

ABSTRACT

Title of Document: WHAT SECONDARY SCIENCE TEACHERS
PAY ATTENTION TO IN THE CLASSROOM:
SITUATING TEACHING IN
INSTITUTIONAL AND SOCIAL SYSTEMS.

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2008

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Instruction

This study concerns the issue of secondary science teachers' attention. In particular, I consider if, how, and when science teachers attend to the substance of student thinking, which is called for by science education reform (NRC, 2007). Using a case study approach, and drawing on ethnographic data sources, I explore what novice and experienced secondary science teachers regularly attend to while teaching, what shapes teachers' attention, and how teachers' attention is consequential for students' science learning. I find that both novice and experienced teachers *can* attend to the substance of student thinking, although the institutional and social systems of school draw teachers' attention to other foci--particularly to correctness of conceptual knowledge and the vocabulary that signals correctness and "misconceptions." Furthermore, I argue that when teachers regularly attend to the substance of student thinking, they can contribute to a classroom culture that supports student inquiry. I

discuss implications of this work for understanding teaching and for teacher education and professional development, and I suggest areas for future research that are motivated by these findings.

WHAT SECONDARY SCIENCE TEACHERS PAY ATTENTION TO IN THE
CLASSROOM: SITUATING TEACHING IN INSTITUTIONAL AND SOCIAL
SYSTEMS.

By

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2008

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Dedication

For Gemma Flamberg and Noah Levin

Acknowledgements¹

Acknowledgment of all the people who have helped and supported me in many ways throughout this process will never be complete. Not only will I ultimately fail to acknowledge all of my teachers, students, colleagues, friends, and family members who have contributed to my understanding of teaching and learning, but I will also fail to acknowledge the many ways in which each of the individuals I do acknowledge have helped me in my inquiry.

First, I'd like to acknowledge my committee, who has helped me to develop an understanding of the norms and practices of this community. All have provided immeasurable support and feedback as I have developed and refined my work. Fatimah Jackson is my teacher and my friend, whose willingness to engagement in far reaching conversations about biological anthropology, evolution, culture, and education. Andrew Elby and Daniel Chazan have been critical resources for refining my ideas, checking my interpretations, and developing coherent arguments. In particular, Dan has been extremely influential and supportive in helping me find ways to describe how I understand what teachers attend to in classroom practice. Andy is a master of the tight argument, and he has opened the window for me to see how to make an argument compelling in qualitative research.

I am grateful to David Hammer for multiple conversations, classes, seminars, and work sessions over the course of eight years. David is particularly impressive for his stamina; he has put up with me, consistently, and has provided regular and significant guidance. I've learned much of what I understand about science and science education

¹ The research reported in this study was partially supported by NSF ESI 0455711

with David's guidance. Like Dan and Andy, David has been a great help to me as I developed my ideas and interpretations and learned to tell my stories. I would like to acknowledge David in particular for helping me to develop ideas about amplification and about what constitutes evidence of attention to student thinking.

Janet Coffey has been the best possible advisor I could have had. She deserves a majority of the credit for helping me to articulate myself and to sustain my motivation and my work over the past five years. Janet is the professor who always has time for students. She is accessible and encouraging to me and to all of her students. Janet has the unusual ability to be caring and compassionate while also provoking deep thought, reflection, and analysis. She has influenced my teaching, learning, and research in multiple ways, and I can only hope to repay her by doing for my current and future students what she has done for me.

I would like to thank other the other faculty who have been supportive of me throughout my graduate career: Lindley Darden, Pat Alexander, Steven Koziol, Steve Kanim, Joe Redish, Rachel Scherr, Roger Azevedo, Bill Holliday, Morva McDonald, Victoria-Maria McDonald, Kathleen Travers, Jean Snell, Chauncy Monte-Sano, and Ann Ryu Edwards. I would also like to thank the following colleagues and fellow graduate students: Stacy Pritchett, Paul Hutchison, Matty Lau, Carole Rinke, Rosemary Stallings-Russ, Jordan Schugar, Kitty Tang, Anita Sanyal, Sandy Honda, Elaine Henry, Fielding Winters, David May, Seth Rosenberg, Miriam Sherin, Elizabeth van Es. Additionally, I'd like to thank the following teachers and former student teachers who have served as my colleagues, my students, and my research subjects in this study: Nicole Hopkins, Jenny Tanner, Leslie Van, Maranda Bybee, Elaine Goldberg, Phil Johnson, Desiree

Balla, d'Arcy Sloe, Jennifer Kempf, Charlie Demma, Anne Merrell, Izzy Kovach, Steve Shifflet, Steve Karig, Laura Pomerance, Will Keay, Sarah Henson, Kim Redinger, Erica Stein, Jennifer Balachowski, Carrie Black, and Amy Golladay.

I'd like to thank my friends and my family for their pursuit over the years: my parents, Ruth and Eph Levin, my brothers, Josh and Michael, and my sister Rebecca. I'd like to acknowledge my dad in particular, for reading the entire draft in detail and providing substantive comments and questions. Finally, I'd like to thank Gemma and Noah, without whom this would have no meaning.

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Chapter 1: Introduction

[T]he handles to effective instruction are to be found in persistent attention to the argument and in less attention to right answers (Strike & Posner, 1992).

This study concerns science teachers' attention, and particularly their attention to the substance of students' ideas and the reasoning behind those ideas. In this chapter, I introduce the rationale for focusing on teachers' attention, situating my work in current literature on everyday classroom assessment. Subsequently, I introduce the research questions that guide my study, and provide an overview of the chapters that follow.

Why it is Important to Understand Teachers' Attention

Teachers' Attention is Fundamental to Assessment

This work is situated in research that conceptualizes assessment as an everyday classroom activity (Atkin & Coffey, 2003; Cowie & Bell, 1999; NRC, 1996, 2001). A growing body of work points towards the strong influence that assessment, as it refers to perceptive, ongoing diagnosis of student thinking, has on a teacher's instructional moves and student learning (Black & Wiliam, 1998; Cowie & Bell, 1999; Hammer, 1997).

Assessment that occurs moment-to-moment in classroom activities concerns, fundamentally, teachers' attention to ideas and reasoning (Ball, 1993; Sadler, 1998). In order to better understand assessment, we need to better understand teachers' attention.

Teachers' attention to student thinking concerns attention not only to whether students' thinking is correct or incorrect, but to the substance of students' thinking as well. In learning science, students' abilities to repeat correct understanding may not be as productive as their abilities to reason scientifically, even if their reasoning leads them to the wrong answer. For example, Hammer (2000a), described differences in the ways

elementary school students explained a demonstration in which black pepper was sprinkled over a pan of water and a toothpick dipped in soap was touched to the surface of the water. In this demonstration, the pepper recedes quickly from the toothpick. In their written explanations, some students thought that the soap was pushing the pepper away, as it expanded into the space occupied by the pepper. Others, said that it had something to do with “surface tension;” these students had seen another demonstration with soap and surface tension, but they had little to say about how surface tension was involved. Hammer contended that although the latter students were more “correct,” the former students were thinking more scientifically, because they constructed a mechanistic explanation. The implication is that teachers must attend to student thinking beyond correctness if they are to support students’ science learning.

Of course, it is important that students develop “correct” conceptual understandings, i.e., those that are consistent with the canon of accepted scientific thought. Even assessing whether students’ conceptual understanding is correct, however, requires close attention to the substance of student thinking beyond the correctness of the terminology that they use. Consider the following exchange between a teacher and a student, which is characteristic of the kinds of conversations that occur in many science classrooms:

1. Mr. Stern: Now, let’s talk about genotype and phenotype...uh, Alicia, what does genotype mean?
2. Alicia: Uh, the combination of alleles.
3. Mr. Stern: The combination of alleles, that’s perfect. So what are our two possible genotypes from this cross starting back here?

In this brief exchange, Mr. Stern was apparently attending to Alicia’s repetition of the definition of the term “genotype,” which he assessed as “perfect.” But what did

Alicia understand about the meaning of this phrase? Did she understand for example, that the genotype is the combination of two copies of a particular gene, one from each parent? One may presume so, but the example suggests that Mr. Stern was listening only for the use of the term and the correct definition. He could not assess what Alicia really understood about how alleles combine to form a genotype, because he did not have enough information to do so. That he did not pursue what Alicia meant suggests that this was not where his attention was focused. In this exchange, he did not ask Alicia, or other students, to explain what she meant. My premise here is simply that assessment requires attention: Teachers can only assess student understanding and reasoning if they are paying attention to these things. This link between teachers' attention and assessment is one of the main reasons we should care to understand teachers' attention in the classroom.

Teachers' Attention is Consequential for Students' Attention

A second reason we should care to understand teachers' attention is its affect on student attention: If a teacher is paying attention to the substance of student thinking, students are more likely to pay attention to that substance. Warren and Roseberry (1995) described a middle school science classroom in which the teacher regularly led the class in a routine of sharing and discussing individual students' observations of plant and animal life in aquaria. The teachers' attention to the students' ideas in these conversations drew students' attention to each others' ideas and supported students' nascent abilities to engage in argumentation. For example, the authors describe a particular conversation that occurred when one student had not collected the observations she was supposed to in order to address a particular question about snails. Another

student spoke up to say that he had some data to address the question, in the process announcing to the class that he had 30 snails in an aquarium he was keeping at home. The teacher asked the student how many generations of snails he had, and the student said he had three. Another student asked him how he knew that he had more than one generation. The student (Scott) responded:

Scott: ... (W)hen the snails made eggs, the eggs hatched. And when I looked the snails were still there, because I know their colors. And the same baby made another baby and then the little babies laid eggs. (Warren & Roseberry, 1995; p. 6)

The teacher probed Scott's statement, asking him how he knew that the "grown" babies had their own babies. (That is, how did Scott "know" that he had three generations?) The teacher initiated the line of questioning, but other students in the class quickly took over, challenging Scott's claim that he had three generations of snails. Ultimately, the teacher simply moderated the conversation, as students repeatedly asked Scott to explain his claim and held him accountable for his argument. Arguing with Scott's claim necessitated that students attended to Scott's ideas, and their ability to do so was supported and modeled by their teachers' attention to Scott's ideas. I take it as a second premise that students' science learning includes learning to attend to — and to assess — ideas and reasoning. Thus we care about teacher attention not only for the information it provides teachers but also for how it models a key aspect of scientific reasoning and argumentation for students.

