first learning activity in which students became engaged in any particular day. As we saw in chapter four, Carrie created the considerations sheet to help students make critical decisions in their planning process, which is why it is placed somewhat

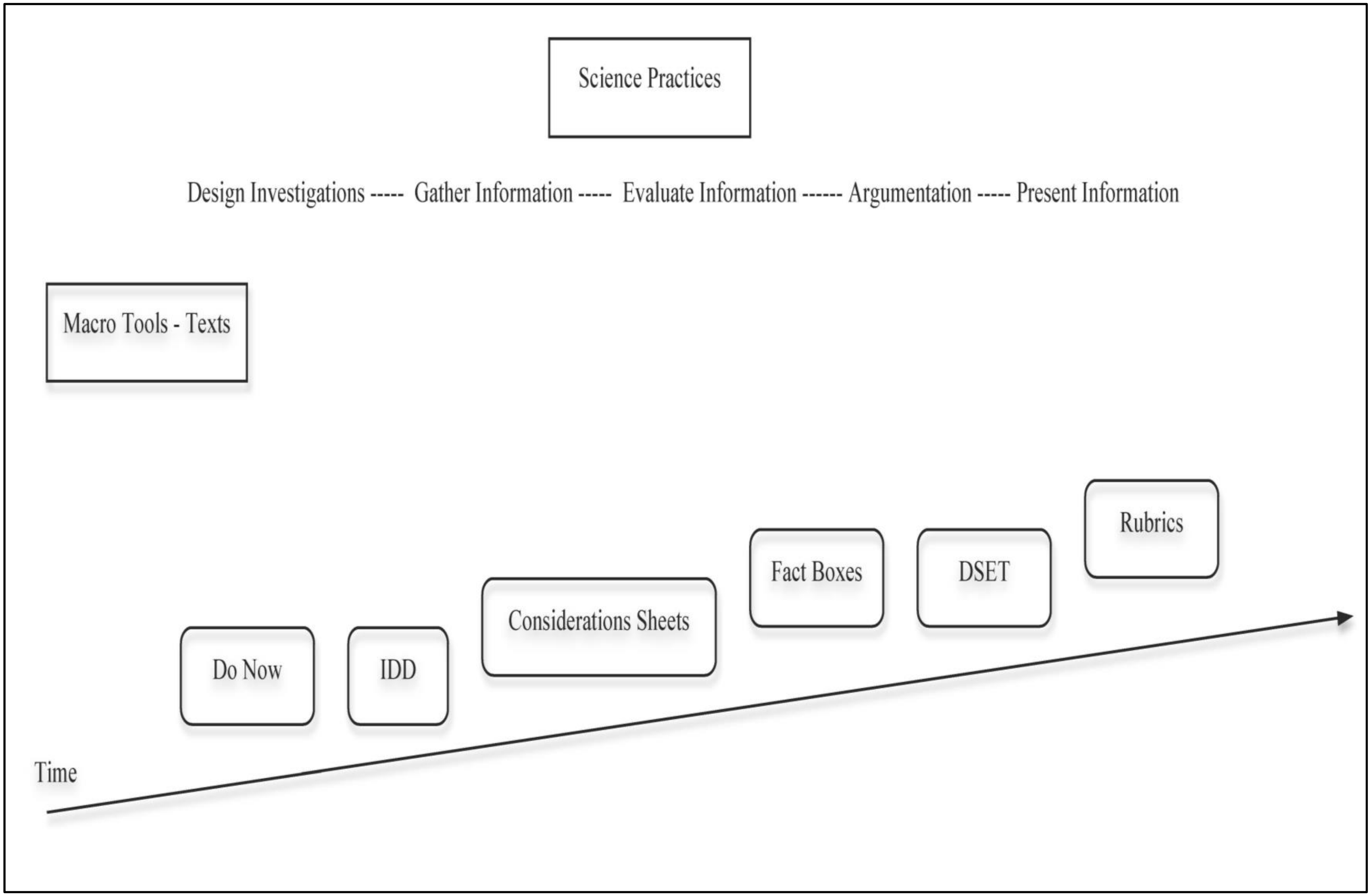


Figure 6.1. The Macro Context of the LTI

near the middle of the time line, because planning happened roughly near the middle of the LTI. And Marilyn used the fact boxes sheets (as did Carrie) at about the mid-point of her LTI to help students collect important content information about their chosen variable.

Roughly, reading the map from left to right, all of the teachers used some version or referred to some element of the IDD every day -- along with other texts -- for several different reasons. One primary reason was to identify and show the relationships among variables (NRC, 2007). They next introduced the IDD, and then after students chose the variables they would study, they organized information about their procedures – using something like the considerations sheet – and collected information about those variables in fact boxes, for example, and then all used the DSET to organize their arguments. Teachers used several different rubrics to evaluate the work through peer review and in advance of the final presentation of the LTI. Finally, the curricular tools – the AMNH videos and readings, and the SEPUP, FOSS, and PBIS materials – are subsumed under general curricular texts because the teachers used these texts to build background knowledge throughout the process.

Along the top of the graphic is a list of the specific science practices that I observed teachers teaching most often during the LTI. These practices are placed on the map in roughly the order in which teachers employed them. However, these practices do not exist in a linear relationship as they appear to be represented here; they are more iterative, informing each other at different points along the LTI's arc. In other words, scientists do not gather information after they have designed the investigation. Rather, they gather background information throughout the process (NRC, 2007; 2011) to support claims, refine ideas, and redesign their inquiries. Because inquiry-based science teaching is, in part, intended to engage students in practices that closely mirror those of professional scientists, the ways that teachers help students to use background information to support their work matters (NRC, 2012). That is, students should have opportunities to use their content knowledge and to conduct research for background information in order to design investigations, support claims about data, and ask new questions. In this light, the graphics I offer here are limited in their ability to capture the iterative and dynamic nature of the work of science.

Situated within this macro contexts are micro contexts (see Figure 6.2). In this figure, the line drawn between macro and micro tools denotes the connection across the diagonal line representing time. Below the line are the major categories of talk as we saw in chapter five: vocabulary, grammar conventions, and writing. These are the tools that teachers use to create micro contexts. At the bottom of the graphic are the theoretical concepts that help to explain the nature of the micro contexts: heteroglossia (which involves centrifugal and centripetal language forces) (Bakhtin, 1981), and intertextuality. The double-sided arrow between macro and mico represents the interconnection between the two, as I will argue are in dialogic relationship.

These concepts of macro and micro contexts draw upon Bakhtin's (1981) concepts of heteroglossia and intertextuality which have been used by many education scholars (Gee, 2008a; Moje, 2008; Rosebery, Ogonowski, DiShino, & Warren, 2010; Vareles, Pappas & Rife, 2006). As we saw in previous chapters, teachers draw upon the several texts and experiences they have provided for their students to develop their LTI plans. And their engagement in practices is negotiated and developed within several different discussion formats (e.g., small group, whole group, etc.).

I start with the claim that teaching the LTI is inherently intertextual: teachers use visual, written, and spoken texts (e.g., video) to develop content knowledge, as seen in the top half of the graphic.

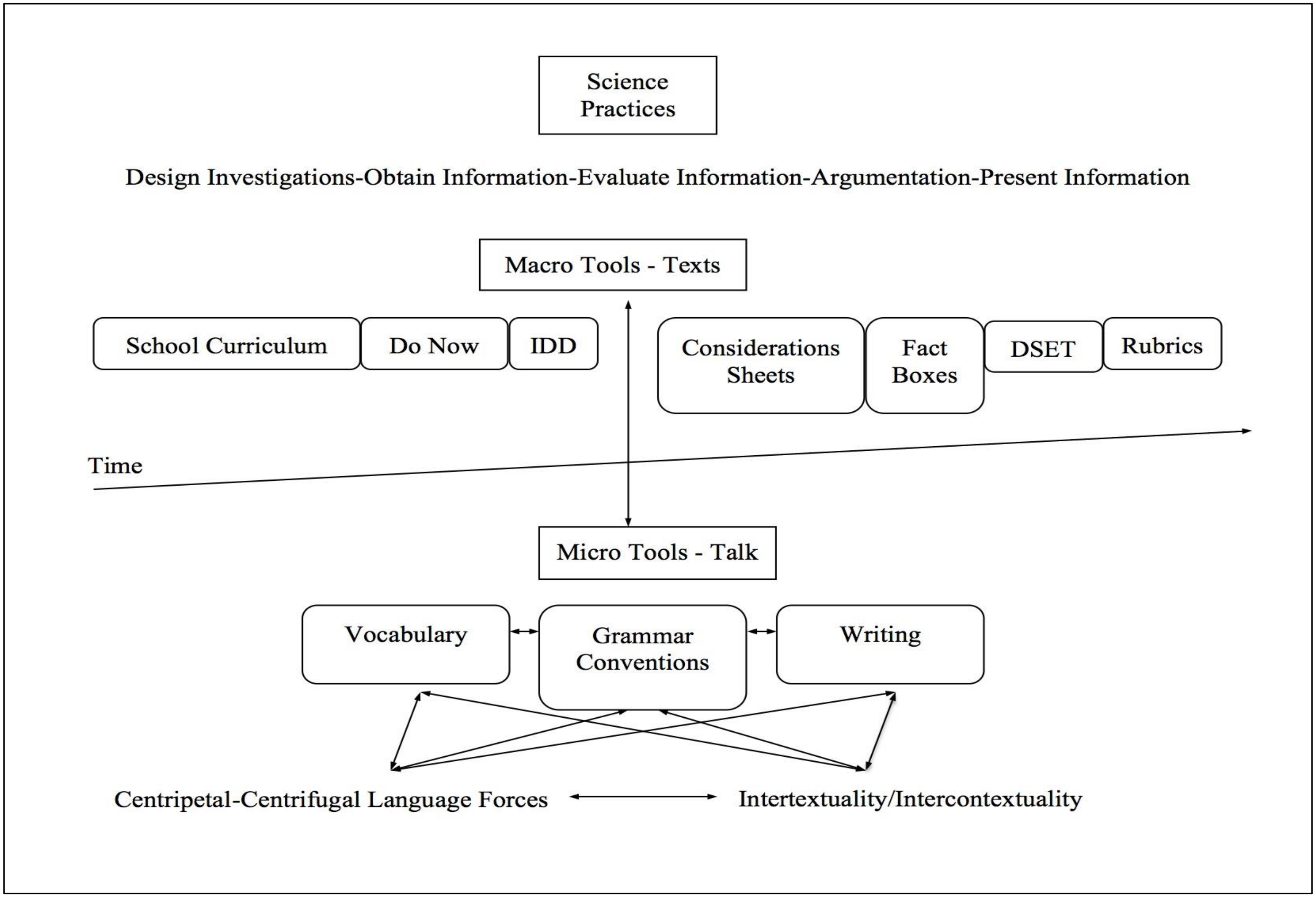


Figure 6.2. Macro and Micro Contexts of the LTI

Gee and Green (1993) relate,

> This dynamic and constructed view of intertextuality suggests that members and analysts alike must consider how members, through their interactions, propose, acknowledge, recognize, and interactionally construct a socially significant past, current, and future texts and related actions. (p. 132)

In other words, as students and teachers interact around science content, they simultaneously draw upon past texts and construct future texts that are leveraged for engaging in science practices throughout the LTI. They use and construct these texts to identify variables and how to measure them, to decide on data collection procedures, to write scientifically sound hypotheses, and to support scientific arguments (NRC, 2012).

Teaching the LTI also involves multiple instantiations of talk as represented at the micro level. Teachers and students both experience and take advantage of the tension between informal and formal registers and ways of being in classroom language communities (Brown & Spang, 2008; Gee, 2008a, 2008b). Bakhtin (1981) explains this tension as a central element of heteroglossia: “Every utterance participates in the ‘unitary language’ (in its centripetal forces and tendencies) and at the same time partakes of social and historical heteroglossia (the centrifugal, stratifying forces)” (p. 272). That is, at the same time that the centripetal forces of language pull our language forms toward the center (or unifying), or more formal forms (determined by the social context), the centrifugal forces also pull our language outward toward forms that are less likely to be recognized by formal codes of the particular speech community. This push-pull creates the stratification of language forms, or heteroglossia, that are always in tension.

Bakhtin argues that all language is populated with other forms and processes, that people use such forms to generate new language forms that constitute the context within which they are created. In other words, each new speech context is constructed by and for those who participate in the context. In this analysis, the contexts involve students and their teachers, who draw upon previous experiences and texts and meanings in order to develop new plans for investigating phenomena.

As is represented in Figure 6.2, this work is inter(con)textual as well (Gee & Green, 1998). That is, multiple contexts -- here the macro and the micro -- interact to form new contexts for meaning making. Gee and Green (1998) discuss one particular approach to discourse analysis that involves the multiple contexts of meaning making in social interaction. Using an example of a year-long ethnographic study of 6th graders in science (Florian, 1993), Green and Gee described how students' shared experiences generated ideas and specific phrases that held historical significance for them, shaped their work in whatever current activity they were engaged in, and "signaled future use of current texts and practices" (p. 133). These moments become historically important and socially relevant to these students as they constructed "cultural models that they now drew upon to guide their participation " (p. 133).

Two Cases

Here I present two cases to illustrate the dynamic and dialogic relationship between the macro and micro. One case involves Diana helping her students to understand the relationships between variables in the zebra mussel investigation; the other concerns how Carrie helps her students to decide on the data they will collect and how to get the best data.

I chose these two examples as cases because they represent two different kinds of conversations, or contexts (Erickson & Shultz, 1981), that engaged the same science practice: “planning and conducting investigations.” Planning and conducting investigations (NRC, 2012) involves the careful consideration of variables and their relationships. According to the NRC Framework for K-12 Science Education (2011),

> Planning and designing such investigations require the ability to design experimental or observational inquiries that are appropriate to answering the question being asked or testing a hypothesis that has been formed. This process begins by identifying the relevant variables and considering how they might be observed, measured, and controlled (constrained by the experimental design to take particular values). (p. 59)

We will see in the micro-analysis of each teacher how -- in interaction with her students – the class comes to use a "unitary language" to generate science knowledge, but inside of that language, they draw upon more informal talk forms as well.[17] We will also see how the teachers and their students draw upon other contexts for learning - a visit to a zoo, a previous discussion about a video case study, previous lessons in which they discuss scientific terminology - for engendering new roles and responsibilities as they engage in the LTI.