Research Questions

Despite the importance of teachers' attention to student learning, little research has looked specifically at what science teachers pay attention to while teaching. Do

teachers pay attention to students' ideas and reasoning? What about student ideas and reasoning are they most attuned to? Certainly the science classroom is a complex place, with multiple pulls on teachers' attention: Are students accumulating facts and vocabulary that they must identify correctly on the next high-stakes test? Are students engaged and participating in the class? Are they behaving?

In the interest of better understanding what teachers attend to, and the consequences of teachers' attention, I raise the following questions in this dissertation:

- To what do teachers attend in the classroom, while teaching?
- What shapes teachers' attention?
- How is teachers' attention consequential for what occurs in the science classroom?

Organization of the Dissertation

My dissertation is organized to address these questions. In the next chapter, I review how teachers' attention has been discussed by others in the literature and explain how I use the construct throughout this study. I discuss my conceptualization of teachers' attention as situated within institutional and social systems. I present the rationale for conceptualizing teacher attention not as a unitary property of individuals, but as multiple possibilities that are shaped and constrained by systems. I explain how I use this lens to focus my inquiry into teachers' attention, how it is shaped, and how it is consequential for students' science learning. In addition to the overview of relevant literature in this chapter, in each of the data chapters (4,5, and 6), I review the literature most pertinent for the foci of those chapters, generally organized around understanding what teachers attend to, the factors that shape attention, and the consequences of teachers' attention.

In Chapter 3, I discuss the research context and methods of my inquiry. I conducted this research within the contexts of two larger studies: (1) an evaluation of the science pedagogy course sequence in a graduate certification program, the “Masters Certification” (or MCERT) program, and (2) a research and professional development project that focused (initially) on how teachers make modifications to curriculum.

Chapter 4 is a case study of novice science teachers in the 2006-7 MCERT program. This chapter is structured as an argument against “stage-based” models of teacher development, which suggest that novice teachers concerns with classroom routines, and restructuring their “identities as teachers,” render them unable to attend to the substance of student thinking (e.g., Kagan, 1992). This chapter is important in establishing a claim that is fundamental to the dissertation as a whole: Science teachers, even novice science teachers, can attend to the substance of student thinking, and their failure to do so cannot be solely attributed to personal limitations, developmental or otherwise.

Chapter 5 is a case study of teachers’ attention, using a single class period as a central example to ground analysis and discussion. Although the case study centers around one teacher’s classroom, it draws from examples of teaching and conversations about teaching among teachers throughout the school and the district who participated in the research and professional development project. As such, it is intended as a representative example of teachers’ nascent abilities to attend to student thinking, the things that draw teachers’ attention in practice, and the factors that shape teachers’ attention.

Chapter 6 takes a close look into another example of teaching—from the classroom of a teacher who regularly attended to the substance of students’ thinking as part of her teaching practice. This case provides insights to how teachers’ attention to student thinking can be consequential for student science learning. In particular, I focus on the ways in which teachers’ attention to student thinking can support a classroom culture that facilitates inquiry.

Finally, In Chapter 7 I discuss the findings I draw from this study. My work suggests that teachers can attend to the substance of student thinking, but the institutional system, as it is organized, contributes to drawing their attention toward other concerns. Furthermore, I find that when teachers regularly attend to the substance of student thinking, they draw students’ attention to that substance and foster student inquiry.

In this final chapter, I also discuss the implications of my findings for teacher education and professional development, and I introduce areas of future research that are motivated by this work. In general, my research suggests that teacher education and professional development that support teachers’ attention to student thinking can help prepare teachers to teach science in ways that are productive for students’ science learning. Further research will focus on understanding the mechanisms by which these efforts support teachers’ attention to student thinking and understanding how teachers’ abilities to attend to student thinking grow and develop. Furthermore, my research suggests that there is considerable variation in when and how individual teachers attend to student thinking, and considerable variation among teachers, as some have an easier time than others in consistently attending to the substance of student thinking. Additional research is needed to elucidate the factors that contribute to this variation.

My goal with this work is to draw attention to the importance of teachers' attention in the science classroom. Teachers' attention to students' ideas and reasoning is fundamental to teachers' assessment and instruction and thus to their support of students' science learning. For this reason, it constitutes an important area of study. There are many things that teachers can attend to in the classroom; it is important to understand what those things are and the ways in which teachers' attention is constrained and afforded by the institutional system, so that we can help support teachers in attending to those things that matter most—those things that are most important for students' science learning.

Chapter 2: Teachers' Attention: A Systems Perspective

In this chapter, I describe a conceptualization of teachers' attention as situated within institutional and social systems. I review how teachers' attention has been defined and discussed by others in the literature and explain how I understand the construct and use it in this study. I also present the rationale for conceptualizing teacher attention not as a unitary property of individuals, but as multiple possibilities that are shaped and constrained by systems. Finally, I explain how I use this lens to focus my inquiry into teachers' attention, how it is shaped, and how it is consequential for students' science learning.

Teachers' Attention and Professional Vision

The predominant body of literature explicitly discussing teachers' attention is discussed in the mathematics education research under the umbrella term "noticing" (Jacobs, Clement, Philipp, Schappelle, & Burke, 2007; Sherin & Es, 2008; Sherin & Han, 2004; van Es & Sherin, 2006). Van Es and Sherin (2006) propose that the skill of noticing consists of (a) identifying what is important in a teaching situation and (b) drawing on one's knowledge of teaching and learning to reason about the situation. In this sense, noticing depends both on teachers' abilities to focus their attention on "what is significant in a complex situation" (p. 125) and draw on their "pedagogical content knowledge" (Shulman, 1987) of students, subject matter, and the school context to reason and interpret what they notice. Teachers' pedagogical content knowledge plays an important role in how they draw interpretations (van Es & Sherin, 2006). Anyone can reason and interpret what they notice, but teachers' pedagogical content knowledge, and

knowledge of the pedagogical *context* (see Barnett & Hodson, 2001)² support the kinds of interpretations they make.

Despite other researchers' efforts to decompose aspects of noticing into particular skills (Jacobs et al., 2007), I view noticing and interpretation as co-constitutive. That is, it is impossible for teachers to interpret or reason about something upon which they do not focus their attention, and teachers are constrained in focusing their attention by relevant background knowledge (both tacit and explicit) that help them to interpret classroom events as significant.

Most of the research on teachers' attention has focused on what teachers attend to when observing records of classroom practice, such as videotapes, transcripts, and samples of student work (Hammer, 2000b; Jacobs et al., 2007; Sandoval, Deneroff, & Franke, 2002; Sherin & Han, 2004). In this dissertation, I am primarily concerned with understanding what science teachers attend to *while teaching*. In considering what an individual teacher attends to while teaching, I view an individual teacher's attention in terms of the interplay between what they focus their attention on and their ongoing interpretations, in line with the work of Sherin and van Es (van Es & Sherin, 2006). In this study, *I take teachers' attention in the classroom to be what teachers focus on while*

² It is easier to distinguish aspects of content knowledge that might shape teachers' attention than it is to consider how teaching contexts, and teachers' explicit and tacit understanding of the context, may help shape the foci of teachers' attention. To address this gap Barnett and Hobson (2001), described teachers' pedagogical content knowledge as situated in the "minutiae of everyday classroom life" and the "educational contexts and microworlds" of teaching. To accommodate context, they coined the term "pedagogical context knowledge."

The sources of this knowledge are both internal and external: internal sources include reflection on personal experiences of teaching, including feelings about the responses of students, parents, and other teachers to one's actions; external sources include subject matter knowledge, governmental regulation, school policies, and the like. Interaction with other teachers at both formal and informal levels is both a source of pedagogical context knowledge and a stimulus for its further development. (p. 436).

teaching, which I assume to be mediated by their interpretations, and which, in turn, are shaped by their knowledge of the pedagogical content and context.

This perspective on teachers' attention differs in important ways from that of Sherin and colleagues. In most of the above-cited research, noticing is treated as a skill to be learned, and the goal is to help teachers develop these skills in alignment with calls from educational reform (Sherin & Es, 2008). In focusing on understanding what teachers attend to while teaching, *I view teachers' attention as a fundamental feature of teaching practice. Situated in institutional and social systems, in which teachers participate and interact socially, what teachers attend to is similar among teachers in important ways.* I am trying to move beyond thinking of teachers' attention as an individual skill to be developed, and focus instead on what teachers' attend to as shared "rationality" particular to the practice, which "cannot be reduced to individual wisdom, gift, sensibility or skill, since [it is] common to people who perform the same job" (Herbst & Chazan, 2003, p.2)

This view of teachers' attention, as a property of a social group that cannot be explained solely by individual cognition, shares much in common with Goodwin's (1994) notion of professional vision, "which consists of socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (Goodwin, 1994, p.606). Goodwin used the Rodney King trial to demonstrate how perception of a meaningful event is not simply an individual psychological process, but a socially situated activity. In the 1992 trial of four white policemen charged with beating Rodney King, an African-American motorist who had been stopped for speeding, an amateur videotape of the beating became the most important piece of evidence. The

trial was highly publicized, and to the general public (myself included), the videotape seemed to show an objective record of a savage and unnecessary beating. The prosecution used the tapes as self-explicating, objective evidence, and the policemen appeared guilty of a horrific, racially motivated crime. The defense, however, did not treat the videotape in this manner, but argued that it could be understood only by embedding the scene depicted within the “work life of a profession” (Goodwin, 1994, p. 616). Ultimately, the main issue in the trial became whether the policemen’s actions could be considered appropriate based on how they perceived Mr. King’s actions within the norms and structures of responsible police work. Juror testimony after the trial suggests that the defense strategy of trying to facilitate the jurors’ abilities to “see the scene” as police officers do established reasonable doubt, which led to acquittal of the officers.