Unpacking Turbidity: Understanding Variables

I begin with a discussion of a stretch of classroom talk about a particular variable and how it was supported through the Diana's use of the Do Now handout, a textual tool that structures the macro context. I will then show how other parts of the same conversation supported a student, Marlyse, as she developed the hypothesis for her LTI. Recall that in Diana's classroom, students produced secondary research investigations, which involves using

[17] I use the terms "informal" and "formal" in terms of register and related to the social context (Gee, 2008a). In science classrooms, the formal register of science - using highly technical, tier three terminology, for example - becomes the goal. But teachers often draw upon other forms of language in order to generate science knowledge at the same time that students are learning and using their emergent science language (Brown & Spang, 2008; Gee, 2008a, Gee, 2008b). I do not use the terms "informal" and "formal" in any evaluative sense, that one form is more desirable than another.

data collected by others to answer questions about phenomena. Diana situated the work first through the development of background knowledge about the specific factors that the Carey Institute scientists measured, as well as the data collection process (e.g., which tools are used to gather information on the river and decisions that ecologists make about data collection – when, where, how much, etc.). In so doing, Diana was presuming that, in order to ask questions using a large dataset, students first need to understand the variables and how data are collected answered. Part of Diana's approach, then, was to provide her students with the background knowledge they would need to understand the variables under study.

Diana began with explicit instruction of freshwater ecosystems and of the specific case of the zebra mussel's impact on the Hudson River. Diana also took students on a field trip to the river so that they could experience collecting some of the same data the Carey scientists had, using the same kinds of scientific tools (a plankton net, for example). She blended students' authentic experiences (e.g., the field trip) with classroom discussions about the case study videos and the accompanying texts. She also used several different textual tools – the IDD, the DSET, and several Do Now handouts as well as curriculum materials, as we saw in chapters four and five – to provide a structure for these conversations. All of these texts, videos, experiences, and tools operated as macro contexts that support student knowledge of variables and how they interact (Erickson & Shultz, 1981).

Diana taught about these relationships about halfway through the SR project. At the beginning of class one day, Diana led a whole class discussion concerning the question, "How do zebra mussels affect the biotic and abiotic factors in the Hudson River?" Students discussed the question, completed a chart about the environmental factors (e.g., phytoplankton, zooplankton, dissolved oxygen), and discussed a second question: "What happens to other organisms in the river that eat plankton?" Diana then asked them a third question: "What happened to the turbidity of the water?"

Before reading what they said, let's consider the task. Figure 6.3 provides just one page of a three-page Do Now handout that Diana used to conduct one of many conversations about variables her students will later explore in their LTIs. In Diana's classroom, the "AIM" is written at the top of the handout, as well as written on the chalkboard at the front of the room. The AIM remains the same for several lessons, as it represents the project's larger goals, or helps to situate the day's lesson. The Do Now section asks students to respond in writing about some aspect of material that they have read in anticipation of the day's classroom discussion. Here, the question is, "The scientists were predicting that the zebra mussels would have a huge impact on the ecosystem. What **evidence** are they looking for to support this hypothesis?" Notice that this question asks students to refer back to the video and texts they had viewed and read the day before about the Carey Institute study of the Hudson River. In this way, this tool automatically involves an intertextual relationship across activities in the LTI. In referring to these other texts, Diana explicitly asks students to locate the evidence, and link it to their hypothesis.

Completing this part of the handout requires students to use prior information both about the zebra mussel case, and of the terms, "evidence" and "hypothesis." Notice too that Diana uses the word "predicted" in the first line to denote hypothesis. Again, in terms of scientific vocabulary, as we saw in chapter five, students would have to know to connect these two terms as existing on different registers, but meaning the same thing (Gee, 2008a, 2008b).

Diana does not offer direct instruction about these terms. Rather, she uses the terms in their different registers in situ. She naturally uses "predicted" and "hypothesis" interchangeably without explanation, which illustrates the interplay between the more centralizing and de-centralizing forces of language, or heteroglossia, at work.

The chart also asks students to record changes in three variables (e.g., phytoplankton, zooplankton, and DO) in relationship to the information from reading passage three, which links to the third (of four) videos. This second question asks students to make connections between the tertiary impact of other organisms as a result of the change in plankton numbers – asking them to make a causal link (NRC, 2007). The last question on this page, which asks about how the turbidity of the water changed as (the presumed) result of the zebra mussel populations, is the focus of the discussion I present next.

The excerpt begins with a question Diana asks her students to respond to in class discussion, and in writing. Her first utterance in line one involves point out how to use the readings to answer the question.

1 Diana: The reading. We highlighted together.
2 So Marlyse why might turbidity change?
3 Marlyse: The turbidity might change because we know that zebra mussels like to eat a lot of plankton.
4 Diana: Thank you!
5 Because we know, the zebra mussels eat... plankton=
6 Marlyse: =a lot of plankton.
7 And they eat the plankton and…
8 like there would be not much left in the water and then..
9 Diana: So what happens to the cl- how clear the water is?
10 Marlyse: It would become like more clear.

11 Diana: It would become more clear.

12 Do you guys get THAT connection?

13 Students: Yeah.

14 Diana: That's how turbidity might change.

In this exchange, Diana involves Marlyse in explaining what she knows for the benefit of the whole class. When Marlyse answers correctly, Diana repeats her answer (line 3). In line 4, Marlyse takes back her turn, not waiting for Diana's cue, and continues her explanation, latching onto Diana's response (Erickson, 2006; Schegloff, 2007; Tannen, 2007). Latching –when a speaker interrupts another to continue a (presumed shared) thought – demonstrates engagement between speakers (Tannen, 2007). Marlyse continues her own thought, which connects to Diana's, "a LOT of plankton," placing emphasis on Diana's phrase "the zebra mussels eat... plankton." The hesitation between the words "eat" and "plankton" in Diana's turn is because she is writing ideas on the board as she speaks, her pause follows her writing pace, and is not a hedge (Schegloff, 2007).

Diana asks the next logical question, "So what happens to the cl- how clear the water is?" (line 5). Diana stops mid-sentence to shift her word choice from "clarity" to "how clear the water is." She does not use the nominalized form, "clarity," in favor of a phrase that describes the term, "how clear the water is" (Latour & Woolgar, 1986). This move demonstrates a form of heteroglossia, in that Diana chooses a less formal way to express "clarity," which, in its nominalized form, is part of the most formal science register (Latour & Woolgar). She moves between the centrifugal and centripetal forces of her own language choice, in the split-second decision to move toward the informal expression. Marlyse answers, "It would become like more

Aim: How do zebra mussels affect the other biotic and abiotic factors in the Hudson River?

Do Now: The scientists were predicting that the zebra mussels would have a huge impact on the ecosystem. What ***evidence*** are they looking for to support this hypothesis?

____

____

____

____

Video Clip and Reading Passage # 3

1. How did zebra mussels change different *biotic* and *abiotic* factors?

Environmental Factor	How did it change?
Phytoplankton	Up/Down by __________ %
zooplankton (total)	Up/Down by __________ %
dissolved oxygen (DO)	Up/Down by __________ %

2. What happened to the other organisms in the river that eat plankton? Be specific.

____

____

3. What happened to the turbidity of the water? Why did it change?

____

____

Figure 6.3. Diana's Do Now Tool

clear," which also uses the more informal register. Diana repeats her answer using a similarly informal register, showing alignment with (support for) Marlyse's thought (Schegloff, 2007).

Diana reinforces Marlyse's answer by saying, "Thank you!" and repeating, "Because we know, the zebra mussels eat... plankton" (line 3). The repetition and affirmation of Marlyse's response "indexes" a correct answer (Johnstone, 2008; Mehan, 1979). Indexicality is a "linguistic form or social action that, in addition to or instead of contributing to the denotational or "literal" meaning, points to and sometimes helps establish "social" meaning" (Johnstone, 2008, p. 132). Indexicals can both point to previous social meaning, or create new social meaning. In this moment, Diana and Marlyse jointly establish -- they index -- the connections between variables.

After having established one connection, Diana proceeds to introduce the next question: "So what happens to the cl- how clear the water is?" (line 5). Finally, in line 7, Diana repeats Marlyse's answer again with, "it would become more clear. Do you guys get THAT connection?" which serves to metacognitively link the concepts "phytoplankton" and "clarity" (NRC, 2007). Again by making these connections, Diana is providing both explicit and implicit (or modeled) explanations of the language students are using. She connects words to texts and experiences. She works intertextually, and the language she uses to do so leverages both students' and her own heterogeneous forms for meaning-making (Rosebery, Ogonowski, DiShino, & Warren, 2010).

Let's now consider what happens as Marlyse then transfers this conversation into her written response on the Do Now form, which students are asked to write during class time. If we piece together all of Marlyse's turns in talk (Sacks, Schegloff, & Jefferson, 1974) from the transcript, we can see her spoken ideas closely mirroring her written response. Recall her spoken response:

> The turbidity might change because we know that zebra mussels like to eat a lot of plankton… a lot of plankton. And they eat the plankton and... like there would be not much left in the water and then… It would become like more clear.

Her written response was: “The turbidity went down which means the water was more clear because of phytoplankton being eaten by zebra mussels.”

In the first instance, we see Marlyse's reasoning about how the water becomes clearer: “there would not be much left in the water." And in her written response, she explains “the turbidity went down,” which means that “the water was more clear.” In other words, she connects the idea about turbidity to water clarity, and is able to provide a reasoned rationale as to why: “because of the phytoplankton being eaten by zebra mussels.” In both oral and written responses, she makes a direct causal link between turbidity and the zebra mussels (NRC, 2007). Thus, Marlyse is working intertextually.

The conversation continues below as Diana moves to the next conceptual step. After recognizing that turbidity is determined by the number of plankton in the water, Diana shifts to thinking about the link between plankton and chlorophyll. That is, the amount of chlorophyll is the measure of the amount of phytoplankton in the water, and thus is another way to express turbidity.

1 Diana: I agree with her. Faith.
2 What is chlorophyll? Why do I care about chlorophyll?
3 Student: [boy student starts to answer] Is it...
4 Diana: Hold on I wanna see if Faith knows it.

Faith: Hmm...

Diana: Chlorophyll's important.

Why is it important?

Especially in this ecosystem...

Faith: I don't know.

Diana: Cameron?

Cameron: The type of chlorophyll?

Diana: Chlorophyll is not a TYPE of phytoplankton,

but you're SO:: close. Mario?

Mario: It's chemical that umm...

Diana: Thank you.

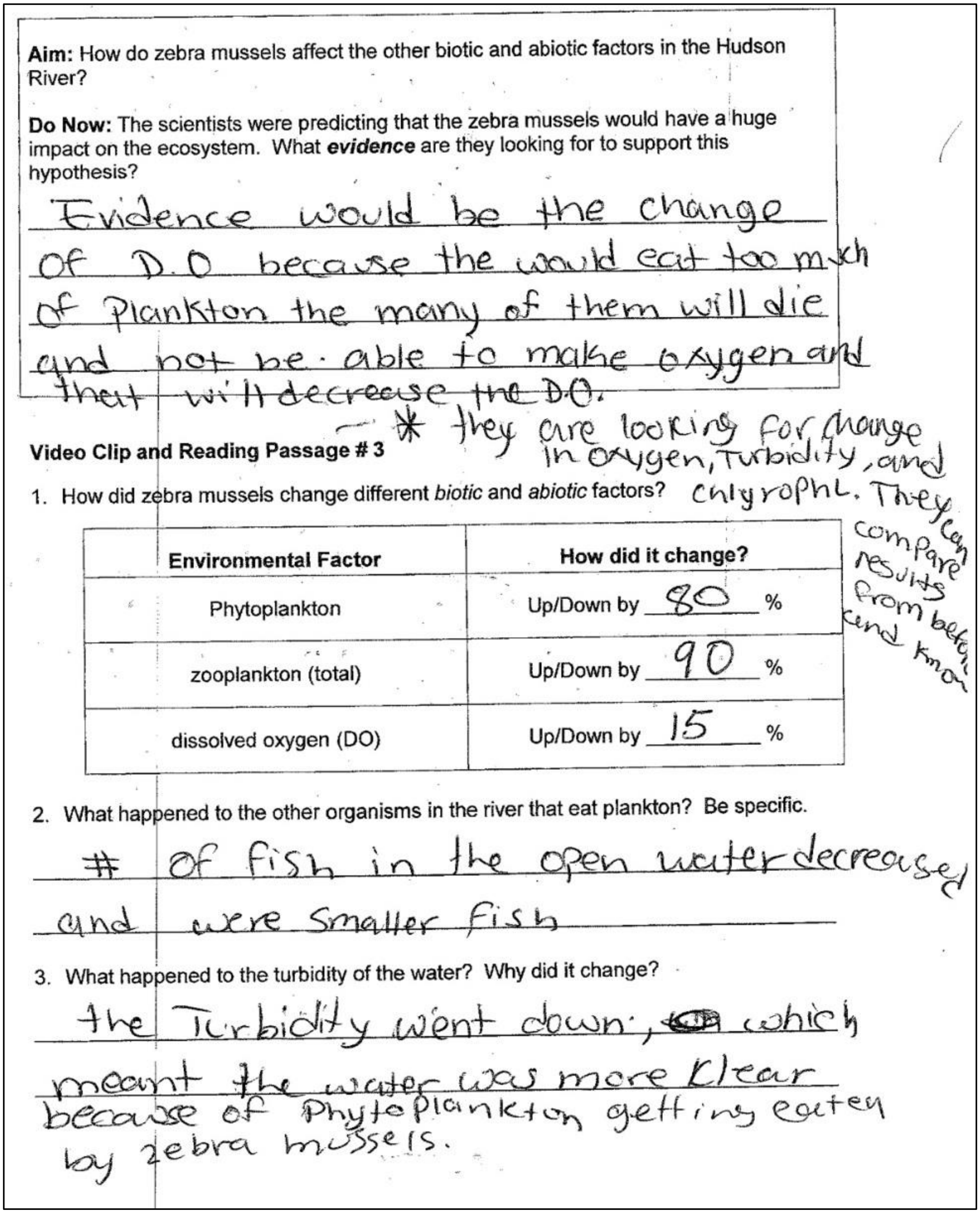
Mario: ... has to do with photosynthesis.

Diana: Thank you.

((to Faith)) Did you hear what Mario said? What is it?

Faith: ((she answers faintly.)) It has to do with photosynthesis.

Here, Diana guides her students to the next step in the logic of these relationships. In order for students to know how the turbidity changed in terms of the phytoplankton numbers, they would have to know that phytoplankton is measured by the amount of chlorophyll found in the water. Notice that Diana intuits that students (here it is Faith) do not fully understand what chlorophyll is, and so turns to Mario who may be able to explain it. She does not elect to explain it herself, leaving that privilege to the students. Her role, at this point, is to keep the direction of the



Aim: How do zebra mussels affect the other biotic and abiotic factors in the Hudson River?

Do Now: The scientists were predicting that the zebra mussels would have a huge impact on the ecosystem. What ***evidence*** are they looking for to support this hypothesis?

Evidence would be the change of D.O because the would eat too much of Plankton the many of them will die and not be able to make oxygen and that will decrease the D.O.

— * they are looking for change in oxygen, Turbidity, and chlyrophl. They can compare results from before and know

Video Clip and Reading Passage # 3

1. How did zebra mussels change different *biotic* and *abiotic* factors?

Environmental Factor	How did it change?
Phytoplankton	Up/Down by 80 %
zooplankton (total)	Up/Down by 90 %
dissolved oxygen (DO)	Up/Down by 15 %

2. What happened to the other organisms in the river that eat plankton? Be specific.

# of fish in the open water decreased and were smaller fish

3. What happened to the turbidity of the water? Why did it change?

the Turbidity went down, which meant the water was more Clear because of Phytoplankton getting eaten by zebra mussels.

Figure 6.4. Marlyse's Response to the Do Now

conversation moving forward. Like a conductor, she orchestrates how the logical connections are made, allowing the students to provide the content. She also keeps Faith involved in the conversation by coming back to her at the end, encouraging her to try her answer now, so that she can verbalize what she now knows from listening to her classmate. This is another way in which Diana engages students in the LTI, keeping them engaged in the micro-contexts.

So far, we have seen how Diana lead her students in a discussion about the variables involved in the secondary research project about the zebra mussels' impact on the Hudson River ecosystem. Marlyse's spoken response connected to her written response on the Do Now handout. In both her spoken and written response, she accurately described that the plankton numbers, as measured by chlorophyll, would decrease because zebra mussels eat phytoplankton. In her written response, she linked this to the idea of clarity, thus completing the two causal relationships that are crucial to exploring the effects of the zebra mussels (the independent variable) on the river's turbidity (Marlyse's chosen dependent variable): the relationship between zebra mussels and phytoplankton, and the relationship between phytoplankton (as measured by chlorophyll) and turbidity (NRC, 2007).

Recall that the micro tools of language involved teachers' talk about vocabulary, grammatical conventions and writing (chapter 5). In Marlyse's hypothesis (see Figure 6.4), we have an artifact of all three aspects of language. Marlyse demonstrates her knowledge of the vocabulary: "phytoplankton," "chlorophyll," and "photosynthesis." She also is able – even with her teaching tool's minimal scaffolding – to write a hypothesis using the appropriate language construction: "If X, then Y, because we know that..."

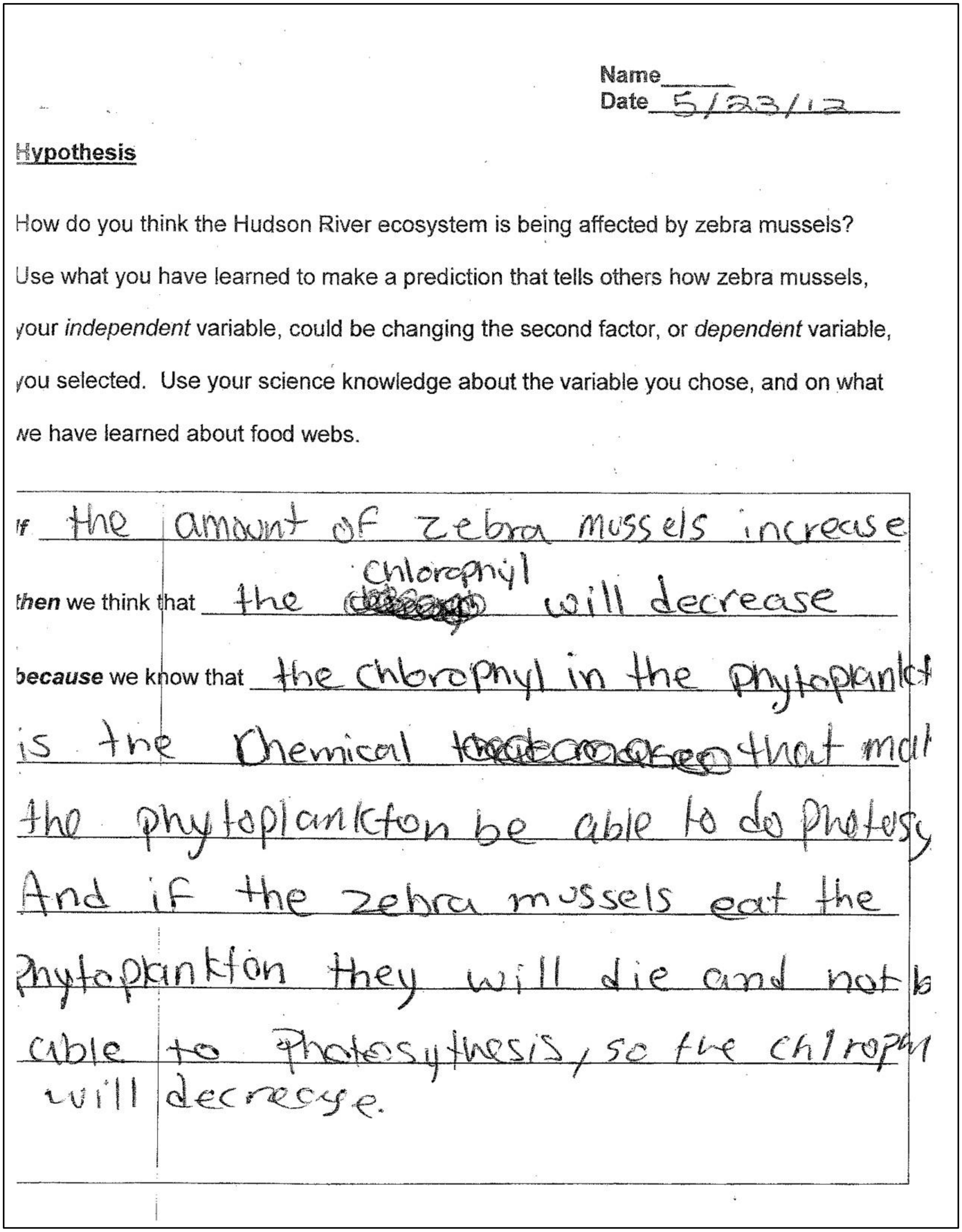
Marlyse's hypothesis reads:

> If the amount of zebra mussels increase then I think that the chlorophyll will decrease because we know that the chlorophyll in the phytoplankton is the chemical that makes the phytoplankton be able to do photosynthesis. And if the zebra mussels eat the phytoplankton, they will die and not be able to do photosynthesis, so the chlorophyll will decrease.

Here Marlyse integrates elements of the whole class discussion with the readings. She constructs links between the variables in a scientifically accurate way: a decrease in the phytoplankton will cause a decrease in the chlorophyll numbers. She also makes revisions as she writes, as indicated by her scribbles.

This case illustrates how a particular micro context -- understanding variables -- engages several different strategies and roles for involving students in the practice (NRC, 2012). Diana orchestrated the talk about the variables her students will study in their LTI (e.g., turbidity), employing several discursive tools. She did not take the lead role in explaining concepts: rather, she provided them opportunities to do so. She indexed when students were providing sound explanations, and asked new questions to redirect their thinking when necessary. She asked questions to also direct the logic of the relationships -- typically a causal relationship -- and pressed students to consider each others' ideas (e.g., "Did you hear what he just said?"). We also saw an example of how one student, Marlyse, leveraged the conversations into her written responses on the Do Now form and in her hypothesis.

Now I turn to another case, an example of Carrie's approach to engage a small group of students in planning for their LTI. In this case, students have learned about their variables, and now are grappling with how to write a procedure that will collect the data they need. Additional



Name_____
Date 5/23/12

Hypothesis

How do you think the Hudson River ecosystem is being affected by zebra mussels? Use what you have learned to make a prediction that tells others how zebra mussels, your *independent* variable, could be changing the second factor, or *dependent* variable, you selected. Use your science knowledge about the variable you chose, and on what we have learned about food webs.

If the amount of zebra mussels increase

then we think that the ~~[illegible]~~ Chlorophyl will decrease

because we know that the chlorophyl in the phytoplankt is the chemical ~~[illegible]~~ that mak the phytoplanktton be able to do photosy. And if the zebra mussels eat the phytoplankton they will die and not b able to photosythesis, so the chlroph will decreage.

Figure 6.5. Marlyse's Hypothesis

examples of inter(con)textual work follow, as students move back and forth between what they have learned and what they have yet to know to make important methodological decisions.

"Because You Get More Productive Data": Crafting a Plan for Data Collection

In this case, Carrie is working with her students to refine their plans for data collection. In chapter three, I introduced how Carrie drew upon long-term projects conducted earlier in the school year in order to help small groups of students develop their LTIs. I showed how they used several tools to support their learning and to organize information about the variables they were studying. In Carrie's classroom, students use considerations sheets to develop their ideas about how to collect data aligned to their investigation question.

In this lesson, Carrie is working with a small group as they plan their field study of gorilla behavior using the considerations sheets. In this excerpt, they discuss the possible revisions to the first parts of their lab reports, which includes the hypothesis statement.

1 Maddy: So over here,
2 do I have to write the behaviors in my hypothesis....
3 Carrie: No you can describe it here ((referring to a section in the lab report)).
4 Maddy: Oh, I have to move my hypothesis...
5 Carrie: So you can work on finding more background info
6 on what behaviors gorillas exhibit.
7 So is there you know feeding behavior.
8 Are there grooming behaviors, social, like specific behaviors that you guys could possibly see when you go to the zoo.
9 Maddy: So do I need to add most of my hypothesis.. ((unclear))
10 I mean I do I know I do, but I mean like specific...

11 Carrie: So you guys ((reading, unclear))

12 So why do you think being a close, ancestor genetically,

13 that's what you're getting at here right?

14 Why do you think being a close ancestor genetically, would make them, more likely to be active… or....

15 Maddy: So like humans are most interactive.. ((unclear)) So... ((unclear))

16 Carrie: And that's what you need. So...

17 Maddy: Should I change my hypothesis?

18 Carrie: Yes.

19 You want to have some science supporting what you're thinking. Okay?

This brief excerpt shows Carrie working with a small group to decide on how to write their hypothesis. Their research topic is “The Effect of Time of Day on Gorilla Social Behavior,” and the task is to define the behaviors they are choosing to study. One student begins by asking about whether to describe the behaviors in their hypothesis. While Carrie says that they can describe those behaviors somewhere else in their report, she does encourage them to become very clear about what specific behaviors they want to study (line 4). She asks a key question in line 6, “Why do you think being a close ancestor genetically would make them more likely to be active…” This is in response to the group’s earlier assumption that they could predict the gorilla behavior based on what we know about humans since humans and gorillas are close genetically (see chapter 5).

Carrie supports their logic with “And that’s what you need…” (line 8) in response to her student providing a logical response, that “most humans are interactive…[during a particular time of day].” This is an alignment move (Schegloff, 2007), which indexes that Carrie is supporting students' reasoning (NRC, 2012) about the comparison between human and gorilla behavior. But she also presses them (Windschitl, Thompson, & Braaten, 2013) to then "support what you're thinking" (line 10). All of these communicative behaviors – alignment, pressing, questioning – are moves that Carrie makes in the service of helping her students to write this part of their lab reports for their LTI.

However, we could also read this exchange as both Carrie and her students talking past one another, as opposed to interacting in joint negotiation (Rosebery, Ogonowski, DiShino, & Warren, 2010). If we look closely at Carrie's turns, we see that she focuses on the content knowledge students need to add to their hypothesis. Putting all of Carrie's turns together shows the following.

1 No you can describe it here ((referring to a section in the lab report)).

2 So you can work on finding more background info on what behaviors gorillas exhibit. So is there you know feeding behavior. Are there grooming behaviors, social, like specific behaviors that you guys could possibly see when you go to the zoo.

3 So you guys ((reading, unclear)) So why do you think being a close, ancestor genetically, that's what you're getting at here right? Why do you think being a close ancestor genetically, would make them, more likely to be active.. or....

4 And that's what you need. So...

5 Yes. You want to have some science supporting what you're thinking. Okay?

Carrie's responses are almost all focused on pressing students to go back to the background knowledge to support their thinking, while Maddy, as the unofficial spokesperson for her group in this particular exchange has something else in mind. She says,

1 So over here, do I have to write the behaviors in my hypothesis....

2 Oh, I have to move my hypothesis...

3 So do I need to add most of my hypothesis.. ((unclear)) I mean I do I know I do, but I mean like specific...

4 So like humans are most interactive... ((unclear)) So... ((unclear))

5 Should I change my hypothesis?

Notice that Maddy speaks in terms of smaller, surface level changes she needs to make to her writing. She opens with a concern about writing about the behaviors, but after Carrie says that she can describe the behaviors someplace else in her report, Maddy continues to think in terms of the surface features of the text. Maddy's fourth turn, "So like humans are most interactive… so…." is in response to Carrie's direct question about why being a close ancestor genetically would be enough support for to reason that gorilla activity is similar to humans and that we can describe them in the same way.

Carrie's incisive interactions with her students keeps science content in the foreground of the interactional and scientific, discursive work in this exchange. This is an example of a teacher's improvisational work that occurs in small groups during inquiry-based science. In Carrie's example, we can see one possible example of the teacher's role in the social space of the science classroom, of her role in the development of content knowledge that draws from the texts and contexts within which she works, and how in these moment-to-moment talk moves are also central in helping students acquire knowledge.

I continue this idea in the following exchange, which is a continuation of the conversation from above. The small group has moved on to discussing specific behaviors they will look for in their data collection. The students have included aggression among their list of dependent variables they will attempt to count. Carrie presses them to define the behaviors that constitute gorilla aggression. She impresses upon them that background research is important to making major decisions about investigation design (NRC, 2012), allowing the students to decide for themselves if it is scientifically reasonable to attempt to describe aggression in zoo animals. The transcript picks up from the previous example, with Carrie checking in on what the group means by gorilla aggression, and ensuring that they can support their definition with research.

1 Carrie: On gorilla aggression?

2 Now do you guys have any research that shows that they're aggressive?

3 In... captivity? In their habitat?

4 Natalie: Uhh...

5 Maddy: It actually said that they don't …((very unclear, a lot of background noise in the classroom is overlapping the soft voices of the students here)).

6 Carrie: And did you guys write… did you guys write the experts at the at the Bronx Zoo?

7 Allison: Yeah we wrote an email.

8 Maddy: But she didn't really say anything she said the teacher should…

9 'cause we emailed them our background research

10 and she said the teacher should tell you something or something like that.

11 Carrie: Is the email in here?

12 Maddy: No, it's on the computer.

13 Carrie: Because my fear…

14 if they know if they wrote you, that they train them NOT to be aggressive...

The primary element of this exchange is the way that Carrie presses the students to be accountable for and precise about the information that they gather (NRC, 2012). She accomplishes this (line 9) by asking questions, and clarifying her own thinking, or metacognition (Cazden, 2001). Carrie presses them, in line one, to look for information about how gorillas behave in captivity, to distinguish the possible behaviors from gorillas studied in the wild. She asks if they used their resources: the scientist/UA partner at the Bronx Zoo where they will do their data collection. Carrie clarifies, metacognitively, why she is asking for this information: that if the zoo trains aggression out of the gorillas, then the students would not be able to explore this behavior, which would impact their investigation design. With that, Carrie indexes the importance of precision and logical thinking in information gathering to the design process (NRC, 2012).