My goal in exploring teachers’ attention as a social property of teaching practice adds to current work that replaces the emphasis on individual knowledge or beliefs with a focus on shared practices that make sense to teachers as they are situated in institutional and social systems (e.g., Herbst and Chazan, 2003). Thus, in Chapter 5, I pursue my first question by looking for common foci of attention among several teachers in a school and throughout a district. I examine one teacher’s classroom in particular, as a lens into how these common foci play out in classroom activity, and guide what teachers and students do. I also draw on interviews with teachers, and comments by teachers in conversations, that support interpretation of the particular common foci of attention. In this same chapter, I directly confront an alternative argument, that what one teacher attends to can be entirely explained by her own pedagogical content knowledge, and provide evidence

to show that this argument proves inadequate.

My exploration into the shared foci of teachers' attention connects to my second research question: what shapes teachers' attention? Unquestionably, there may be variation in how individuals' attention is shaped moment-to-moment, but the set of possibilities that one may attend to is "established by the system that is organizing their perception" (Goodwin, 1994 p.609). My task, then, becomes exploring those systems that organize teachers' attention, to understand why particular foci of attention are most salient to teachers and their teaching. In the sections below, I will discuss how I understand and use ideas of complex systems to explore those factors that shape what teachers attend to, and the mechanisms by which teachers' attention is shaped and supported.

Before I move on to discuss more theoretical tools, however, it is important to mention that while I position my work as differing from that of Sherin and colleagues, these researchers also ground their work in professional vision (e.g., van Es and Sherin, 2006). More recently, however, Sherin and van Es (2008) clarified that they were interested in *professional vision for reform teaching*, which they emphasize as something teachers must learn to do that is not always in line with teachers' current professional vision. This is different from the way I draw on Goodwin's (1994) work. Following Goodwin, I seek to understand teachers' attention as an aspect of their professional vision as it is situated in the everyday work of teaching.

In thinking about teachers' attention as an aspect of socially shared practice, I work to understand the range of possibilities in what teachers can attend to within the constraints and affordances of their systems. In Chapters 4, 5, and 6, I demonstrate that

novice and experienced secondary science teachers *can* attend to the substance of students' thinking, as promoted by science education reform (NRC, 2007), despite this focus not being amplified by the system. In these chapters, there is also evidence of substantial variation, however, both in individual teachers' tendencies to attend to the substance of student thinking, and even in terms of a particular teacher's attention in particular contexts. In this study, I present some of this variation and speculate on how we might explore it, to find out how social practices of teachers' attention "allow the emergence of diversity within similarity" which can be useful for understanding teaching and promoting communication between teachers and among teachers and researchers (Herbst and Chazan, 2003, p.2). Furthermore, understanding this diversity, the "what is possible," within teachers' work lives can help us to identify and amplify for teachers those aspects of their teaching practice that are consistent with science educational reform, in particular, their nascent abilities to attend to the substance of student thinking.

I will return to the issue of variation later in this chapter. For now I turn to a description of the framework that I use for understanding how teachers' attention is shaped, and how it is consequential for student learning.

A Framework for Understanding Teachers' Attention

To understand what teachers attend to in the classroom and how this is shaped, we must look both within and beyond the classroom. I pull from theoretical work on complex systems, activity theory, and frame theory to help me understand the complexity and dynamics of teachers' attention. This framework provides me a way of connecting the macro- and micro- levels of analysis that are relevant to understand the work of teachers within institutional and social systems of schools. This framework has developed

over the course of my research, and it continues to develop. In the remainder of this chapter, I introduce the analytical toolkit that helps me to understand teachers' attention as situated in social and institutional systems, and describe how this has been useful in making sense of my research.

Teachers' Attention in Complex Educational Systems: Complex Systems Theory

In common usage, talk about “school systems” refers to the structural and hierarchical organizational systems that manage learning and teaching, from federal to local structures. Ultimately, however, it is the dynamics of interaction among the people, communities, institutions and the material world that define the system (Goodwin, 1994; Kaput et al., 1999). Approaching educational research from a systems perspective raises questions about the degree to which institutions, social practices, and individual behavior are coupled (Coburn, 2004; Kaput et al., 1999; Weick, 1976), patterns that emerge from the interaction among elements in the system (Conrad, 2006; Kaput et al., 1999), and the consequences of these emergent patterns for teaching and learning (Conrad, 2006). The emerging perspective of complex systems theory, which draws on ideas and methods from a variety of disciplines including mathematics, cognitive science, physical and biological sciences, and social sciences (Conrad, 2006; Detrain & Deneubourg, 2006; Jacobson & Wilensky, 2006), contributes to my framework for understanding how teachers' attention is shaped in context in important ways.

The traditional paradigm of research in education assumes a simple and direct connection between aspects of participants' cognition and their behavior (Conrad, 2006). A teacher's attention, for example, may be seen primarily as an aspect of a teacher's pedagogical content knowledge (Sherin & Han, 2004). While a teachers' pedagogical

content knowledge no doubt contributes to her attention, it cannot capture the complexity of teaching and teachers' attention *in situ*. Complex systems theory can be used to describe that complexity and explore the relations among teachers, students, content, complex bodies of rules of interaction, and policy decisions made at district and school levels (Conrad, 2006). It is useful for understanding teachers' attention from the perspective of their situativity within systems composed of interacting elements.

Complex systems are characterized by the “interactions of numerous individual elements or agents that “self-organize” to show “emergent and complex properties not exhibited by the individual elements/agents” (Conrad, 2006). Self-organizing systems impact the operation of populations and organizations and the everyday lives of individuals (Jacobson & Wilensky, 2006). Consideration of educational systems as self-organizing systems raises important questions about teachers' attention. First, how do the systems of public school education shape teachers' attention? In chapter 5, I use the example from Ms. Hawkins' class and related observational and interview data at her school, to describe how a system that includes accountabilities to high-stakes tests, local professional communities, and students points teachers' attention to conceptual correctness and target vocabulary.

Second, in what way are these systems “self-organized?” How do teachers in turn, as participants in systems, contribute to the organization of those systems? How does teachers' attention in moment-to-moment interactions with each other, with materials, and with students in the classroom contribute to the overall organization of the broader institutional system over time? I assume that the broader system is organized by the history of these interactions. For example, in participating in the system described in

Chapter 5, teachers contribute at multiple levels, both inside and outside the classroom (for example, in local professional communities), by helping to reify particular patterns of activity and discourse that focus attention on vocabulary, conceptual correctness, and “misconceptions.” The particulars of how teachers’ attention contributes to this reification, both in the classroom and in the activities of local professional communities, is an important area for future research.

While principles of self-organization have been applied to biological and social systems, it is understood that such systems lack the rigidity and predictability of physical and chemical systems (Detrain & Deneubourg, 2006). Individual actors, after all, have agency, and may act (or may attend) in diverse ways (Holland, Lachicotte, Skinner, & Cain, 1998). Therefore, while self-organizing complex systems may constrain individual behavior, these systems may afford certain “degrees of freedom” (Kaput et al., 1999) for individual attention and action. What are the degrees of freedom afforded what teachers attend to in the classroom? What factors contribute to individual teachers’ agency to attend to various aspects of classroom activity? Why might some teachers have an easier time attending to the substance of student thinking in the classroom than others? These questions have arisen out of my research, and I discuss them again in my conclusion.

Feedback and amplification

Two concepts from complex systems theory are particularly useful in my understanding of the ways in which institutional systems shape, and are shaped by, what teachers attend to: feedback and amplification. The organization of a system is largely regulated by feedback, in which processes in the system are affected by products of the system. This regulation can be both positive, in which outcomes reinforce and sustain the

processes that produce them, and negative, in which outcomes inhibit the processes that produce them (Conrad, 2006; Jacobson & Wilensky, 2006; Sterman, 1994).

Examples of feedback regulation abound in the physical, chemical, and biological sciences. For instance, in the human endocrine system, the secretion of hormones is controlled by feedback. Most endocrine glands are under the control of negative feedback mechanisms. The parathyroid glands, for example secrete parathyroid hormone, which regulates the concentration of calcium in the blood. If calcium decreases, the parathyroid glands sense the decrease and secrete more parathyroid hormone. The parathyroid hormone stimulates calcium release from the bones and increases the calcium uptake into the bloodstream from the kidneys. Conversely, if blood calcium is too high, the high level is sensed by the parathyroid glands and parathyroid hormone production is reduced. In both cases, the feedback is negative, because the outcome is opposite to the stimulus, and has the effect of returning the system to homeostasis. Positive feedback mechanisms have the opposite effect, promoting rather than negating the original stimulus. For example, during childbirth, the hormone oxytocin stimulates and enhances labor contractions. As the baby moves toward the vagina, pressure receptors within the cervix send messages to the brain to produce more oxytocin, which travels to the uterus to produce more contractions. The contractions thus intensify and increase until the baby is delivered (Jones & Lopez, 2006).