Carrie and her students continue the conversation, beginning with Carrie, who is reading from an email the group received from Andrea. After reading the email, the UA partner at the zoo, she reports that it is legitimate to investigate aggressive behaviors in gorillas. It turns out that Andrea provides them some additional resources, again, further indexing the importance of background research to the design process (e.g., intertextuality).

15 Carrie: Well, Andrea is saying that, you can do it.
16 So maybe even though they've trained them not to be,
17 maybe sometimes they still do (get aggressive).
18 And she was going to give you some sites to go to to find information.
Because in your question you ask about the background research.
19 So she's saying you can check those sites out.
20 So when you guys, who observed the gorillas before?

21 Allison: I did.

22 Carrie: Okay. Did you see any aggressive behaviors?

23 Allison: A little.

24 Maddy: Yeah.

25 Carrie: Okay. And how do you… how do you KNOW that they are aggressive behaviors?

26 Allison: In general.. sometimes.. a gorilla will come over and hit another gorilla. And it...

27 Carrie: So, what I want you guys to be very clear on are the behaviors.

28 What's the difference between play, and aggression...

29 Allison: No, they wanted them to move. They wanted them to move.

30 Carrie: So. I want you guys to be clear in your background research,

31 make sure you know, you know, clearly what gorillas do when they're playing

32 when they're socializing

33 when they're grooming when they're, being aggressive.

34 What are the signs that they are being aggressive

35 so when you were doing your observations when you were at the zoo.

36 You know exactly which ones are aggression

37 and which ones fall into the other category.

Carrie encourages the students to get more background information, which will help them to decide the categories of behavior for their data collection (line 19). In the middle segment of this excerpt (lines 10 through 17), Carrie asks students to be accountable for their knowledge once again, asking how their previous experience (the macro context) influences their choice for exploring aggression. The students report that they did, in fact, see what they would define as aggressive behaviors in the form of hitting. The students interpret hitting, presumably according to the context in which they saw the behavior, as "wanting them to move." Carrie presses back again in line 19, by asking the students to distinguish between playing, socializing, grooming, and aggression. Again, this move indexes the importance of what recent science reform states is precision of thought in investigation design (NRC, 2012). Carrie has engaged the students in inter(con)textual work as well, as she leverages their previous experience to help inform the decisions they must now make as they refine their investigation design.

A few moments later, Carrie returns to this group, which has now begun to make decisions about how to collect the data. Here, they consider the time of day, the independent variable, and how best to design their collection procedures accordingly. Consider how Carrie involves her students in making decisions, and in using different macro contexts (previous experiences and texts) within this micro context (e.g., talk) to further develop their investigation design. Now they have decided on the behaviors they will study, they work to make sound decisions about how to collect data.

1 Carrie: Alright checking back in, any questions?

2 Maddy: For this would it be one if we just went once?

3 Carrie: ((reading)) "The effect of time of day on gorilla social behavior."

4 Maddy: So if we do it twice=

5 Carrie: =So if you go once, I would make sure=

6 Maddy: =So twice per IV=

7 Carrie: =that you do it for a longer time, um=

Allison: ((student in background)) =So, I would say twice=

Carrie: =in the morning and the afternoon.

Maddy: So, we go twice and we then just do it at 12, 1:30, 3.

Allison: About two times on each day.

Maddy: And then we average out the data.

Carrie: Sounds good. Now, who did gorillas before?

Allison: Me.

Carrie: And what was your IV before?

Allison: It was um.. like, um...

Natalie: ((in background))... grooming behavior.

Maddy: Actually it was... time of day=

Carrie: =was it time of day?=

Maddy: =time of day on gorilla grooming behavior=

Carrie: =Because you might be able to bring in some of the data from before.

Natalie: ((unclear))

Carrie: Good. Now are these the same times as you used before?

Allison: No. We only did it twice and=

Natalie: =and we did it at 11:30 and at 2=

Maddy: ((in background)) What time? 11:30 and=

Allison: =I think it should be::..
3 times because you get more productive data.

Carrie: So...

Maddy: So we have more to work with.

Carrie: Excellent. Okay.
So I like that you're making this one, you're like, "no, we need more data,"
which are some of those improvements that we talked about.
So good. No questions? We're all set?
Make sure you're talking and everyone's on the same page.

This conversation developed during a lesson in which students were asked to complete a considerations sheet. Students talk about their projects while filling in the sheets. They have also begun to collect information on their fact boxes form. Again, this work is intertextual, as the students use information they collected from before to make important choices about what new texts will come from their planning session, namely their written procedure.

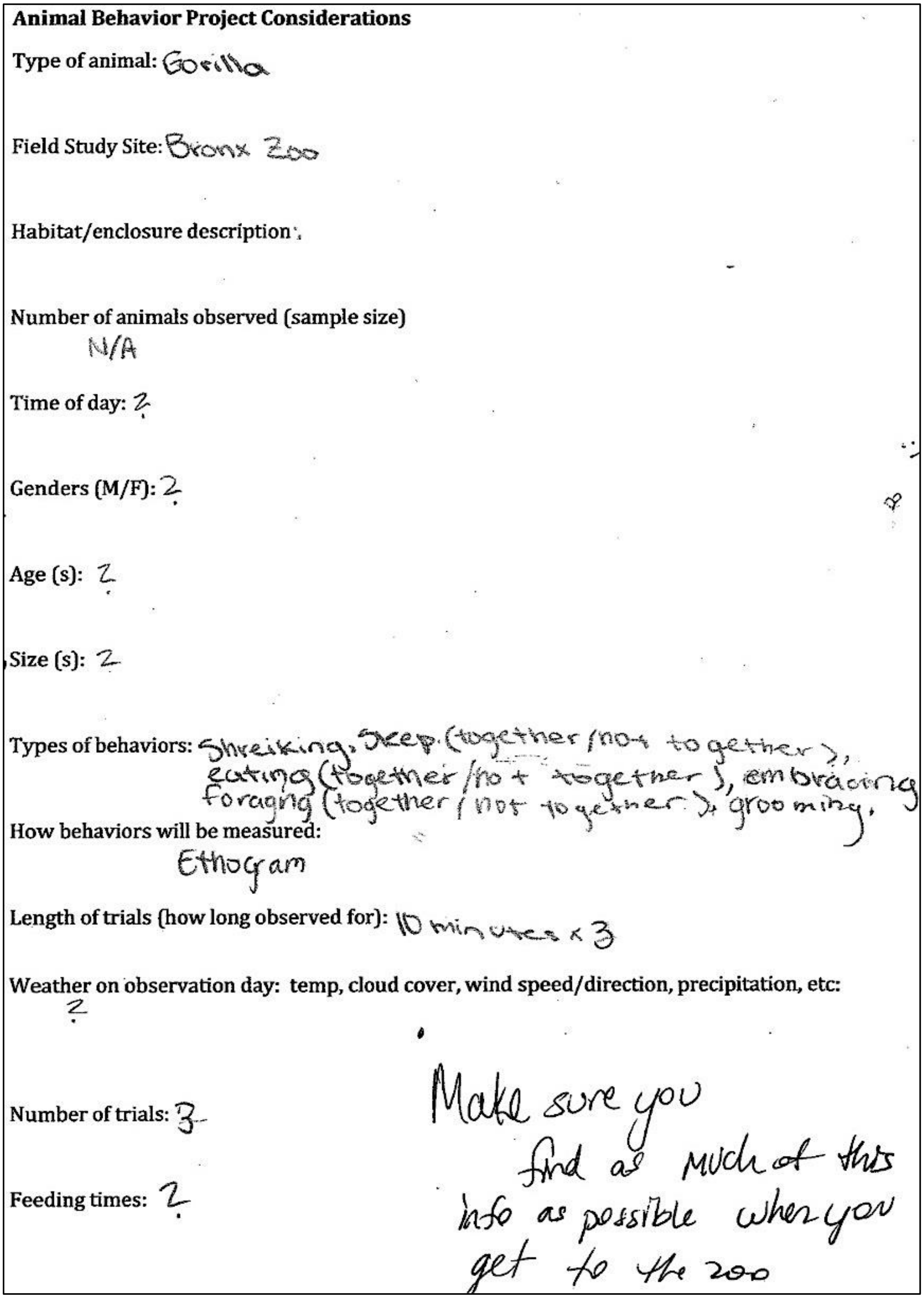
Specifically, this exchange centers around students' concerns about how many times they ought to collect their data in order to get the "best" data, to measure the effect of the IV (time of day) on the DV (gorilla social behavior). Carrie had begun the lesson with students in a discussion about how to make improvements on the investigations they did earlier in the school year. Since their LTIs drew upon these earlier experiences, Carrie is able to refer the students to what they learned the first time around to make decisions about their new projects. This becomes another macro context from which students draw through an inter(con)textual reference. We see her strategy at work in the last half of this excerpt, in lines 13 through 26. Carrie asks the students to consider how many times they collected data in relationship to their new plan. With this question in mind, students decide that making one additional observation would improve their data. Maddysays, "I think it should be 3 times because you get more productive data… we have more to work with" (lines 27 through 29). Deciding on a data collection plan is part of the "planning and carrying out investigations" practice described in the

NGSS (Achieve, Inc., 2013) and the NRC (2012). And Carrie engaged these students in talk about why it is important to think carefully about how to get the best data given the resources that they have available to them (i.e., access to a zoo, background knowledge about gorilla social behavior, and strategies for organizing information such as Fact Boxes, the IDD, and the considerations sheets). She uses previous contexts in light of what the written text asked of them (Driver et al., 1994).

Carrie's interactional strategies are of note here as well. She gives most of the conversational floor to her students, interjecting her ideas in joint negotiation of their plan along the way (Erickson, 2006; Hymes, 1983; Rosebery, Ogonowski, DiShino, & Warren, 2010). She gives one suggestion (lines 7 and 9) about taking a longer time to observe if they were to observe once instead of more often. With this, she offers another option for observing: duration versus number of observations. In the end, the students chose more observations over duration. They have full ownership of this choice, informed by Carrie's questions, and their previous experience.

If we look now to their considerations sheets, we can see this dialogue in action in writing. The students filled in the sheet during the conversation, and Carrie's written responses reflect the ideas about data collection we discussed here (Figure 6.6).

Notice that much of this considerations sheet is left blank and that the most detailed response is under the prompt, "types of behaviors." As Carrie and this group discussed their project ideas, they focused largely on finding ways to define the behaviors they were wanting to observe. They also made choices about how many trials they were going to include in their procedure. The ideas the group brought to the discussion with Carrie align neatly with those represented on the considerations sheet.



Animal Behavior Project Considerations

Type of animal: Gorilla

Field Study Site: Bronx Zoo

Habitat/enclosure description:

Number of animals observed (sample size)
N/A

Time of day: ?

Genders (M/F): ?

Age (s): ?

Size (s): ?

Types of behaviors: Shreiking, Sleep (together/not together), eating (together/not together), embracing foraging (together/not together), grooming.

How behaviors will be measured:
Ethogram

Length of trials (how long observed for): 10 minutes x 3

Weather on observation day: temp, cloud cover, wind speed/direction, precipitation, etc:
?

Number of trials: 3

Feeding times: ?

Make sure you find as much of this info as possible when you get to the zoo

Figure 6.6. Animal Behavior Considerations Sheet by Maddy, Allison, and Natalie

Nowhere on this sheet is the idea of gorilla aggression. Since I do not have transcript data of the discussion that occurred after the one presented here – in which aggression figures prominently – I can only surmise that the group decided to eliminate that behavior category as a possible variable to study.

Since we do not have video evidence to trace whether the group completed the considerations sheet before, during, or after the discussion, we cannot make a claim about which activity came first. However, we can say that the text and talk were dialogically related; they existed together in the same activity space, as part of the same discourse, informed by other contexts, other texts. Also, note that this group completed a lab report and final PowerPoint in which the final hypothesis they crafted noted the time of day on gorilla social behavior, but did not go further into which specific behaviors they expected to see at different times of the day.

In the opening slide to their lab report, notice that the hypothesis does not mention the specific behaviors individually (Figure 6.7). The behaviors the group studied in the end included grooming, foraging, walking, eating, sitting, climbing, embracing, sleeping, playing, communicating, and watching. Thus, somewhere along the line, in moments I was not privy to, the students surrendered their idea of gorilla aggression. This back-and-forth nature of decision-making mirrors the work of scientists (NRC, 2012).

Discussion

These cases illustrate how the macro and micro contexts of the LTI are in a dialogic relationship to one another, in part because teachers engaged students in micro-contexts (talk) that drew upon the macro contexts of experiences, structures, and texts to make meaning of particular science practices. While I showed two cases about one scientific practice -- planning an investigation -- the relationships between micro and macro contexts are embedded throughout the arc of the LTI, involving other practices, in other contexts, with other texts.

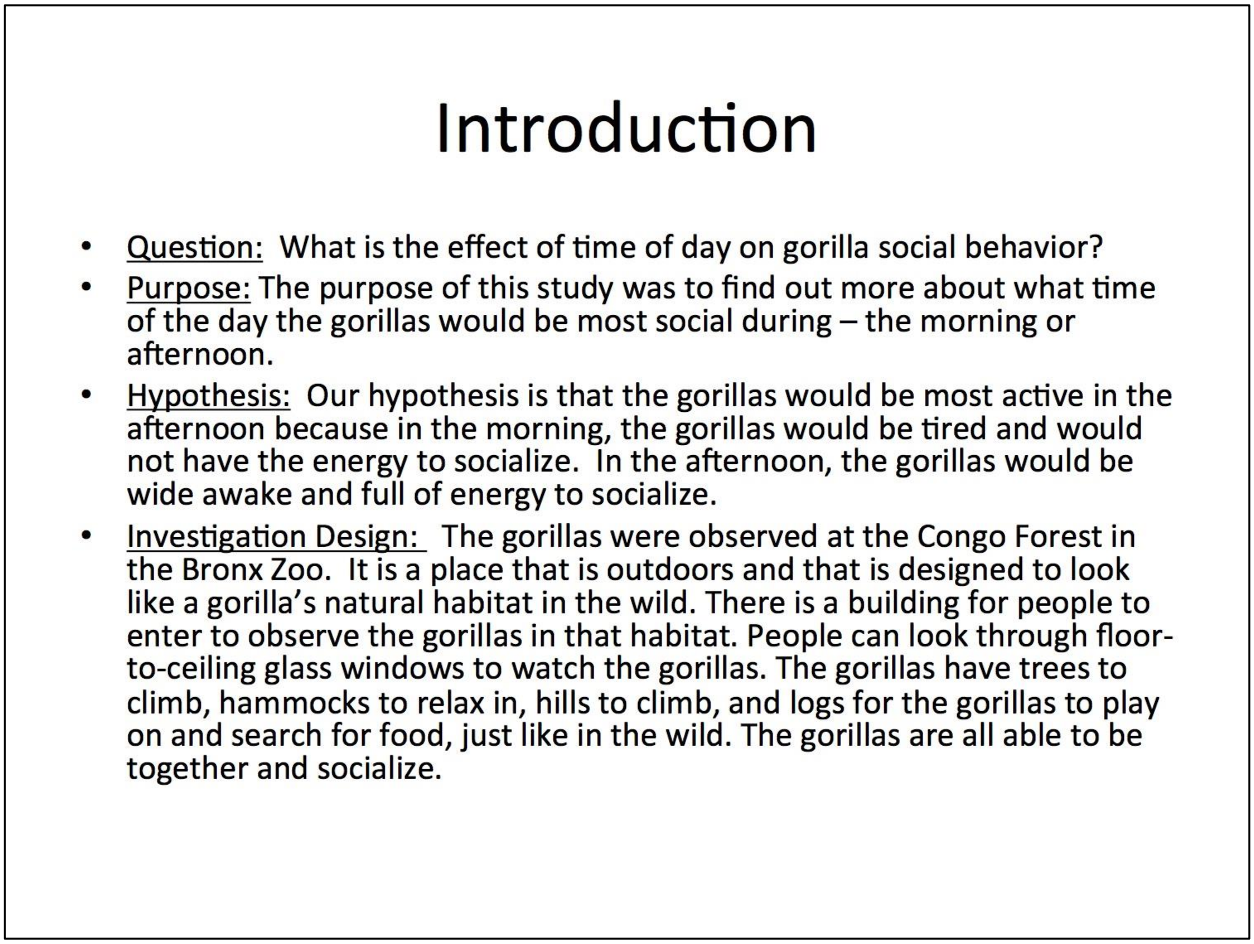


Figure 6.7. Introduction Power Point Slide from Carrie's Gorilla Behavior Group

In both examples, teachers leverage scientific knowledge-making intertextually. That is, they developed the LTIs across time, using particular texts from which students could draw in new contexts for meaning making. Inside of these micro contexts, teachers and students were engaged in multiple language forms as they made decisions about content as well as the practice of investigation design. The cases also illuminate how teaching the LTI is inherently heteroglossic. As teachers talked with students in the micro contexts of their discourse, they leveraged informal forms of talk (i.e., "how clear the water is" v. "clarity") to engage students in the discussions and keep them there. But these language forms were not all about engagement in the discussion itself, but engagement in the ideas. Carrie explored the idea of aggression using a conversational style that was a part of the language community of her classroom. Diana explored turbidity in the same way. And we saw how students' scientific written texts were closely linked to the discussions from which they derived. This is the dialogism to which I refer to earlier.

In sum, the work of developing the LTI moves beyond the texts, no matter how well-scaffolded they are to students' needs. Teachers make use of the micro and macro contexts to leverage the texts for student acquisition of science discourse. This chapter provided a close-up view of what those contexts have the potential to teach us. I will explore those potentialities in the final chapter.

Chapter 7

Language of Science in Long-term Investigations

There has been no lack of interest in inquiry-based teaching in science education. Reports have been issued, professional development offered, materials created. Yet after more than at least 30 years of promoting inquiry and researching, there is little agreement about what constitutes inquiry based teaching (Minner, Levy, & Century, 2010). This may be because the discourse remains at the level of idealized notions of inquiry-based teaching, not careful descriptions of what actually happens when traditional, successful, engaged teachers adopt an inquiry-based perspective.

Of course, there are other reasons why inquiry has not taken root in American classrooms. Teaching in a more inquiry-oriented way requires teachers and their students to engage in several modes of d/Discourse (Gee, 2008a). In schools that have been dominated by a single discourse for hundreds of years, this is no small feat. Further, participating successfully in science discussions assumes that all interlocutors (teachers and students alike) understand the specific and technical language of science, or at least are participating somewhat equally in emergent instantiations of this language. As we have seen here, this involves using a language that is familiar to them while working toward the more technical forms of the language of science (Brown & Spang, 2008; Gee, 2008a, 2008b; Lemke, 1990; Rosebery & Warren, 2010). Pushing forward on that path is not easy.

Yet Carrie, Marilyn, and Diane all teach from an inquiry-based perspective and thoughtfully lead their students down the path toward acquiring the discourse of science. While I observed and talked to these teachers during a small portion of their paths, I discovered that LTIs are more complex than they may seem on the surface. In this chapter, I begin by describing the lessons I learned through studying these teachers, and then move to explain these lessons in terms of the theoretical lenses through which I conducted my interpretive work. I conclude by exploring the potential contributions for future research and challenges for science education.

Lesson 1: Engagement Over Time

The challenges of developing inquiry-based learning through long-term investigations is not simply better curriculum materials, nor is it teaching teachers the steps of the LTI or managing a class discussion or science language. While teachers certainly rely on all of these, the key to engaging students in an LTI – at least for these three teachers - is also a matter of a long-range view of the work, a teacher's sensibility of and related perspectives about the temporal nature of the work.

In one approach to looking at learning over time, Mercer (2008) presents the concept of a dialogic trajectory that brings attention to developments in how students talk to one another: "speakers moving together through a series of related interactions within the same institution" (p. 39). Mercer claims that, over time, one can see the "continuities and discontinuities" in the development of ideas, of the ways that individuals participate over the arc of that activity (Rasmussen, 2005). Rasmussen (in one of the very few studies drawing from this perspective) developed the concept of a participation trajectory to describe patterns of children's involvement in a particular activity from beginning to end. As Mercer (2008) explains, a participation trajectory and a dialogic trajectory differ in that the former focuses on individuals' participation in the activity over time, whereas the latter focuses on the movement of talk (and of the individuals who perform that talk) over time.

I propose that viewing experienced, skilled teachers' work in an LTI has a distinct temporal sensibility worth studying. For now, there are two elements of teachers' work that appeared to be inherently temporal: the teachers' long-range consideration of students' participation in the LTI, and shifting of language registers over time. I describe both elements here.

Engaging a long-range view. Teaching the LTI with a long-range view involves having an array of strategies at hand, employing them independently, and interweaving them at appropriate times. It also involves a year-long vision of goals for student learning, such as successfully writing a report that would be presented publicly at the school science fair at the end of the school year. A long-range view also involves a teacher's careful layering of inquiry and investigation skills that build upon each other over time. A long-range view is informed by the teacher's knowledge of science practices, student needs, and curricular goals.

And the long-range view is highly contextual, and takes many forms. For example, Carrie developed her LTI over the course of the school year, first developing students' ideas about inquiry through a series of mini-lessons. She then conducted three whole-group investigations that developed students' investigation skills and practices (NRC, 2012) across different investigation types (e.g., field study, design study, and controlled experiment). When students were finally required to conduct the LTIs independently, they revisited the investigations from earlier in the school year. Students learned how to troubleshoot and revise the investigation design to answer new questions.

Marilyn developed the LTI over the course of the school year as well, but took a different approach than Carrie, in that she provided students with several different short-term experiences whose purpose was to practice new science inquiry skills (e.g., data collection, conducting background research, etc.). Her students were then free to investigate science questions of their own interest using oceanography as a theme. Marilyn's storyline involved teaching discrete skills first and relying on their previous experiences from sixth grade to prepare them to conduct their LTI.

Diana's LTI involved teaching secondary research using a large database. Diana designed several experiences that helped her students to understand how the data were collected and the relationships among variables. In this way, the storyline of Diana's LTI was to focus on the background knowledge that the students would need to conduct their investigations. The various experiences she provided developed vocabulary and supported students' writing of the final draft of the LTI report they would present at the school science fair.

Expectations of language registers shift over time. I also looked at the shifts in teachers' use of language across the arc of the LTI. Specifically, I observed that, over time, teachers' expectations for students' use of language (in both talk and writing) shifted from informal registers to a more specific scientific register.

Lee, Quinn and Valdes (2013) state that when students and teachers use the language of science involving an interplay of different registers "they participate in academic tasks and activities and demonstrate their knowledge in oral and written forms" (p. 228). In their discussion about what science teachers *do* with the language, they outline several different examples of both written and oral receptive (reading and listening) and productive (writing and speaking) language forms and registers. All of these involve colloquial and classroom registers, as well as disciplinary language and terminology. This means that students and teachers are constantly using their own forms of language - as connected to the cultural community in which they participate outside of school - as well as their classroom registers and even more technical language of a discipline.

The shifts I observed these teachers enact, however, were not linear, but rather, existed in a tension, which I describe later as a push-pull between two opposing, and yet interwoven, language forces (Bakhtin, 1981). For instance, Carrie insisted that students revisit a previous investigation instead of trying something completely new so that she could revisit and refine students' knowledge of the specific content as well as their participation in scientific discussions. I heard Carrie often refer to strategies and talk structures from past experiences -- such as how to write a science question using both the IV and the DV, or how to improve observations in a field study -- to shift students' use of science language in both spoken discussions and in writing.

Likewise, Diana provided opportunities for students to continually practice new language forms. And many of these opportunities opened the door for impromptu language work (Rosebery, Ogonowski, & Warren, 2010). When students debated the scientists' rationale for continuous monitoring of the Hudson River (as explained in the Carey/AMNH videos), one student presented the idea of adaptation. In exploring what that term meant, Diana was challenged to negotiate with that student -- in the service of helping all students in the classroom learn from this moment -- about what adaptation meant. The student’s explanation was "they get used to it" (presuming that "it" meant the conditions of the river). And while adaptation was certainly a part of the story, it did not account for other reasons scientists might conduct longitudinal studies of the ecosystem. Nevertheless, Diana, working inside of her long-range view of the work, and her temporal sensibility - that there will be future opportunities to develop these ideas further, or that students thrive with repeated exposure to new language forms -- used this moment to highlight a student's thinking.

The register shifts are not only related to speech; they also involve shifts in textual forms. Throughout this dissertation, I have explored various textual language structures that teachers enacted over the arc of the LTI. Teachers helped students develop science vocabulary, practice using the grammatical structures of science (e.g., nominalization and passive voice) (Gee, 2008b; Latour & Woolgar, 1986; Lemke, 1990), and write several different kinds of texts (e.g., class notes, responses to questions on the Do Now forms, and formal lab reports, to PowerPoint© © documents for their LTI) (Moje, 2008).

The Do Now forms in Diana's classroom engaged students in a mix of uses of written language. Students were asked to respond directly to content questions, represent information on a table, draw graphic representations of relationships between variables, and write portions of their investigation design through the support of small written prompts, such as sentence starters for each phrase in a hypothesis (see Figure 6.5). But before writing these responses on the Do Now, students talked about what they knew first in small groups and later in the whole group sharing sessions. They revised their written responses based on their classmates' ideas shared in the whole group discussion - and recorded by Diana on the Smart Board at the front of the classroom. Their ideas were taken up by their teacher, and transferred from oral to written language, from productive to receptive forms, from colloquial to formal registers (Lee, Quinn, & Valdes, 2013).

Lesson Two: Adaptations According to Local Contexts

While the model for the LTI these teachers were using came from the Urban Advantage PD program, these curricular materials were easily adaptable across contexts. These teachers, experienced, lead UA teachers, had redesigned the textual materials -- as well as their practice -- to meet their students' needs. This demonstrates that good curricular materials serve as a framework for which experienced science teachers develop experiences and strategies for engaging students in the LTI. Teachers in this study adapted the materials in two distinct ways.

They adapted the textual materials themselves (e.g., the IDD and DSET), and adapted their teaching practices within the LTI according to the sociocultural needs of their students (i.e., they had specific ideas about how discussion structures would best support their students' learning).

Textual adaptations. One way that teachers constructed the macro contexts, or the larger structure for the LTIs was to adapt curricular materials. They developed their own variations on the IDD form and deconstructed parts of the form into other texts that helped their students with investigation design. All three teachers used a Do Now exercise at the beginning of class to set the frame for the day’s lesson. Diana, in particular, stayed close to the Do Now as she developed daily paper-and-pencil tasks. She followed the format of the Do Now handout every day during her whole class lessons, while Carrie and Marilyn engaged students in brief discussions - sometimes only 15 minutes - that situated the lesson’s topic, but did not structure the entire lesson as it did for Diana's class. Some differences between Diana's use of the Do Now and Carrie’s and Marilyn's had to do with individual teaching style, some with the particular type of lesson, and some differences had to do with their students' needs.

For example, Diana supported her students' language development through several scaffolding questions on the Do Now sheets that asked about vocabulary and the meaning of variables. She represented these ideas in several different ways: in charts, in drawings of food webs, in questions that directly related to the case study videos of the Carey Institute study, in graphs representing the different variables. She drew upon a field trip during which students gathered data on the water quality of the Hudson River in much the same ways as the biologists in the case study had. She asked them to generate their own food webs and label the relationships and explain them in writing.

Adaptations concerning sociocultural factors. As much as they worked to engage students in class discussions, some social factors were beyond the teachers' influence, but impacted some of the LTI work as reported in interviews. Diana reported that her students were mostly Spanish-speaking children of Mexican immigrants, and were generally shy about their language use, embarrassed about how they sounded. She noted that the Mexican American students often relied on each other during class discussions to help with understanding the language, and thus, the concepts. Therefore, she conducted many whole group conversations in which students were able to participate when they felt comfortable, but also balanced the whole group lessons with the small group activities so that students could have opportunities to share their language with each other in less high-stakes circumstances.

Meanwhile, the social constraints on student engagement were different for Carrie and Marilyn. They often cited student competition and a need for "being right" as their main social concern. Therefore, their small group activities often involved students working with others who they felt most comfortable with, but both teachers were careful about constructing small groups that challenged students to work with those they did not know as well. For example, Carrie cited one case in which one particular student shared much more often in the small group he worked with because he happened to be the most academically strong student in that group. But, place him in another group of boys - sitting just across the room from him - and this same student would have fallen into the background, allowing the other students to take over the activity. Because Carrie placed him in this particular group, he naturally took on a leadership role, participated in more meaningful ways, which benefitted him and the other group members.

Marilyn also adjusted activities for her students' needs. In an early lesson, she developed science vocabulary on geology. She recognized that the text they were to read was more difficult than she had wanted. So she developed a graphic organizer and a small group participation structure (e.g., a jigsaw group) that would afford students the opportunity to grapple with new concepts with each other before presenting them to a new group of students. She also worked with each and every group, making sure that the students understood the content. To ameliorate the effects of competition, Marilyn and Carrie both had students working in different configurations often, and talked with them openly about not being concerned about their grades.

Lesson 3: Different Views of the Macro and Micro Dialogic

Examining the data through micro and macro lenses allowed me to interpret various levels of interaction. I found that inside of the basic structures of the LTI -- formed through texts and larger social contexts -- the activity of each teacher's LTI looked vastly different from each other. By activity I mean the moment-to-moment interactions between teachers and students. These activity spaces, bound to a particular macro context, or practice (data collection, for example) engendered various kinds of talk. In other words, the structure of the LTI laid the groundwork for the diverse interactional experiences as teachers and students engaged with each other (Erickson & Shultz, 1981).