How might feedback regulation be relevant to understanding institutional and social systems, particularly the systems surrounding public school teaching? Imagine a teacher, herself educated in public school systems that emphasize learning in terms of performance on tests. As she reenters the system as a teacher, if the emphasis remains on

learning in these terms, her attention to students' test performance is sustained. If her students perform poorly on tests, she receives a signal that functions to further direct her attention to students' performance on the test. She must consider how she can improve her students' performance. This will lead to further efforts on her part to improve her students' test scores (Caine & Caine, 1997).

In this way, a self-amplifying feedback loop is formed (Conrad, 2006).

Amplification refers to the ways in which small effects in a complex system may continuously feed back to produce a correspondingly larger effect (Jacobson & Wilensky, 2006). Thus, the day-to-day attention of all actors in the system may contribute to the amplification of attention to particular foci, in this example to the sustained focus on improving test scores. In my analysis, I explore the dynamics of feedback and amplification within the social and institutional systems of schools, particularly in terms of how they become significant for what teachers' attend to in the secondary science classroom.

The Consequences of Teachers' Attention: Activity Theory

While I am concerned with understanding what teachers attend to in the classroom and how attention is shaped, I am also interested in the consequences of teachers' attention for what occurs in science classrooms. To do this, I need a way to understand how the system of classroom activity is organized, the consequences of that organization, and the role the teacher's attention helps to play in that organization. Cultural-historical activity theory provides a relevant unit of analysis, the "activity system," and useful theoretical tools for understanding the dynamics of classroom

teaching and learning (Chaiklin & Lave, 1996; Engestrom, Miettinen, & Punamaki, 1999).

Activity theory arose out of the work of Russian psychologists, particularly Vygotsky (1978). It has been further developed in the last several decades to describe how groups of people work together (e.g., Chaiklin & Lave, 1996; Engestrom, 1987; Engestrom et al., 1999). At the heart of activity theory is the notion of the activity system as a unit of analysis. In an activity system, a single or collective *subject* pursues an *object*. Pursuit of an object is mediated by *artifacts* (tangible tools and patterns of language and discourse), the communities of practice connected to the system and the norms and rules for interaction, with which the subject(s) interact in pursuing the object (Engestrom, 1987; Gallego, Cole, & LCHC, 2001).

While the term object has often been conflated with an objective, it is not simply a goal that drives an individual person's attention, but a property of the system, which constrains and directs individual and collective *motive*. The collective *motive* sets the specifics of what is important to address in that activity: "By maximizing one goal, one set of behaviors, and the like over others, the motive also determines what will be given up if need be in order to accomplish something else" (Wertsch, 1985, p.212). Thus, the collective motive provides an activity with a certain focus that determines suitable behavior.

In recent years, activity theory has become increasingly popular in educational research (Roth & Lee, 2007; Valli & Chambliss, 2007) and the activity system has come to be seen as an appropriate unit of analysis for understanding the "culture" of a classroom (Gallego et al., 2001). From this perspective, researchers have viewed the

classroom as an activity system, working to understand the objects that organize classroom teaching and learning and how the participants, tools, and communities of practice function to mediate the pursuit of these objects. (Gallego et al., 2001; Grossman, Smagorinsky, & Valencia, 1999; Valli & Chambliss, 2007). In any particular classroom, teacher and students work together toward a collective object, mediated by tools, by the systemic context in which the classroom sits, and by the broader communities involved in similar pursuits.

For example, imagine a teacher trying to teach students a procedure, like “The Well-Designed Investigation,” a version of reified “scientific method” popular in the school district in which my work is situated. With the object set on learning the steps of the method, teacher and students have a motive for students to learn the steps and reliably reproduce their understanding of the steps on summative assessments. Tools, including concrete tools such as curricular documents and worksheets, as well as practices of discourse, contribute to the pursuit of the object. Furthermore, teachers and students participation in other systems and communities of practice, involving other teachers, administrators, parents and other students, helps to focus individual action around the object of learning the steps. Any individuals involved in this system may have different personal goals that are continuous with or discontinuous with the overall object (Engestrom, 2000). The teacher, for example, may have an ultimate goal of having her students sensibly design controlled experiments. While this goal doesn’t necessarily conflict with the overall object, it may not appear salient in the way the activity is organized by the elements within and outside of the classroom³.

³ See (Tang, Coffey, Levin, Honda, & Elby, 2007) for an extended classroom case upon which this example is based.

Similarly, while it is not my primary focus in the case study presented in Chapter 5, the case suggests that, in attending primarily to vocabulary, conceptual correctness, and “misconceptions,” teachers draw students’ attention to these foci, and help to organize the classroom activity system around them, often to the neglect of students’ reasoning and practices of classroom inquiry. How might classrooms be different if teachers’ attended primarily to the substance of student thinking, in terms of the meaning students are trying to convey? In Chapter 6, I focus the lens on the activity system at the level of the classroom, to understand how teachers’ attention to the substance of student thinking can amplify attention to ideas and help support a classroom culture (Gallego et al., 2001) that can foster inquiry. In exploring the role of the teachers’ attention in this system, I look to see how the teachers’ attention helps to mediate the object of the classroom and establishes the norms and expectations for classroom activity. To do this, I focus on the classroom of one teacher, Ms. Brown, who consistently attended to the substance of student thinking as part of her regular teaching practice.

Exploring Teachers’ Attention in Systems on Multiple Levels

I use the plural *systems* to refer to the multiple systems, at various levels, and with diverse components, in which teachers participate. Systems interact in complex ways, and a systems lens can be said to illuminate a “fractal topology” of “subsystems within systems,” wherein similar organization can be seen at the different levels (Lemke, 1997). This perspective blurs the “dichotomy between micro-level processes and macro-level structures” (Engestrom, 2000) and can elucidate the relations among systems operating at different levels (Engestrom, 1987; Rogoff, 1995). I understand the system of the classroom, which organizes classroom activity, as a subsystem of the institutional system

of schools, which continuously informs the organization of the classroom activity system. Furthermore, local professional communities, with their own activities and tools, constitute another level within the institutional system, which both organizes and is organized by the institutional system and classroom levels.

The plural *systems* also conveys a “mosaic topology,” (Lemke, 1997) in which different systems with similar or different objects overlap and interact. Interesting opportunities for systemic change occur when diverse systems with discontinuous objects interact. The issue of interacting systems comes up in Chapter 4 of this dissertation, where I explore what happens when novice teachers simultaneously participate in the public school system and the system represented by a teacher education program that prioritizes attention to student thinking. Here, I consider the system in the teachers’ student teaching internship interacting with the system represented by the teacher education program, and how different teachers’ abilities to attend to the substance of student thinking are shaped in this interaction.

Expanding the Framework to Account for Variation: Framing

The evidence in chapters 4, 5, and 6 suggests that there is variation in how and when individual teachers attend to the substance of student thinking, that some teachers appear to have an easier time attending to the substance of student thinking than others, and that some teachers frequently attend to student thinking in greater depth than others. Any framework for understanding teachers’ attention must be able to account for this within- and among-subject variation. Consideration of within-subject variation is beyond the scope of this dissertation, but in my final chapter, I consider how we may account for both the teachers who regularly attend to the substance of student thinking and those who

are more frequently distracted by their accountabilities to the institutional system. To account for this variation, I use the concept of framing, which is useful for relating the organization of systems and individual behavior.

The notion of framing has two different yet related meanings. In one sense, the *framing* of a situation, which “provides a first answer to the question, ‘What is it that’s going on here?’” is a shared property of a social group that is a central element of its culture (Goffman, 1974). So, for example, the institutional and social systems of schools frames “what’s going on here” for teachers and thus shapes teachers’ attention collectively. As teachers participate in these systems, by teaching their classes and working in local professional communities, they continuously contribute to, sustain, and amplify this framing. Thus in this sense, the teaching of science takes on certain properties as framed by the system and the people that inhabit it.

Framing can also be thought of in terms of the individual, in terms of the individual’s sense of what kind of activity is occurring in a given situation (Hammer, Elby, Scherr, & Redish, 2005)⁴. I take both meanings of framing to be important in my theoretical framework. Individuals and the systems in which they participate cannot be easily separated, but are co-constitutive (Greeno, 1997), and it follows that the way in which teaching is framed by the institutional system plays a powerful role in determining how a teacher frames the activity (and vice-versa). Thinking about individual teachers’ framing, however, affords a consideration of the differences that individual teachers bring to a similar situation. An important question for future research is how to account for the

⁴ In fact, an individual’s framing of a situation can be itself thought of as another level of systems. Through previous participation in diverse systems, individuals acquire resources for understanding activity. Systems of resources are activated in particular situations to support a framing of “what’s going on.”(Hammer et al., 2005)

variation that I have observed in teachers' tendencies to attend to the substance of student thinking. In my conclusions, I speculate that this variation can be explained in large part by the different ways in which teaching can be framed for different individuals and in different situations.

Summary

This framework provides me a way of understanding teachers' attention as it is situated in school teaching. The framework has developed over time, growing out of my desire to represent teaching from the point of view of teachers' work in the systems of schooling, and it continues to develop, as I describe in the next chapter. I then take this framework to my data in Chapters 4, 5, and 6 with the goal of further understanding my research questions regarding what teachers attend to while teaching, how their attention is organized, and how teachers' attention is consequential for students' learning.

Chapter 3: Research Context and Methods

In this chapter, I describe the research context and methods of the main study reported in this dissertation, the research on what practicing teachers attend to in the classroom, while teaching. The research context and methodology of the study of novice teachers' attention is discussed in more detail in Chapter 4, although I will refer to that work here as well.

Genesis of Research Questions and Method

The research methods reported here have developed over time, and the methodology has evolved as the study progressed and my research questions were refined. I began this work with a sense, as a teacher in the institutional system described here, that my teaching was often constrained by things other than my sense of how to best help my students learn science. I encountered frustrating situations that I interpreted as constraints imposed by systemic priorities, which did not promote good science teaching and learning.