But within this structure, teachers' strategies for engaging the micro and the macro differed. Teachers employed different strategies for engaging students in talk about science, they cared about different aspects of the work (as we saw in the previous section), they highlighted different kinds of language structures. Yet, some similarities existed too. They generated very similar science process vocabulary across all lessons. Terms like, "IV" and "DV" and "evidence" were used often in all three classrooms. Committed to the UA framework for inquiry-based science teaching, teachers helped students develop final project display boards that included the same elements, such as a research question and hypothesis that includes the IV and DV and background knowledge about the phenomenon of study.

One reason for the differences is that teachers were challenged to respond to what students brought to the interactional space, the micro contexts: their social ways of being, their language, their ideas, their questions. The sociocultural differences between Diana's school and Carrie and Marilyn's school provide an explanation for these micro contexts (the classroom interactions) to be vastly different from one another.

These micro contexts challenged teachers to think carefully about managing and directing the flow of the conversation (NRC, 2007). To better manage these contexts, teachers structured the interactional spaces through a series of whole group and small group activities, for example. Using these structures allowed for some sense of predictability for which teachers had strategies, such as moving from group to group to check in on progress, various questioning strategies, and strategies for keeping all students accountable for their work.

Managing group work was one similarity among all three teachers. Teachers were intentional about when to organize the LTI work in small groups or in whole group conversations. Diana, Carrie and Marilyn all remarked that whole group discussions were easier to manage than small group work because it was easier to keep the conversation "on track" and focused on content. They valued small group work, however, and found it useful for assessing students' knowledge and individual needs. All three teachers also believed that small groups afforded important opportunities for students who were less apt to participate in classroom discussions. They believed that talking about science helped students understand it, and provided students with daily opportunities to do so.

However, as I presented elsewhere in this study and in the above section on the sociocultural adaptations teachers made to the LTI work, the differences among the teachers appeared more connected to the moment-to-moment interactions, which, of course, are connected to teaching style, and not necessarily a result of differences in curriculum or training. That is, though curriculum materials, like the UA materials, structure the macro frame for teachers (e.g., content topic, supports for engaging in discussion, supports for assessment, etc.), the micro contexts in which teachers and students engage are impactful, and therefore, ought to be studied for the affordances and constraints of individual adaptations that teachers make to the materials to fit the needs of their students.

A "Push-Pull" Language: Heteroglossia and Teacher-Student Interactions in Science

In chapter six I introduced the Bakhtinian (1986) notion that the language of the science classroom is inherently heteroglossic, that is, that generating knowledge in science classrooms involves multiple language forms and meaning-making strategies (Gee, 2008a, 2008b; Warren, Ogonowski, & Pothier, 2005; Rosebery & Warren 2008; Rosebery, Ogonowski, DiShino, & Warren, 2010). Bakhtin (1986) theorized that all language is created in other language, that any momentary utterance -- loosely defined as a complete idea expressed by a speaker or writer -- is borne of the language that comes before, at the same time that it "populates" future language. But this process is also inherently, and necessarily, tension-filled, and perhaps it is through this tension that language forms are created and become stratified.

The tension to which Bakhtin refers is that between a unifying or centralizing language which interlocutors experience, or produce, and a stratified, or outward-moving language. Like the centripetal force in physics, in which matter is pulled toward the center of a spinning object, language that is influenced by the centripetal is language that is pulled to be more centralized or unified (or in linguistic terms, the "standard"). The language of science is an example of a centralized or unified language, as it includes highly structured, specific vocabulary, strategies for argumentation and expectations about how to communicate knowledge (Lemke, 1990). In classrooms, however, science discourse does not dominate, which may help to explain why science has struggled to get a foothold in American classrooms. There are always competing discourses, deemed more relevant at particular times, for particular reasons. Achieving a science discourse -- something that takes up only part of a child's school day -- is particularly difficult.

But teachers develop several strategies for developing the language of science, in both macro and micro contexts, working within the push-pull of language forms. They consider the forms of vocabulary (Gee, 2008b; Nagy & Townsend, 2012; Shanahan & Shanahan, 2008; Snow, 2008), phrases and clauses that promote a particular logic in science (Bakhtin, 1981; 1986; NRC, 2011; Moje, 2008), and writing in the standardized forms of scientific communication most often practiced in schools (Gee, 2008b; Latour & Woolgar, 1989; NRC, 2011; Moje, 2008). I demonstrated how teachers worked diligently to support students' emergent science language over time.

But, according to Bakhtin (1986), the centralizing forms are in constant tension with diverging, or centrifugal forms as well. He states,

> But the centripetal forces of the life of language, embodied in a “unitary language,” operate in the midst of heteroglossia. At any given moment of its evolution, language is stratified not only into linguistic dialects in the strict sense of the word (according to formal linguistic markers, especially phonetic), but also – and for us this is the essential point – into languages that are socio-ideological: language of social groups,

> “professional” and “generic” languages, languages of generations and so forth. (pp. 271-2).

Some would argue that these socio-ideological forms of language are colloquial, or not of the mainstream forms in any given language community -- such as in classrooms (Brown & Spang, 2008; Heath, 1983; Hymes, 1980).

On the other hand, the centrifugal forms are those that pull the standardized, or unified (Bakhtin, 1986), forms outward, away from the center. They are the forms responsible for the diversification among languages across and within cultures. They are inherently responsible for heteroglossia. In Bakhtin's words:

> The processes of centralization and decentralization, of unification and disunification, interest in the utterance; the utterance not only answers the requirements of its own language as an individualized embodiment of a speech act, but it answers the requirements of heteroglossia as well; it is in fact an active participant in such speech diversity. (p. 272)

The centripetal and centrifugal, which together comprise heteroglossia, are always in tension, pushing and pulling against one another from utterance to utterance, resulting in (sometimes) the construction of diverse language forms, and ways of participating. We saw examples of these forms in tension in teachers' discussions with students, especially around concept development.

For example, at times Diana presented information using a word choice that favored the informal forms of language, or the more colloquial forms of the language of her students' community (see below, when she chooses the word "murky" instead of "turbulent" to help students make the connection to "turbidity" in the zebra mussel study.) Yet at other times, Diana chose the most formal variation of the language with her students (recall when she repeatedly used "nutrients" instead of "food" in the discussion of what bacteria need to survive).

Importantly, the centripetal and centrifugal co-exist. Consider a brief example when Diana attempts to develop the idea of turbidity with her class. She asks numerous questions of her students to get them to understand that the term "turbidity" is a relatively easy concept for them, and that it involves information they already know. Watch as Diana and her students move back and forth from the terms that the students provide using informal terms (or level 2) (Snow, 2008), as she takes up these ideas to move their language toward the most formal vocabulary term, "turbidity" (or a level 3 term). I should point out that this excerpt begins with Diana taking up the term that a student used to describe why the scientists would not be able to see the Secchi disk when it is lowered to a particular depth.

1 Diana: Because it's murky?
2 Is that the word you used?
3 Okay can anyone else put it in their own words?
4 Adrian?
5 Adrian: Because it has high turbidity.
6 Diana: Because it has high turbidity.
7 Okay we can say it means that there's high.. turbidity..
8 we can say that the water looks murky.
9 Why does it look murky, Adrian? Why does the water look murky?
((Adrian provides an inaudible answer, the conversation continues.))
10 Diana: Alright. That isn't wrong. Michelle?
11 Michelle: Turbulence.

Diana: 'Cause of turbulence?
Okay, why would turbulence make the water murky?
Adrian: Because it's mixing it up.
Diana: Because it's mixing what up?
Adrian: The dirt and the chlorophyll.
Diana: The dirt, the ((unclear)).
One thing, Marlyse, that would make, um, the water murky or dirty
could be little particles or sediment.
Marlyse, what else in the water makes it difficult?
Marlyse: Plankton and plants.
Diana: Plankton. If there's a lot of plankton in the water it's also hard to see.
Okay?

Diana continues the conversation to incorporate the concept – and language – of photosynthesis. Many words are being tossed about here: "murky" and "turbidity," "turbulence . . . mixing . . . dirty . . . . particles . . . sediment." Here, Diana uses both registers she pushes students to move from what some psychologists have called a “naïve” view of the process to one that uses scientific language and explanations.

Heteroglossia does not only explain diversity in terms of spoken language, but also the ways that written language forms become diversified. Part of this process is through intertextuality. As I described above, intertextuality is the process by which people make sense of texts (written or social) through their understandings of related texts. It includes the notion that former texts inform, or construct, the ideas in new texts. In the Bakhtinian sense, the former texts "populate" the newer texts.

I have showed how this process occurred as I presented the various ways that the teachers used multiple texts over time to support the learning that occurred in the most current text. In other words, in a lesson in which Carrie's students were planning their investigations, she asked them to use a considerations sheet as well as to draw upon previous experiences (intercontextuality) to make important decisions about the plans for the most current LTI. Diana's and Marilyn's students did so as well. In Diana's classroom, students used the video case studies and the accompanying readings to develop their hypotheses and food web diagrams. Marilyn's students used their knowledge of investigation design -- from other experiences early in the school year -- as well as emails from the UA scientists, websites, and the like to make well-informed decisions about their designs. None of this work could have happened without the flexible use and integration of other texts and experiences (contexts) (Erickson & Shultz, 1981; Gee, 2008b).

But what does it mean to identify these forms of the language? What does this description buy us in terms of future teaching, teacher education, or science education research? I would first argue that the description of how language forms are used, through a Bakhtinian framework, may inform teachers' ideas about language so that they can develop other possible ways of interacting that are equally, if not more, successful in engaging students in the LTI, and to learn the language of science. It is not enough to recognize that there are heterogeneous forms of language that can act as pathways toward the most specific forms of scientific language use; rather, students' meaning making depends on the ways that teachers use this knowledge.

For instance, helping teachers to think about the arc of language use over the course of the year (at the macro level) or helping them anticipate the naïve language students might first use (across communities) that is relevant to specific scientific language (just as elementary teachers need to understand that “borrowing” in mathematics is not the same as borrowing a cup of sugar), perhaps science teachers need to learn that students will think of ideas of "dirty" or "murkiness" when first encountering the phenomenon of turbidity.

This line of reasoning evokes the literature that details why teachers of all subjects should have greater awareness of language diversity and language development (Adger, 2003; Adger, Snow & Christian, 2002; Adger, Wolfram, & Christian, 2007; Cazden, 2001; Denham & Lobeck, 2010; Lucas, Vilegas, & Freedson-Gonzales, 2008: Nagy & Townsend, 2012). Drawing from studies in linguistics and children's development of language (Lindfors, 1997), this work provides teachers with basic understandings of linguistics and language awareness and the ways that knowledge of language - the primary source of information sharing in classrooms - and metalinguistic awareness influences learning. In response to recent calls in science education for increasing awareness of language and cultural diversity in classrooms (Lee, Quinn, & Valdes, 2013; NGACBP, 2012; Rosebery, Ogonowski, & Warren, 2010), we might do well to develop specific tools that help teachers engage students in purposeful experiences with language in science -- in a sense, a refining of the practices around language observed in this study.

Final Thoughts

I close with some thoughts about the future work and implications to which this study contributes. I consider the ways that the results may influence professional development in science, and discuss the challenges of this work, especially with respect to the Next Generation Science Standards (Achieve, Inc., 2013).

For more than 30 years, education researchers and classroom ethnographers have attempted to understand the interactional space of the classroom (Heath, 1983; Hymes, 1980; Phillips, 1982). Warren and Rosebery's work in science classrooms has taught us that students from non-dominant language communities oftentimes have sophisticated reasoning strategies in science, but that it is the role of the teacher to open up the classroom space for authentic dialogic discussion, and to take up and extend students' ideas (Rosebery, Ogonowski, DiShino, & Warren, 2010; Rosebery & Warren, 2000, 2008; Warren & Rosebery, 1993). This requires that teachers develop intuitive and responsive skills that support students' ideas as they work toward learning the formalized language of science.

Following this perspective, this study opens the door for further questions and micro-analysis about teacher responsiveness. To what extent are teachers' responses to students' thinking connected to students' decision making during long-term investigations? In other words, what responses promote independent thinking in students, and which responses engender students in merely repeating the teacher's ideas? Another question this study opens is: to what extent is the investigation design phase connected to the development of student content knowledge?

Other potential implications of this work is that it may inform our ideas about how best to structure LTIs, especially with regard to the NGSS. With the new language about science practices, how might long-term investigations look different? Windschitl and Thompson (2008) have proposed that science teaching should involve model-based inquiry (MBI). They proposed MBI as an alternative approach to the more typical investigation process (or, The Scientific Method) by which students create from their data visual models that lead to more meaningful reasoning about science concepts (e.g., connections between variables, explanations of phenomena, explanations of findings, etc.). Instead of The Scientific Method, the researchers propose that we ask students to design investigations based on their conceptual development of models or simulations of the phenomena of study. These models would generate stronger rationale for the decisions that students make in the design process. But because this work was done prior to the new NRC (2012) practices and NGSS (NGACBP), and involves research on new teachers and the extent to which they enact the MBI system, we may need descriptive studies of experienced teachers who use model-based thinking during LTIs so that we can trace the impact of model based inquiry with the NGSS practices in mind. This study has the potential to contribute to this line of work as well.

Further, this study involves a small sample of three teachers to represent one case of the LTI. It would be useful to expand this work to several teachers who teach in linguistically diverse classrooms to better understand how teachers develop practices about language in science and literacy practices, especially in light of the NGSS. Since many of the goals of NGSS involve a clear cross-over between literacy skills and science language, we may benefit from larger descriptive studies that trace how teachers who are learning to incorporate the NGSS practices into their teaching also learn to respond to the linguistic demands of teaching science. Along with such a study might be one which investigates teacher knowledge of language and teacher attitudes about language diversity as it impacts teaching the language of science inside of teaching the practices (NGACBP).

Another potential contribution of this study is to pursue more examples of LTIs that occur over time, to trace the development of an investigation as a trajectory of engagement, to develop more examples of what such a trajectory may entail. Doing so would help us to imagine long-range curriculum planning in light of LTIs, and to develop strategies for researching the development of an LTI in terms of language development.

Of course, this new work invites challenges as well. Researching teachers' incorporation of the practices into their science classroom investigations challenges us to steer clear of definitions of practice that do not fully consider how students and teachers from non-dominant language communities might practice them. A caution then, would be for the field to continue to look for diverse examples of science practices that are inclusive of many cultural perspectives (Nasir, Rosebery, Warren, & Lee, 2006).