For example, in the years prior to the start of this research project, I was teaching high school biology. In line with increased attention to standards, accountability, and testing, the district science teaching administration and the local school and departmental administration expected teachers to meet together as a "biology team". We were expected to design common tests, aligned with district-wide final exams and state tests, and to align the pacing of our curriculum and the content we covered with each other and with the district curriculum. We were given professional development time to work in

pairs to construct common tests, which, after being reviewed and modified by others on the team, came to define what it was students were expected to know. As we began this process, it became clear that I would have to begin to think about my teaching in terms of what others on the biology team were doing to teach to these common tests. In constructing the common tests and developing test items, teachers would draw on particular activities that they or other team members used with their classes. In many cases, the questions were so closely tied to the activities, or to representations used in the activities, that if you had not used those activities with your classes, you could almost ensure that your students would have difficulty with those items on the exam. What monopolized my attention in planning and teaching was the importance of making sure my students encountered those particular activities and got what they were supposed to get out of them.

At the same time, as a graduate student in science education, I was reading literature and engaging in discourse about what science teaching that supported “good” science learning could look like. In the literature and in my conversations with people in science education, I often felt that there was too little appreciation for understanding science teaching as it was situated within school science--for understanding teaching without blaming teachers. As I began to think about doing my own research, I was preoccupied with a desire to represent what it is like to teach science in the public schools--to describe the possibilities in teaching that were constrained and afforded by the institutional system. Most importantly, I wanted to represent the context of public

school teaching in a way that was fair to teachers, and did not simply blame them for teaching in ways inconsistent with science and science education reform.

In this way, my research began with very general questions. At the time I proposed this research I was thinking of “institutional pressures” on teaching in terms of accountability to high-stakes tests and standardized curriculum. I was also interested in how practices of local communities – such as the biology team I experienced -- filtered and mediated those pressures. Furthermore I knew that I would have to consider the ways in which the teaching I observed might not necessarily align with the priorities of the broader institutional setting or local community. After all, teaching has often been thought of as an individual pursuit; the imagery of “behind the classroom doors” isolation is pervasive in common perception of secondary science teaching. My initial research questions were as follows:

- In what ways, if any, do institutional pressures shape biology teaching?
- What, if any, are the practices of the biology team that address institutional pressures?
- In what ways, if any, do these practices shape biology teaching in classrooms?
- In what ways, if any, is biology teaching idiosyncratic and unconnected from the institutional pressures or the practices of the biology team?

In the section on data analysis below I describe in greater detail how these questions shifted, and how I came to narrow my focus to look specifically at teachers’ attention. As I began to design my research, my desire to represent the institutional system of public school teaching and provide “thick description⁵” (Geertz, 1973) of what

⁵ As opposed to “thin description,” which merely describes behavior, Geertz (1973) described “thick description” as an approach that describes not just behavior, but the contexts for the occurrence of behavior as well, such that an outsider can understand behavior in terms of its meaning for an insider.

it was like to teach in this system was the principle guiding force in how I focused my inquiry and collected my data.

Case Study Approach

My interest in understanding the institutional system of biology teaching naturally suggested a case study approach. Case study research is commonly used for studying complex phenomena in naturalistic settings, especially when contextual factors play an important role (Yin, 2003). I imagined my research as an “embedded” case study, thinking of the institutional system as a whole composed of subunits that merited study (Scholz & Tietje, 2002). Yes, I wanted to study teaching, but I wanted to study it in such a way that I could establish the relationships among the teacher and the teaching, the professional communities in which she participated, and the larger influences emanating from district and state policies. To this end, I envisioned a multi-level case of classroom biology teaching, embedded in local professional communities, within a broader institutional context. I expected to write a chapter describing the institutional and policy context, a chapter describing the local professional communities, and a chapter describing the teaching I observed in three teachers’ classrooms.

As I began to analyze data, however, my approach changed, and I began to consider the question, “What is this a case of?” (Ragin, 1992).⁶ I realized that it was most important to describe what was happening in the classroom and to understand how (and when) it was connected to the priorities of the system. While this still meant collecting

⁶ The continual reconsideration of what a case *is a case of* is an important aspect of case research, as it affords ongoing opportunities to reconsider the relations between ideas and evidence (Ragin, 1992)

data about institutional policy and the local professional community, it meant starting with what occurred in the classroom and allowing the cases to develop out of that. In this way, the cases I thought I was trying to describe changed over time. I began to think of describing cases not of the organizational entities but of classroom science teaching situated in institutional systems. This reconsideration of the cases paralleled a shift in the way I conducted my data analysis, as I will describe below. Ultimately I worked to construct cases that began with aspects of classroom teaching; these evolved into a case study of what teachers attend to and how teachers' attention is shaped, and a case study of how teachers attention to student thinking is consequential for what occurs in science classrooms.

Site Selection

I collected most of my data at Jebediah Springfield High School⁷ during the 2005-2006 and 2006-2007 academic school years, from classrooms of teachers in the science department and on the biology team in particular. An additional data stream came from conversations among teachers involved in a collaborative research and professional development project involving university researchers in science education, and secondary science teachers throughout the district.

Local Professional Community

Springfield is the largest high school in a large suburban county school district in the Eastern United States. The school serves a diverse population of approximately 3000

⁷ All names used in this dissertation are pseudonyms

students each year. I chose to conduct my research at Springfield for a variety of reasons. For one, I was a participant on the Springfield biology team since the team's inception. This position as a researcher and as a full participant (Glesne & Peshkin, 1992) on the biology team afforded me unique access to the particulars and dynamics of team practice, as I discuss below.

My knowledge of the biology team suggested that it had features of a "strong" professional community (McLaughlin & Talbert, 2001). This is another reason that I chose to conduct my research at Springfield. McLaughlin & Talbert (2001), define a "strong professional community" as one in which "teachers share a sense of common mission and negotiate principles, policies, and resources for their practice" (p.63). A high degree of collegiality exists in such communities. Moreover, in strong professional communities, with a high degree of collaboration and collegiality, important policy decisions are made that substantially influence individual teachers' classroom practice (McLaughlin & Talbert, 2001; Siskin, 1990).

As a member of the biology team, I had experienced a high degree of collaboration and collegiality, and shared a sense of mission with my teaching colleagues on the biology team. Three of the seven members of the team (including two of my research subjects) began their careers at Springfield and had only taught biology under the leadership of the then current science department chair and the then current biology team leader. The other members of the team, including myself, had been on the biology team since it was first established in 2001. None of the team members had participated in

a biology team in a different school. The team met regularly to discuss the pacing of the curriculum and to plan activities, and met together in science department meetings to plan for and respond to policy initiatives of the school and the science department.

Additionally, team members shared instructional resources readily outside of these meetings, e-mailing materials or placing them in each others' mailboxes. Furthermore, team members frequently ate lunch together and socialized outside of school; conversations in these informal settings often turned to teaching. All of these factors suggested that this team constituted a strong professional community, and would be a good place to look to understand how the local professional community worked to shape biology teaching.

The Collaborative Research and Professional Development Effort

While I did not intend to study this effort as a particular case, I collected considerable data that was useful for understanding my research questions, as I describe below. The project began with the intent of studying teachers' curricular modifications, including the nature of their changes, the underlying rationales of these changes, and the influence on student learning and attitudes. The project was divided into three cohorts organized around content and curricula: an environmental science cohort, a physics cohort, and a biology cohort. I draw on data from the biology cohort in this work. The biology cohort met every two weeks during the school year for two hours and for one week in the summer (an additional three days of summer work involved individual work with teachers). The project, funded for three years, ends in the spring of 2008. In the

first year, the team of researchers and teachers watched videotape of teachers' classrooms and discussed how teachers modified instruction. In the second year, we continued to watch video, but we shifted to a more explicit focus on professional development, specifically to support teachers' abilities to attend to the substance of student thinking⁸. In the final year, teachers began to write cases studies of their classrooms, drawing on the student thinking made apparent in classroom transcripts and student work as evidence for what was happening in their classes.

Selection of Research Subjects

In thinking about the classroom level of my case study, I initially chose to focus on the classrooms of three teachers, Ms. Hawkins, Ms. Turner, and Ms. Vai, for two main reasons. First, all three were members of the biology team at Springfield, and all three had only taught biology within the organization of the biology team at Springfield. Consequently, I expected that understanding of their teaching might reveal important ways in which biology teaching is organized and constrained by the practices of the biology team. Secondly, all three teachers were also participants in the collaborative research and professional development project (hereafter referred to as the "Mod Squad" project), which provided an additional data stream for informing how the teachers understood their teaching and the expectations of the local professional community and the institution. Additionally, it provided an opportunity to hear how other teachers in this system interpreted the teaching and learning that occurred in these teachers' classrooms.

⁸ This shift was significant in how my thinking about my own research changed. I describe this shift in more detail in the data analysis section.

In the second year of this study, Ms. Vai switched to teaching mostly physical science and left both the biology team and the Mod Squad biology cohort. As a result, while the interview and classroom observation data that I collected from Ms. Vai in the first year informed my analysis, I did not ultimately analyze her classroom teaching in depth. Instead, I drew on data from Ms. Brown's classroom teaching. Ms. Brown was a student in the Masters Certification (MCERT) program (discussed in Chapter 4) during the 2005-6 academic year and a new teacher at Springfield during the 2006-7 year. She also joined the Mod Squad biology cohort in its second year. Focusing on Ms. Brown's classroom provided an excellent opportunity to explore the classroom teaching of someone who had participated in both the MCERT and the Mod Squad project.