Another challenge is that researching language is cumbersome work. And, as has been noted in the past by Gee and Green (1998) and more recently by Moses (2012), discourse analytic research involves the integration of theoretical perspectives that consider how groups use different cultural tools to communicate and make meaning. In general, this means that as we develop strategies for recognizing the NGSS practices and cross-cutting concepts as they are practiced in classrooms with experienced teachers, we might also be wise to develop new methodological strategies for discourse analysis that consider cultural practices in science (Bang, Medin, & Altran, 2007; Hakuta & Santos, 2012; Lee, Quinn, & Sanches, 2013; Nasir, Rosebery, Warren, & Lee, 2006).

In sum, this dissertation provides a careful description of the ways that teachers and students interact across time in a focused scientific investigation, or LTI. I developed a model for considering the on-the-ground work of teachers during such investigations, which involved both macro and micro contexts. Within these contexts, we were able to see the complexity of the interactional work, that, perhaps most clearly, curricular texts played a very small part in the production of knowledge. Rather, it was through discussion, and the intuitive, responsive, content-focused behaviors of the teachers that students engaged in the LTIs. And spoken and written language was a predominant theme of this work as teachers developed students' awareness and application of the language of science through two layers of interaction: as metalinguistic work in which teachers made clear the language goals of each task, and through more intuitive, tacit understandings about language - especially in using the language of their local community - to promote engagement in science.

APPENDICES

Appendix A
Text Translation for Figure 4.4

Exploratorium 9: Lab Report Peer Review May 21, 2012

Do Now: What's <u>Good</u> about and what needs to be changed for the following?

A)

- It needs the title
- It needs the time unit
- The x-axis needs equal intervals

- The y-axis is labeled
- The x-axis is labeled

B)

1. Theodora started the stopwatch – the stopwatch was started
2. = was good
3. We recorded the data on an ethogram – the data was recorded on an ethogram
4. = was good

C)

Made connection between hypothesis and results
Needs to switch "correct" to "supported"

Appendix B
Interview 1

Thank you for setting aside some time to talk with me today. This is the first of three interviews we'll have together over the course of the school year. The purpose today is to discuss your background and experiences as a teacher. I hope to audio record this interview today for accuracy. Is that okay with you? (Get consent before turning on the tape. If teacher consents, turn on recorder, if not, then write responses by hand.)

Remember that as a participant in this study, you can choose not to answer any question, or to stop the interview at any time for any reason without having to explain it to me. Also, you may ask me to turn off the recorder at any time (if recording).

BACKGROUND

1. Let's first talk briefly about your experiences as a teacher. Tell me about your teaching background, particularly how you came to be a science teacher.
   Probes:
   - How long have you been a science teacher? In same school? Grades?
   - What do you enjoy most about being a science teacher?
   - Have you worked as a professional a scientist? If so, how/why did you decide to become a teacher?

2. How did you get involved in Urban Advantage?
   Probes:
   - How many years involved?

3. (if not answered in Q2) Talk a little about your experience(s) as a UA lead teacher. How did you become a lead teacher? How long have you been a lead teacher?

4. What are your responsibilities as a UA lead teacher?
   Probes:
   - Any special responsibilities specific to your role at your specific school that other lead teachers may not have?
   - Talk about your work with the partner institutions: Do you work with other program staff? If so, in what ways?

CURRENT TEACHING CONTEXT

5. Describe your current school. How many teachers? Students? How many science teachers? What is the general make up of the student body? How long have you taught at your current school?

6. Describe your current teaching assignment. How many classes do you teach? How long is each class? Approximately how many students are there in each class? How many preps?

7. Do teachers in your school work in teams to create curriculum plans, map out science units together, or collaborate on planning, or in using the curriculum in any other ways?

(Appendix A Cont'd.)

8. How much do you use the UA curriculum materials? To what extent do they work alongside your school's curriculum?

9. Do you have any students from minority language communities in your classroom? If so, about what percentage of your classes makes up this population? What languages or countries are represented in your classes?

10. Do you speak any languages other than English? If so, what? If so, do you use that language as a teacher? If so, in what ways?

TEACHING SCIENCE

11. As you know, teaching science with an inquiry stance is a central part of the UA program. How do you describe teaching science through inquiry? How do you approach teaching science through inquiry in your classroom?

12. What has teaching in a classroom where students speak many languages taught you about teaching science, or about teaching more generally?

13. Inquiry-based teaching often involves students talking with each other to share ideas. How often do you ask students to participate in activities in pairs? Small groups? As members of a whole group discussion? Talk about when and why you decide to use each kind of group configuration. From your experience, how does each kind of group configuration support students in sharing what they know?

14. How do you encourage students to participate orally (or to discuss their ideas) in discussions in class (either in pairs, small groups, or in whole class discussions)?

15. (if not addressed in other questions) Has your work as a leader in UA impacted how you think about science inquiry? If so, in what ways?

16. Thank you for your time today. Is there anything else you'd like me to know about your work as a UA lead teacher, or as a science teacher in general?

Appendix C
Interview 2

Note: This interview will involve listening to audio clip(s) of less than 2 minutes in which students are engaging with each other in a science lesson. The first set of questions focus on that excerpt specifically. The last set of questions are about your general teaching practices. I will provide a transcript of the discussion.

AFTER REVIEWING THE CLIP(S) TOGETHER:

1. How would you describe your students' engagement here? (e.g., who's engaged most? why? is this typical?) If we focus in on the students from non-mainstream language communities for a moment (e.g., ELLs or students who speak minority varieties of English like African American English), how would you describe their engagement? What examples from this recording help you with this description?

   (Alternative: Are there any ELLs or former ELLs in this group that you can identify? Tell me about their engagement.)

2. When did your students in this(these) clip(s) seem to be communicating in the most meaningful ways? When and how did students seem to be learning the most about science through their communication (either oral or written)?

3. What else would you like me to know about this(these) clip(s)?

GENERAL QUESTIONS (not related to the specific audio sample):

4. What are you listening for when your students are sharing ideas in the whole class discussion format? Do you listen for different things when they are working in small groups? One-on-one? Why?

5. How do you decide when to use whole group, small group, or one-on-one (or other) discussion tasks? From your experience, in what ways does each kind of configuration seem to help students learn about and do science inquiry?

6. (if applicable) Your classroom has many students who speak minority languages. From what you have observed, how does this language diversity impact how all students participate in your class?

7. What else would you like me to know?

Appendix D
Interview 3

Thank you once again for meeting with me. Today's interview will be more brief than the first two. The goal for today is to check in with you about how things are going since it has been some time since we've been in touch. I wanted to get a sense about how you are thinking about teaching and student engagement especially in light of our second interview and what may have occurred to you since then.

INTRODUCTORY QUESTION

1. We had a wonderful conversation during the second interview in which you talked about the audio recordings of your students. Since then have you had any further thoughts about those students' participation? The recordings in general?

2. One of the things that I am trying to understand is how you think about how students participate in discussion about their science ideas in your classroom. Now that I have had a chance to listen to our interviews, I wanted to check with you about my understanding of your views. Based on those interviews, it sounds to me like you see discussion . . . . [provide a summary of ideas from past interviews] Is my interpretation close to how you think about this? Is there anything I should change?

3. Is there anything that I have missed?

UA-SPECIFIC QUESTIONS (to tap their expertise as UA leaders and how it influences their classroom practice)

1. As you know, I was able to observe a few classes when you had students working on their Exit Projects. Can you explain your process of guiding them through the project? With what aspects of this project do your students typically need the most help? What specific things do you do to guide them through the challenges?

2. Tell me about having students working in small groups to do the Exit Project. (probe: Why?) How do students work together? (Probe: Do they have specific roles? How much do you structure the small group's work?) What do students learn working in the small groups that they might not learn working individually?

3. Tell me a little about working to help students to conduct exit projects in a class in which students come from diverse language communities. When (during what tasks) are students most successful and when might they might need more help? What specific things do you do to help? Can you think of a particular child who you worked with and tell me the story of how he/she experienced working on the exit project?

GENERAL REFLECTION QUESTIONS

4. What, in your opinion, is the value of having students discuss ideas in science class? How do you structure your class for discussion?

(Appendix C Cont'd.)

5. Describe a moment from this past school year that taught you something important about engaging students in discussions in classrooms where not everyone speaks the same language (particularly related to science learning).

(Alternate for teachers who do not have English Language Learners: Describe a moment from this school year that taught you something important about engaging students in discussions in science.)

6. What are the challenges of teaching science in classrooms where there is quite a bit of cultural and language diversity? How do you specifically address these challenges? What are the positives?

7. Is there anything else you would like me to know that we haven't already had the chance to discuss?

Appendix E

Table 1. Interpretive Codes

Code	Abbreviation	Description
Directions	DIR	Teacher gives directions about a task.
Manage Progress	MAN-P	Teacher manages the progress of group work.
Manage Behavior	MAN-B	Teacher manages student behavior
Manage Materials	MAN-M	Teacher discusses how to manage materials (e.g., passing out papers, or science equipment).
Explain	EXPLAIN	Teacher explains a scientific concept.
Process	PROCESS	Teacher discusses science process skills (may also be practices).
Nature of Science	NOS	Teacher presents an idea that involves thinking about the nature of science.
Metalinguistic/Metacognitive	META	Teacher talks about one's own thinking or language as she does a task, or asks students to engage in a task.
Language	LANG	Teacher talks about the language (spoken or written) that one uses in science*
Literacy	LIT	Teacher discusses how to write or read science texts*
Student-Initiated Questions	SIQ	Student approaches a teacher to ask a question.
Interruption	I	When working with a small group, teacher gets interrupted by a student from outside of the group
Talk	TALK	Teacher specifically asks students to talk to one another, encourages discussion.
Check-In	CHECK	Teacher checks in on students when working in a small group (different than MAN-P, in that MAN-P is usually a directive. CHECK is usually provided as a question or an opener.)
Content	CONTENT	Teacher discusses or asks a question about science content.
Repeat	REP	Teacher repeats what a student says
Humor	HUMOR	Teacher uses humor related or not related to science.
Revoice	REVOICE	Teacher revoices something she has heard before (e.g., "they were like, 'we have to do this over to get better data.'").
Question About Real Life	Q REAL	Teacher asks a question about how a specific science concept relates to students' lives.
Problem Solving	PROB SOLV	Teacher helps students to solve a problem, either socially, or conceptually.

(Table 1 Cont'd.)

Technology	TECH	Teacher talks about how to use technical equipment (e.g., computers or science equipment).
Identity	IDENTITY	Teachers talk about taking on the identity of a scientist, or refers to students as scientists.
Press	PRESS	Teacher presses students for more information about their conceptual knowledge (See Windchitl & Thompson, 2008).
Information with Questioning Tone	ANS Q	Student gives information using a questioning tone, as if to be unsure of one's answer.

* These codes were later broken into subcodes for one analysis because they were so numerous.

Appendix F

Table 2. Codes for Literacy in Science Practices

Code	**Abbreviation**	**Description**
Notetaking	NOTE	taking notes during a lesson or from reading science texts
Organization	ORG	organizing notes or data gathered during an investigation
Meaning Making	MEANING	reading for meaning from science texts, discussing the meaning of science terms
Precise/Domain Specific Language	LANG	using specific words, phrases, grammatical conventions for writing in science
Gather Information	GATHER	conduct background research from texts (e.g., video, audio, written texts, etc.) on specific science topics relevant to investigations
Intertextuality	INTER	Comparing information from one text to the information gathered in another
Formal Style	FORMAL	writing in a formal tone of voice (e.g., using passive voice and past tense verbs in writing procedures)
Conclusion	CONCL	writing a well-reasoned conclusion to an investigation that makes use of background information
Claims	CLAIM	writing or determine/identify a scientific claim from a text
Evidence	EVID	writing or determining/identifying scientific evidence
Reasoning	REAS	writing or determining/identifying scientific reasoning using evidence
Explain Content	CONT	written or spoken explanations about content ideas gained from texts
Procedure	PROC	writing or following (reading) a scientific procedure
Review/Revise	R/R	engaging in or talking about the revision process, in writing about science or in writing procedures based on exploration.
Technology	TECH	using technology tools to write, organize, or gather information about science.
Conventions	CONV	Teachers discuss grammar conventions with students (e.g., spelling, verb tense agreement, etc.)

Adapted from two areas of the *Common Core State Standards for English Language Arts*: Literacy in History, Science, and Technical Subjects, and Writing in History, Science, and Technical Subjects (National Governors Association Center for Best Practices, 2012) Grades 6-8.

Appendix G

Table 3. Codes for Science Practices

Code	Abbreviation	Description
Ask Questions and Define Problems	QUES	Teacher discusses how to compose (written or spoken) a researchable science question.
Develop and use Models	MODELS	Teacher describes how to develop a model or how to interpret how a model works to represent a particular phenomenon.
Planning Investigations	PLAN	Teacher talks about how to make a scientific plan. (Including calling this a "procedure.")
Carrying out Investigations	CARRY OUT	Teacher talks about specifics of carrying out a procedure (i.e., discusses how to use a Secci disk, or how to make sure data is collected correctly.)
Analyze and Interpret Data	ANALYZE/INTERPRET	Teacher discusses how to analyze and interpret data (i.e., how to interpret information on a graph or other visual.)
Use Mathematics and Computational Thinking	USE MATH	Teacher discusses how to use math to make a measurement, or calculation.
Constructing Explanations	EXPLANATIONS	Teacher discusses how to compose (written or spoken) a scientific explanation (e.g., part of the DSET)
Engage in Argument from Evidence	ARGUE	Teacher discusses how to compose a scientific argument (e.g., part of the DSET).
Obtaining Information	OBTAIN (GATHER) INFO	Teacher discusses gathering background information to support a hypothesis, explanation, or argument, or as a regular practice in understanding variables.
Evaluating Information	EVAL INFO	Teacher discusses evaluating information for its accuracy, precision, or usefulness (e.g., asking students if they think what they read is useful for an argument, or asking students to evaluate the claims of others).
Communicating Information	COMM INFO	Teacher discusses how to communicate (either in writing or orally) idas in science (e.g., putting information in final form for the LTI display boards, or giving an oral presentation).

Adopted from *The Framework for K-12 Science Education* (NRC, 2012).

REFERENCES

REFERENCES

http://www.urbanadvantage.org/site_res_view_template.aspx?id=74997f47-0837-46c1-902e-38af3e87c779

Achieve, Inc. (2013). *Next generation science standards*. Achieve, Inc.

Adger, C. T., Snow, C. E., & Christian, D. (Eds.). (2002). *What teachers need to know about language*. McHenry, IL: Delta Systems, Co.

Adger, C. T. (2003). Discourse in educational settings. In D. Schiffrin, D. Tannen & H. Hamilton (Eds.), *The handbook of discourse analysi*s (pp. 503-517). Malden, MA: Blackwell.

Adger, C. T., Wolfram, W., & Christian, D. (2007). *Dialects in schools and communities* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Ball, A., & Feedman, S. W. (Eds.). (2004). *Bakhtinian perspectives on language, literacy, and learning*. Cambridge: Cambridge University Press.

Bang, M., Medin, D. L., & Atran, S. (2007). Cultural mosaics and mental models of nature. *Publication of the National Academy of Sciences, 104*, 13868-13874.

Bazerman, C. (2004). Intertextualities: Volosinov, Bakhtin, literary theory, and literacy studies. In A. Ball & S. W. Feedman (Eds.), *Bakhtinian perspectives on language, literacy, and learning* (pp. 53-65). Cambridge: Cambridge University Press.

Bazerman, C., & Prior, P. A. (Eds.). (2004). *What writing does and how it does it: An introduction to analyzing texts and textual practices*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Bakhtin, M. M. (Ed.). (1981). *The dialogic imagination: Four essays*. Austin, TX: University of Texas Press.

Bakhtin, M. M. (1986). *Speech genres and other late essays* (V. W. McGee, Trans.). Austin, TX: University of Texas Press.

Bakhtin, M. M. (1986). The problem with speech genres (V. W. McGee, Trans.). In C. Emerson & M. Holquist (Eds.), *Speech genres and other late essays* (pp. 60-102). Austin, TX: University of Texas Press.

Bennett, J., Hogarth, S., Lubben, F., Campbell, B., & Robinson, A. (2010). Talking science: The research evidence on the use of small group discussions in science teaching. *International Journal of Science Education, 32*, 69-95.

Bloome, D., Power Carter, S., Morton Christian, B., Otto, S., Shuart-Faris, N., & Smith, M. (2008). *On discourse analysis in classrooms: Approaches to langauge and literacy research*. New York: Teachers College Press.

Brown, B. A. (2006). "It isn't no slang that can be said about this stuff": Language, identity, and appropriating science discourse. *Journal of Research in Science Teaching, 43*, 96-126.

Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing everyday and science language in the classroom. *Science Education, 92*, 708-732.

Brown, B. A., & Ryoo, K. (2008). Teaching science as a language: A "Content-First" approach to science teaching. *Journal of Research in Science Teaching, 45*, 529-553.

Cazden, C. (2001). *Classroom discourse: The language of teaching and learning* (2nd ed.). Portsmouth, NH: Heinemann.

Cazden, C., John, V. P., & Hymes, D. (Eds.). (1985). *Functions of language in the classroom*. Prospect Heights, IL: Waveland Press.

Cole, M. (1994). A conception of culture for a communication theory of mind. In D. Vocate (Ed.), *Intrapersonal communication: Different voices, different minds*. Hillsdale, NJ: Erlbaum.

Cohen, D., Raudenbush, S. W., & Ball, D. L. (2003). Resources, instruction, and research. *Educational Evaluation and Policy Analysis, 25*, 119-142.

Cothron, J. H., Giese, R. N., & Rezba, R. J. (2006). *Students and research* (4th ed.): Kendall/Hunt Publishing Company.

Crawford, B. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37*, 916-937.

Crawford, B. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching, 44*, 613-642.

DeLisi, J., McNeill, K., & Minner, D. (2011). *Illuminating the relationship between inquiry science instruction and student learning: Results from three case studies*. Paper presented at the Annual Conference of the National Association of Research in Science Teaching, Orlando, FL.

Denham, K., & Lobeck, A. (Eds.). (2010). *Linguistics at school: Language awareness in primary and secondary education*. Cambridge: Cambridge University Press.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, *23*, 5–12.

Emerson, R. M., Fretz, R. I., & Shaw, L. L. (1995). *Writing ethnographic fieldnotes*. Chicago: University of Chicago Press.

Erickson, F. (2004). *Talk and social theory*. Cambridge: Polity.

Erickson, F., & Shultz, J. (1981). When is a context? Some issues and methods in the analysis of social competence. In J. L. Green & C. Wallat (Eds.), *Ethnography and language in educational settings* (pp. 147-160). Norwood, NJ: Ablex.

Florio-Ruane, S. (1987). Sociolinguistics for educational researchers. *American Educational Research Journal, 24*, 185-197.

Gallas, K. (1995). *Talking their way into science: Hearing children's questions and theories, responding with curricula*. New York: Teachers College Press.

Gee, J. P. (2005). *An introduction to discourse analysis: Theory and method* (2nd Ed.). New York: Routledge.

Gee, J. P. (2008a). *Social linguistics and literacies: Ideology in discourses* (3rd ed.). New York: Routledge.

Gee, J. P. (2008b). What is academic language? In A. Rosebery & B. Warren (Eds.), *Teaching science to English language learners* (pp. 57-69). Arlington, VA: National Science Teachers Association.

Gee, J. P., & Green, J. L. (1998). Discourse analysis, learning, and social practice: A methodological study. *Review of Research in Education, 23*, 119-169.

Cothron, J. H., Giese, R. N., & Rezba, R. J. (2000). *Students and research: Practical strategies for science classrooms and competitions*. New York: Kendall/Hunt Publishing.

Gumperz, J. J. (1977). Sociocultural knowledge in conversational inference. *Linguistics and Anthropology* (pp. 191-211). Washington, D.C.: Georgetown University Press.

Gumperz, J. J. (1982). *Discourse strategies*. Cambridge: Cambridge University Press.

Gumperz, J. J. (2001). Interactional sociolinguistics: A personal perspective. In D. Schiffrin, D. Tannen & H. E. Hamilton (Eds.), *The handbook of discourse analysis* (pp. 215-228). Malden, MA: Blackwell.

Hakuta, K., & Santos, M. (2012. month). *Conference overview*. Paper presented at the Understanding Language Conference, Stanford, CA.

Heath, S. B. (1983). *Ways with words: Language, life and work in communities and classrooms*. Cambridge, MA: Cambridge University Press.

Herrenkohl, L. R., & Guerra, M. R. (1998). Participant structures, scientific discourse, and student engagement in fourth grade. *Cognition and Instruction, 16*, 431-473.

Hull, G., & Moje, E. (2012). *What is the development of literacy the development of?* Paper presented at the Understanding Language Conference, Stanford, CA.

Hymes, D. (1980). *Language in education: Ethnolinguistic essays*. Washington, D.C: Center for Applied Linguistics.

Jaworski, A., & Coupland, N. (Eds.). (2006). *The discourse reader* (2nd ed.). New York: Routledge.

Johnstone, B. (2008). *Discourse analysis* (2nd ed.). Malden, MA: Blackwell.

Kolodner, J., Krajcik, J. S., Edelson, B., Reiser, B., & Starr, M. (2009). *Good friends and germs*. Mt. Kisco, NY: It's About Time Publishing.

Krajcik, J. S., Czerniak, C., & Berger, C. (1999). *Teaching children science: A project-based approach*. Boston, MA: McGraw-Hill.

Kvale, S. (1996). *InterViews: An introduction to qualitative research interviewing*. Thousand Oaks, CA: Sage.

Ladewski, B. G., Krajcik, J. S., & Harvey, C. L. (1994). A middle grade science teacher's emerging understanding of project-based instruction. *Elementary School Journal, 95,* 499-515.

Latour, B., & Woolgar, S. (1986). *Laboratory life: The social construction of scientific facts*. Princeton, NJ: Princeton University Press.

Lawrence Hall of Science. (2011). *Full Option science system*. Berkeley, CA. University of California.

Lawrence Hall of Science. (2011). *Science education for public understanding project*. Berkeley, CA. University of California.

Lee, O., Quinn, H., & Valdes, G. (2013). Science and language for English language learners in realtion to Next Generation Science Standards and with implications for Common Core State Standards for English language arts and mathematics. *Educational Researcher, 42*, 223-233.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex Publishing Corporation.

Lemke, J. L. (2000). Across the scales of time: Artifacts, activities, and meanings in ecosocial systems. *Mind culture and activity, 7*, 273-290.

Leander, K., & Prior, P. A. (2004). Speaking and writing: How talk and text interact in situated practices. In C. Bazerman & P. A. Prior (Eds.), *What writing does and how it does it: An introduction to analyzing texts and textual practices* (pp. 201-238). Mahwah, NJ: Lawrence Erlbaum.

Lindfors, J. W. (1999). *Children's inquiry: Using language to make sense of the world*. New York: Teachers College Press.

Lucas, T., Villegas, A. M., & Freedson-Gonzalez, M. (2008). Linguistically responsive teacher education: Preparing classroom teachers to teach English language learners. *Journal of Teacher Education, 59*, 361-373.

Mehan, H. (1979). *Learning lessons: Social organization in the classroom*. Cambridge: Harvard University Press.

Mercer, N. (2008). The seeds of time: Why classroom dialogue needs a temporal analysis. *Journal of the Learning Sciences, 17*, 33-59.

Michaels, S., Shouse, A.W., and Schweingruber, H.A. (2008). *Ready, Set, Science! Putting Research toWork in K-8 Science Classrooms.* Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Mikeska, J., Bills, P., Dibner, K., Wilson, S. M., Short, J., Carlson, R., & Elgendy, S. (2012, month). *Building middle school science teachers' understanding about scientific inquiry using secondary research*. Paper presented at the American Educational Research Association, Indianapolis, IN.

Minner, D., & DeLisi, J. (2010). Inquiring into Science Instruction Observation Protocol (ISIOP): Middle school version. In EDC (Ed.). Newton, MA: Education Development Center.

Minner, D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction: What is it and does it matter? Results from a research synthesis years 1984-2002. *Journal of Research in Science Teaching*, *47*, 474-496.

Moje, E. (2008). Foregrounding the disciplines in secondary literacy teaching and learning: A call for change. *Journal of Adolescent and Adult Literacy, 52*, 96-107.

Moje, E., Collazo, T., Carillo, R., & Marx, R. W. (2001). "Maestro, what is 'quality'?": Language, literacy, and discourse in project-based science. *Journal of Research in Science Teaching*, *38,* 469-498.

Moses, L. (2012). Microethnographic discourse analysis in an inquiry classroom. *Classroom Discourse*, *3*, 147-165.

Nagy, W., & Townsend, D. (2012). Words as tools: Learning academic vocabulary as language acquisition. *Reading Research Quarterly, 47*, 91-108.

Nasir, N. S., Rosebery, A., Warren, B., & Lee, C. D. (2006). Learning as a cultural process: Achieving equity through diversity. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 489-504). New York: Cambridge University.

National Governors Association Center for Best Practices (2012). *Common Core State Standards: English Language Arts*. Washington D.C.: National Governors Association Center for Best Practices, Council of Chief State School Officers.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academies Press.

National Research Council. (2000). *Inquiry and the national science education standards*. Washington, D.C.: National Academies Press.

National Research Council. (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8*. Committee on Science Learning, Kindergarten Through Eighth Grade. Richard A. Duschl, Heidi A. Schweingruber, and Andrew W. Shouse, Editors. Board on Science Education, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press

National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Ochs, E. (1979). Transcription as theory. In E. Ochs & B. B. Schiefflin (Eds.), *Developmental pragmatics* (pp. 43-72). New York: Academic Press.

O'Connor, M. C., & Michaels, S. (1993). Aligning academic task and participation status through revoicing: Analysis of a classroom discourse strategy. *Anthropology and Education Quarterly, 24*, 318-335.

Oliveira, A. W. (2009). Developing elementary teachers' understanding of the discourse structure of inquiry-based science classrooms. *International Journal of Science and Mathematics Education, 8*, 247-269.

Philips, S. U. (1983). *The invisible culture: Communication in classroom and community on the Warm Springs Indian reservation*. New York: Longman.

Rasmussen, I. (2005). *Project work and ICT: Studying learning as participation trajectories.* (Unpublished doctoral dissertation). University of Oslo, Oslo, Norway.

Rose, M. (2004). *The mind at work: Valuing the intelligence of the American worker*. New York: Penguin.

Rosebery, A., Ogonowski, M., DiSchino, M., & Warren, B. (2010). "The coat traps all your body heat": Heterogeneity as fundamental to learning. *Journal of the Learning Sciences, 19,* 322-357.

Rosebery, A., & Warren, B. (2000). *Children's ways with words in science and mathematics: A conversation across disciplines*. Santa Cruz, CA: Center for Research on Education, Diversity and Excellence.

Rosebery, A., & Warren, B. (Eds.). (2008). *Teaching science to English language learners: Building on students' strengths*. Arlington, VA: National Science Teachers Association.

Rosebery, A., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences, 2*, 61-94.

Sacks, H., Schegloff, E., & Jefferson, G. (1974). A simplest systematics for the organization of turn-taking for conversation. *Language, 50*, 696-735.

Schegloff, E. (2007). *Sequence organization in interaction: A primer in conversation analysis* (Vol. 1). Cambridge: Cambridge University Press.

Scott, P., Mortimer, E., & Aguiar, O. G. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. *Science Education, 90*(4), 605-631.

Snow, C. E. (2008). What is the vocabulary of science? In A. Rosebery & B. Warren (Eds.), *Teaching science to English language learners: Building on students' strengths* (pp. 71-84). Arlington, VA: National Science Teachers Association.

Tannen, D. (2007). *Talking voices: Repetition, dialogue, and imagery in conversational discourse* (2nd ed.). Cambridge: Cambridge University Press.

Vareles, M., Pappas, C., & Rife, initials?. (2006). Exploring the role of intertextuality in concept construction: Urban second graders make sense of evaporation, boiling, and condensation. *Journal of Research in Science Teaching, 43,* 637-666.

Vygotsky, L. (1986). *Thought and language* (A. Kozulin, Trans.). Cambridge, MA: The MIT Press.

Warren, B., & Ogonowski, M. (1998). *From knowledge to knowing: An inquiry into teacher learning in science*. Newton, MA: Center for the Development of Teaching.

Warren, B., Ballenger, C., Ogonowski, M., & Rosebery, A. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching, 38* 529-552.

Warren, B., Ogonowski, M., & Pothier, S. (2005). "Everyday and scientific": Rethinking dichotomies in modes of thinking in science learning. In R. Nemirovsky, A. S. Rosebery, J. Solomon & B. Warren (Eds.), *Everyday matters in science and mathematics: Studies of complex classroom events* (pp. 119-148). Mahwah, NJ: Lawrence Erlbaum Associates.

Warren, B., & Rosebery, A. (1993). Equity in the future tense: Redefining relationships among teachers, students, and science in linguistic minority classrooms. Madison, WI and Santa Cruz, CA: National Center for Research in Mathematical Sciences Education and the National Center for Research on Cultural Diversity and Second Language Learning.

Wells, G. (1994, month). *Discourse as a tool in the activity of learning and teaching*. Paper presented at the National Educational Research Association, New Orleans, LA.

Wilson, S. M., Short, J., Mikeska, J., Elgendy, S., Bills, P., & Dibner, K. (2012, month). *Developing middle school teachers' understandings about scientific inquiry and investigations: A case of formal-informal partnerships*. Paper presented at the American Educational Research Association, Vancouver, BC, Canada.

Windschitl, M., Thompson, J., & Braaten, M. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96*, 878-903.