Data Collection

To gain an understanding of the ways in which institutional systems shape teaching, I relied on ethnographic methods of data collection. I ended up writing about only a small fraction of this data in this dissertation. Much of it was useful, however, for challenging and triangulating claims, as I describe below. This additional data will be invaluable for future study.

During the 2005-6 academic year, while teaching at Springfield, I attended all of the meetings of the biology team and the science department, taking detailed field notes at all times and audio taping conversations when it was appropriate and not disruptive. I collected artifacts that were produced in these meetings, including classroom activities and common tests, and I collected institutional documents that were used in the

production of local curriculum and assessment tools (e.g., county-wide curricula, county final exam review sheets, and rubrics). During several of these meetings I also drew discourse maps in which I represented the positions of the individuals in the room, drawing arrows to show who was speaking to whom and making notations about the topics of the conversations. The notes, documents, and discourse maps together provided a detailed picture of the goals of the biology team, how these meetings were conducted, and the roles that individuals played in these meetings.

During the 2005-6 academic year, I also conducted hour-long semi-structured ethnographic interviews (Glesne & Peshkin, 1992; Schatzman & Strauss, 1973; Spradley, 1979) with Ms. Hawkins, Ms. Turner, and Ms. Vai (three each) and interviewed the science department chair, the biology team leader, and the other three teachers on the biology team each once. In addition to these interviews, I also watched videotapes of Ms. Hawkins' and Ms. Turners' classrooms with them, and interviewed them about what they saw in their students' thinking afterward, and what they found notable in general. These interviews, in addition to conversations about the teachers' classroom videos in the Mod Squad biology cohort meetings, gave valuable insight into teachers' goals for their teaching, how they interpreted events in the classroom, and how they understood their responsibilities in the institutional context.

I spent considerable time in the classrooms of Ms. Hawkins, Ms. Turner, Ms. Vai, and Ms. Brown, videotaping their classes and/or taking detailed field notes. In several cases I also drew discourse maps, which provided some insight into the kinds of

discourse that was occurring in the classroom. I observed Ms. Hawkins's and Ms. Turner's class each at least fifteen times throughout the course of the study, and I observed Ms. Vai's and Ms. Brown's classes at least five times each. All of the data from Ms. Vai's classroom came from the 2005-6 academic year, while most of the data from Ms. Brown's classroom came from the 2006-7 academic year (with the exception of one classroom videotape collected from the previous year, when she was a student teacher at Springfield and a participant in the MCERT program).

I collected videotapes of the Mod Squad biology cohort group meetings. I also took notes during each session and/or drew discourse maps (described above). These meetings primarily entailed watching videotapes of classrooms or looking at student work, discussing the student thinking in evidence, and talking about how teachers modified (or could modify) instruction. Cohort meeting videotapes relevant to the cases presented here were transcribed. This data was useful for triangulating claims drawn from classroom observation and interview data, and representing understandings of teaching that were socially shared by members of the broader teaching community (Herbst & Chazan, 2003). For example, teachers frequently made comments that disparaged the focus on testing, while also articulating the rationality of directly teaching the concepts and vocabulary that would appear on particular tests. Triangulated with other evidence, this apparent contradiction supported my developing arguments that,

while teachers could be highly critical of the priorities of the institutional system, the possibilities for classroom teaching were also highly constrained by the system⁹.

I collected another kind of data that was useful for understanding the system and the teachers' positioning and identification in the system. I asked Ms. Hawkins, Ms. Turner, and Ms. Vai to draw concept maps of themselves in relation to various elements of the institutional system: the biology team, the science department, and the school as a whole. While I used very little of this data directly in analysis, it was useful for triangulating claims drawn from analysis of classroom discourse and interview data¹⁰.

Finally, I kept a journal throughout my research, which was important in several ways. First, I often wrote in the journal when I had informal interactions with teachers or observed things in school settings that I was not able to immediately write down. Second, I often used the journal to draft short analytical memos (Miles & Huberman, 1994); this has been useful for helping me to capture emerging interpretations¹¹ and track

⁹ Additionally, these sessions supported the notion that the local professional community played a powerful role in what happened in classrooms, as teachers frequently referred to "what we do" (referring to their own biology team) when describing how they addressed curricular expectations.

¹⁰ For example, in drawing a map of the Springfield science department, Ms. Hawkins drew a dark storm cloud labeled HSA (High School Assessment) dropping rain on the box labeled "biology team", which supported other evidence that the HSA was an omnipresent threat in teachers' understanding of their work and significant in shaping their attention.

¹¹ I used my journal to begin some data analysis from very early in my data collection. I used the journal as a place to compose short analytic memos that captured emerging interpretations. For example, in thinking about my observations of the activity structure of the biology team, I wrote the following in my journal...

[I notice a] focus on preparing what I would call "stuff" to be shared by the members of the bio team. This includes readings, BCRs, tests, etc...[In a recent meeting] ...Elise [the team leader] was talking about having something for students to do after they finished the biochemistry test. She suggested the idea of someone create something related to the new food period, which she put as, "Do a food pyramid thing with questions." Also, in respect to an article that Paul provided, someone asked him, "I never got the questions for that article, did you do them?" It struck me that it's common practice for members of the team to create some "stuff" to be used by other team members. This stuff often amounts to some "thing" (reading, etc.) that has "questions". These things are shared among the team members, and used in connection with particular units...People

how my thinking about my research has changed over time. Finally, as I will describe below, the journal provided a place for me to check my own subjectivities that I brought to my research in my position as a participant observer (Peshkin, 1991).

Participant Observation

In research on teaching and learning, one may be more-or-less a participant. In some cases, researchers study these systems primarily as outside observers; in others, they can become fully-embedded “participant observers” (Glesne & Peshkin, 1992), which in sociological and anthropological research can often mean taking part in the norms and practices of a culture for months if not years at a time (Chagnon, 1968; Peshkin, 1991; Whyte, 1943)

During the first year of my data collection, I had the advantage of being a participant in the science department and a colleague of the very teachers whose practice I was hoping to better understand and describe. As such I had a unique position as a researcher; I was a participant in the biology team, an important aspect of the system that I was trying to understand. I taught classes similar to other members of the biology team, and in some cases I taught some of the same students my colleagues taught. My position also allowed me to participate with the team in ways outside of formal participation in meetings and observations of their classrooms. I ate lunch with teachers on the team and

rarely ask about the content of these questions, or have in depth discussion of how students respond to them. It's simply about generating “stuff” that can be used to fill instructional time. This stuff is, of course, related to the content, but it is rarely examined carefully or assessed as a group (10/10/05)

Memos like this one helped me to develop a sense of the kinds of activities and discourse that occurred in the various subsystems within the broader system. Triangulated with interview data with other biology team members, this particular memo helped to develop my understanding of the structure of biology team objects and tools, and the structure of biology team activity.

interacted socially with members of the team and the larger science department. I occasionally planned with other members of the team or covered their classes, and we had frequent informal communication in the halls and via e-mail. This afforded me access to a wide variety of data that I could use to triangulate and challenge my developing interpretations.

My role as a participant was also problematic. I recognized that my participation in the system might lead me to think that I understood already how the system shaped teaching and that others understood the system and the context of their teaching in the same way that I did. As a result I was careful to keep track in my journal of my own subjectivities and the ways in which it influenced my analysis and interpretation (Peshkin, 1991). For example, I became aware early on in my research that I was already highly critical of the institutional system and the kinds of teaching that it supported. I was going into teachers' classes expecting and looking for teaching that was responsive to priorities of the system and, in my eyes, not accountable to science. As I wrote in my journal in one of the first classes I observed:

...Returning to my 9/9 observation of Jamie's class--I found myself being very critical of the way that Jamie's use of the "WDI"¹² was just falling in to the same scientific method trap (9/27/05).

Experiences like this one made me sharply aware of my "Critical Self"—in which, largely as a result of my experience in the system, I framed my work as exposing and challenging unproductive aspects of school science teaching. While this critical

¹² The "WDI" refers to the "Well-Designed Investigation," a form of the standard experimental "Scientific Method" that teachers in the district were expected to teach.

stance was ultimately important in helping me to recognize the ways in which the system failed to amplify teachers' productive attention to student thinking, it was also very useful to recognize that my experience had predisposed me to be critical. This awareness of my own subjectivity was important throughout my research. It reminded me that I was at greater risk of being blinded to experiences different from my own than a detached observer might be. It reminded me to check my interpretations regularly against other data, to ensure that I was not blinded to other possible interpretations by my own experience.

Methodologically, it also meant looking for, and trying to understand, counter-examples to my expectations. For example, the choice to focus on Ms. Brown's teaching was largely motivated by the initial contrast between the way she and Ms. Hawkins attended to student thinking in the lesson, described in Chapters 5 and 6, about the evolution of giraffe's necks. By focusing on Ms. Brown's teaching, I moved beyond my assumptions about what the system could afford teachers' practice, particularly in terms of teachers' attention to the substance of student thinking. I found Ms. Brown to be routinely successful at attending to student thinking and providing opportunities for inquiry. The contrast between the teaching described in Ms. Brown's class and the teaching described in the case study in Chapter 5, in Ms. Hawkins' class, raised important questions about variation in *when* and *how* different teachers attended to student thinking, which are important in my future research.

Data Analysis

I began my data analysis by trying to code the large collection of interviews, documents, classroom transcripts and field notes that I had collected. Very quickly, however, I discovered that this was taking a large amount of time, and I was having difficulty focusing on any emergent central narrative. I realized that I was spending quite a lot of time on data that was not directly connected to what occurred in the classroom (i.e., interviews, meeting notes). I was not spending enough time analyzing the classroom discourse and activity, which was what I was most interested in understanding. Furthermore, the data was beginning to suggest ways in which the institutional system might organize teaching (for instance, by drawing teachers' attention to target vocabulary), and I needed to look at the classroom data to understand how this focus played out in real time. This was an important realization in my work. While I had always been interested in the multiple levels of the system, I now shifted to foreground what occurred in the classroom and consider the systemic influences in relation to that.

I had begun to collect a number of classroom transcripts, and I decided to switch gears and begin instead by exploring these transcripts in terms of how they connected the activity of the classroom to the broader institutional system. My approach here was an iterative process of analyzing the discourse of the classroom and connecting it with emerging ideas about situated teaching. I first composed several larger analytical memos that began with classroom discourse and connected out to the interview and systemic data that I had collected and coded. One of these memos, for example, connected Ms. Hawkins' lesson on the evolution of giraffes' necks to the broader priorities of the

system, and became the foundation upon which I based the case study reported in Chapter 5. This early analysis of classroom transcripts helped to shape my developing case studies, by pointing me toward meaningful data and helping me to develop stories about the ways in which the institutional system shaped teaching. I had not yet begun to focus on the role of the institutional system in shaping teachers' attention in particular, however. This focus developed through my collaboration with other researchers in the Mod Squad project.

Developing a Focus on Teachers' Attention

At this time, the focus in the Mod Squad project as a whole was slightly shifting. As I mentioned earlier, initially the purpose of the project was to explore the question of how teachers modified curriculum, with the hypothesis that modifications that were responsive to the substance of students' thinking would be most productive in terms of supporting students' science learning. Early on, however, it became clear that, while teachers were making lots of modifications, they were rarely modifying instruction in response to student thinking. And, that in many cases, teachers were neither creating opportunities for students to articulate their thinking, nor attending to the substance of those ideas that students expressed. The focus of the project shifted; beginning in the second summer, we focused on what teachers paid attention to in the classroom and when watching videotape of classroom activity. We also focused professional development efforts on drawing teachers' attention to the substance of students' ideas, not unlike what we do in the MCERT science pedagogy course sequence, as I will describe in Chapter 4.

It was when the Mod Squad project shifted focus that I recognized teachers' attention as a pivotal concept that could help me to connect teachers' classroom practice to the organization of the system and to teachers' understanding of their work.

As part of this shift, the Mod Squad project focused on broad categories of what teachers attended to in conversations about classroom videos, which the research team derived through several iterations of watching videotape of teachers talking about classroom video, and trying to describe what teachers were attending to. We came up with an initial set of seven codes, summarized here and described in more detail in Appendix A. This initial set include categories of teachers' comments or questions about (1) high-stakes tests, (2) mandated curricular objectives ("indicators"), (3) the nature of the activity, (4) the actions of the teacher on the video (5) students' ideas, (6) student engagement, (7) attributes of students and (8) other. We began coding randomly selected segments of these videos in collaboration with the teachers in the project. As we continued to code, we generated two additional categories, also described in the appendix: comments or questions about (9) student action and (10) science content.

This coding revealed that in discussing classroom video, teachers attended largely to the teacher's actions and the nature of the activity, a finding that is consistent with prior research on teachers' attention in similar professional development settings (e.g., Sandoval et al., 2002). There was also evidence of teachers attending to students' ideas, however. Looking closely at the interactions in these sessions suggested some difficulty in using this data to understand teachers' attention. In many cases, what teachers

attended to in these conversations was largely in response to questions that they were asked by the facilitators or other teachers. Since much of the early focus of the project was around modifications, participants were often thinking in terms of modifications to curriculum, which often naturally led to questions about what the teacher had planned, or what the nature of the activity was. This made it difficult to use any of the data as a reflection of what teachers attended to, as their attention was often framed by the focus on modifications.

More importantly, I realized that this analysis was never going to give me access to what I really wanted to know—what teachers attended to in the classroom and what shaped their attention in the classroom. While some have argued that teachers' cannot attend to the substance of student thinking in the classroom if they cannot do it in a professional development setting (e.g., Jacobs et al., 2007), evidence of ability to attend to student thinking in this setting would not be sufficient to argue for teachers' abilities to attend to student thinking in the classroom. This realization, along with the shift in focus in the Mod Squad project as a whole, led to a reframing of my research questions. I was now asking:

- To what do teachers attend in the classroom?
- What shapes teachers attention?
- How is teachers' attention consequential for what occurs in the science classroom?

Selecting Data for Case Studies of What Teachers Attend to in the Classroom

As I discussed, I ultimately chose to construct case studies of what teachers attend to in the classroom and the consequences for student learning. To do this, it was

important to look into the classroom, where teachers' attention is manifested in real time. At the same, time, I needed to choose classrooms, and classroom activities, that were representative of the typical practices of the broader system. I chose to begin with analysis of Ms. Hawkins' class on the evolution of giraffe's necks, as described above, which I took to be representative for two main reasons.

First, I considered what Ms. Hawkins attended to as a window into common foci of attention shared by many other teachers in the system. I did so primarily because my interviews with Ms. Hawkins, and observations of her classroom, suggested that she consistently worked hard to help her students reach the benchmarks established by the district and by the local professional community. Additionally, she was a central participant on the biology team; she helped the rest of the team to move through the curriculum, and helped newer teachers, like Ms. Turner, to learn the expectations and procedures of the system. Second, I considered the activity on the evolution of giraffes' necks to be typical of the kinds of activities that I frequently observed throughout Ms. Hawkins' school and the rest of the district. Open-ended questions such as the one described in Chapter 5 are frequently used to begin classes.

The case study in Chapter 5 is not simply a case study of this one class, but rather an example of the foci of attention common among teachers in the school and in the district. The classroom example simply provides the starting point for describing these foci of attention. I draw on interview data with Ms. Hawkins and other teachers, examples from other classes, and conversations among teachers on the biology team and in the Mod Squad biology cohort meetings to move the focus beyond this particular class.

I made the decision to focus on this particular class as representative of the foci of teachers' attention and its consequences, but then I continually challenged this focus by examining other classroom examples and looking for counter-examples. This search for counter-examples drew my attention to Ms. Brown's classroom. In many ways, Ms. Brown and Ms. Hawkins might be considered similar teachers. Both were conscientious participants on the biology team and in the broader system, and in many ways, activities in their classrooms seemed superficially very similar. In fact, Ms. Brown had been Ms. Hawkins' student teacher, and the two continued to plan together frequently. Nevertheless, it was in examples from Ms. Brown's classroom that I found counter-examples to the case presented in Chapter 5. As a result, I constructed another case study, presented in Chapter 6, that presents these counter-examples and considers how what Ms. Brown attended to in the classroom was consequential for student learning.

Analyzing What Teachers Attend to in the Classroom

In redesigning my first question specifically around what teachers attended to in the classroom, I needed a way of understanding teachers' attention through analysis of classroom discourse from videotape and transcript data. A useful starting point emerged in preparing the manuscript of the case study of novice teachers' attention to the substance of student thinking for submission (see Chapter 4). We identified what we would take as evidence of teachers' *attention to the substance of student thinking* in analysis of classrooms from field notes or video. I consider it evidence of attention to the substance of student thinking in the classroom when a teacher notices and responds to a student's idea in terms of the meaning of what the student is trying to say, and

irrespective of whether or not the student's idea is correct. The response may be the teacher asking the student or other students to explain or elaborate on the reasoning, rephrasing the idea herself, or shifting the flow of classroom activity in a way that addresses the idea¹³. Furthermore, I take it as evidence of attention to the substance of student thinking when a teacher consistently pursues the substance behind students' ideas when little is in evidence.

An example of a teacher attending to the substance of student thinking can be seen in a transcript from a class discussion in which Ms. Brown and her students were trying to interpret a stanza in the poem, "The Rime of the Ancient Mariner" about a shipwrecked sailor¹⁴, which reads

*Water, water, everywhere,
And all the boards did shrink;
Water, water, everywhere,
Nor any drop to drink.*

Ms. Brown told the students that the poem had been written from the point of view of someone on the ocean. Without prompting, several students insisted that this referred to the fact that you cannot drink seawater. Ms. Brown asked students to explain why you couldn't drink seawater. Lara had a thought, and she interrupted:

1. Lara: Doesn't it have to do with osmosis though?
2. Ms. Brown: Okay, so what does it have to do with osmosis?
3. Lara: Meaning, uh, the water—
4. Ms. Brown: You guys, listen! Shhh.
5. Lara: Like, doesn't it kinda mean, like the water inside the boards left out the boards and then it shrank

¹³ David Hammer is credited for proposing what evidence constitutes attention to the substance of student thinking.

¹⁴ I discuss this example in more detail in Chapter 6

6. Ms. Brown: Why would it do that?
7. Lara: I...(shakes her head)
8. Ms. Brown: Okay, so Lara's saying that the water in the boards left out of the boards, which made them shrink. Okay. The water--the boards, he's talking about what?...What are the boards that he's talking about?
9. Lara: Like on the boat.
10. Ms. Brown: Like on the boat, right. On the boat, so why...why did they, why did the water leave?

In the example above, there is evidence of Ms. Brown's attention to the substance of students' thinking when she asked students to explain why they couldn't drink salt water, thereby asking students to provide the substance behind their claim. She also asked Lara to elaborate on what the stanza had to do with osmosis (2), and asked Lara and the rest of the class why the water would "leave out of the boards" as Lara suggested (6, 10). I take this as an example of attention to the *substance* of student thinking, as Ms. Brown attended to and pursued Lara's idea without marking it as simply correct or incorrect, nor noting that it referred to the second part of the stanza and not the question of why you couldn't drink salt water.

Describing what we meant by attention to the substance of student thinking was a useful starting point for analysis, and central to the case study of the MCERT, but in addressing my question "to what do teachers attend?" I needed to differentiate the kinds of things teachers' might be attending to in a student's idea. Teachers are most likely attending to a variety of things in any one moment when students are expressing ideas, and this attention likely shifts from moment to moment. I needed to begin to look for evidence of what teachers were attending to in what they heard students say. This led me to search for and describe examples of teachers attending to various aspects of student

ideas, such as “engagement”¹⁵, “reasoning”, and “conceptual correctness”. One thing that became clear early in my analysis of classroom discourse was that there were many examples of teachers attending to students’ ideas in terms of their distance from the “correct answer” as often represented by target vocabulary.

For example, in the classroom discussion about the evolution of giraffe’s necks, Ms. Hawkins verbal cues demonstrated her attention to student ideas in terms of their consistency or inconsistency with the particular mechanistic explanation (and the language of that explanation), that was central to curricular expectations. She responded to all incorrect ideas similarly, usually with a neutral “Okay,” By contrast, her reaction to a student’s use of the correct terminology for the correct explanation was quite different. She exclaimed “Ohhh!”, with her voice rising and then falling dramatically. She also made sure to draw students’ attention to the use of the word and the idea it represented, pointing out it was introducing “something different”, when the student tried to claim she was “saying the same thing that everyone else said.” This is an example of the kind of data, which, triangulated with interview data, suggested Ms. Hawkins was attending in that moment primarily to target vocabulary as a proxy for conceptual correctness¹⁶.

An important distinction between the above two examples is that one demonstrates evidence of attention to the need to elicit the substance of students’ ideas

¹⁵ I don’t discuss this category much in any of my case studies, so it’s worth providing an example of what I take as evidence of attention to students’ engagement. In the discussion about the giraffe’s neck described in Chapter 5, Ms. Hawkins told students that it didn’t matter if students’ had the correct answer, but that she just wanted to know what they thought. In combination with Ms. Hawkins’ assertion in the interview that she was doing that to encourage the students to participate, I take this as evidence of attention to student engagement.

¹⁶ This example is discussed in greater detail in Chapter 5.

and to the meaning of the substance of students' ideas when they are in evidence. The other demonstrates attention primarily to correctness. This distinction proved important in how I began to code and describe the discourse of the classrooms.

Analyzing How Teachers' Attention is Situated

Analysis of classroom discourse, triangulated with interview data and data from field notes, was useful in understanding what teachers attend to in science classrooms. However, my work also concerns how teachers' attention gets shaped, and how it is consequential for what occurs in classrooms. To look at these questions, I analyzed the structure of activity at the level of the classroom and examined the broader institutional and social systems. At the level of the classroom, this meant looking at how teachers' attention was mediated by the tools, including discourse patterns, used in the classroom, and by the students themselves. It also meant examining how the teacher's attention helps to shape the substance of what students attend to, and how this impacts the culture of the classroom.

At the level of the broader social and institutional system, I needed to look at the tools, objects, and local communities that shaped teachers' attention. Here my earlier organization of my data, and my earlier memo writing proved to be useful, and I returned to this material with a lens of understanding aspects of the system that specified what it was teachers should attend to. For example, I revisited my early memo about Ms. Turner's teaching of the "Well-Designed Investigation", analyzed the discourse in terms of what Ms. Turner was attending to, and looked at my other data to understand the

forces organizing her attention¹⁷. The classroom analysis suggested that Ms. Turner was attending largely to the students' recognition of the series of steps and the vocabulary associated with the Well-Designed Investigation. In curricular documents that I had earlier coded, I found language explicitly charging teachers to consider these as the central goals in assessing student inquiry, referring to the WDI as "an assessment checklist."

The Components of the Well-Designed Investigation is a summary of the _____ State Science Content Standards related to Inquiry. These standards are used by test developers to design questions for the M.S.A. and the H.S.A. The vocabulary serves as a cue for students to respond to specific questions relating to experimental investigations. Students are required to know and effectively use the five components and vocabulary of the well-designed investigation.

Despite disclaimers that scientific inquiry is to be considered flexible and rarely "linear", the general message from the curriculum writers to the teachers is clear. These are the things on the test; pay attention to these things. My observations of the biology team meetings, and meetings with biology team members, demonstrated how the focus on the WDI as the way to assess inquiry was also sustained and reinforced by the local professional community. The biology team referred to their "Inquiry Labs" as labs in which students were expected to pick from a subset of inquiry questions and explore their questions by following the steps of the WDI. Team members made plans to write BCRs¹⁸ designed to assess students' understanding of the steps of the WDI or associated terms such as "independent" and "dependent" variables. My interpretations of the way

¹⁷ This analysis is ongoing in collaboration with Xiowei Tang and Janet Coffey.

¹⁸ For "Brief Constructed Response" This was the form of short essay that appeared on the HSA, the district-wide final exams, and consequently on all local exams.

the biology team sustained the focus on the decomposed WDI triangulated with interviews with team members and statements from other teachers in the Mod Squad biology cohort¹⁹.

This is just one example of how I began my analysis with classroom discourse and then connected that discourse to the broader social and institutional systems. Ultimately, this became the most productive approach for analyzing my data and addressing my research questions, as it gave me insight into what teachers attended to in the classroom, how teachers' attention was shaped by the institutional system, and how it helped to shape what occurred in the classroom.

Summary

In describing my research methodology, I have tried to tell the story of how my methodology developed over time. It's not a particularly tidy story, but it honestly represents how my analytical methods changed and developed as I began to understand my research more clearly. This is not uncommon in research that relies on ethnographic data and participant observation. As Whyte (1943) argues in the appendix to his landmark ethnographic study of "Street Corner Society."

We do not generally think problems through in a straight line. Often we have the experience of being immersed in a mass of confusing data. We study the data carefully bringing all our powers of logical analysis to bear upon them. We come up with an idea or two. But still the data do not fall in any coherent pattern. Then we go on living with the data—and with the people—until perhaps some chance occurrence casts a totally different light upon the data, and we begin to see a pattern that we have not seen before (p.279).

¹⁹ Who spoke about "What WE do" (referring to their biology team) with respect to teaching the WDI

In this way, I had the early “experience of being immersed in a mass of confusing data”, guided only by my sense that I wanted to honestly and fairly represent how science teaching was constrained by the institutional system. Some ideas came out of my early coding of this data, but it was the shifting of *my attention* to teachers’ attention in particular, and the realization that I needed to begin at the level of the classroom, that “cast a different light upon the data” and led to the particular stories that I ultimately chose to tell in the chapters that follow.

Chapter 4: Novice Teachers' Attention to Student Thinking²⁰

Introduction

Kay was a novice teacher last year, working as a paid intern while she took classes toward her credential. As part of her coursework for the credential program, she was required to videotape and analyze a lesson from one of her classes, paying close attention to the student thinking in evidence. Kay transcribed and analyzed a clip from a lesson in which students were to diagram a cell at each phase of the cell cycle to visualize what happens during each phase. They had spent the previous class completing a “cell cycle notes sheet” together as a class.

1. Kay: Okay, today, as I said yesterday, you are going to be making a little wheel showing the stages of the cell cycle, including stage 1, which is?
2. Students: Interphase.
3. Kay: Stage 2?
4. Students: Mitosis.
5. Kay: Good, mitosis. And stage 3?
6. Students: Cytokinesis.
7. Kay: Now, in mitosis there are how many phases?
8. Students: Four.
9. Kay: Four. Good. What is the little acronym that we learned for the four phases yesterday?
10. James: P-M-A-T.
11. Kay: Good. PMAT. Remember, don't pee on the mat!
12. Students: Giggle and laugh.
13. Kay: Okay, for warm-up, during what stage does the DNA replicate?
14. April: Interphase
15. Kay: Excellent! Interphase!

Given it is the first semester of Kay's first time as a teacher, how should teacher educators think about her work? The class was orderly; her students seemed engaged, and her review affirmed they retained the information from yesterday.

²⁰ A version of this paper, authored with David Hammer and Janet Coffey is in review with the Journal of Teacher Education.

If she were an experienced teacher, we expect teacher educators would have concerns. The review consisted almost entirely of naming terminology, without attention to meaning. In particular, it is unclear what students understood about mitosis. What is “cytokinesis”? What does it mean for DNA to “replicate”? Do students understand how mitosis leads to reproduction of the correct number of chromosomes? Do they know that mitosis is taking place in their own bodies all the time, and that mitosis is how they grow and heal?

The transcript reveals a pattern of “triadic dialogue” a conversational routine in which the teacher generates questions, students give short answers, and the teacher evaluates the answers²¹. This routine is common in classrooms, because it gives the impression that students are participating. Unfortunately, here as in general, this form of participation is high in quantity but low in quality (Lemke, 1990). Kay noticed neither the nature of students’ participation nor the opportunities to probe their conceptual understanding. Her carriage in class and in her analysis conveyed only satisfaction; she wrote that the diagrams and students’ responses in the exchange above demonstrated students understood the cell cycle.

As we review below, by some well-subscribed accounts of teacher learning, at this stage of her career we might not expect Kay to attend closely to the substance of her students’ thinking. The first challenges for her are to develop classroom routines and to establish for herself an identity as a teacher, both of which she appears to be doing admirably. Later, as these routines become second nature to her, she will be able to attend to student thinking. For now, as a first-year teacher, Kay was doing quite well.

²¹ Also referred to as I-R-E, for “initiation–reply–evaluation” (Mehan, 1978)

Indeed, the administration at her school was delighted with her work, with how quickly she was able to manage a class and make progress through the material.

Everyday Assessment -- An Issue of Attention

Why should we care about teachers' attention? Research has begun to conceptualize assessment as an everyday classroom activity (Atkin & Coffey, 2003; Cowie & Bell, 1999; NRC, 1996, 2001), and a growing body of work points towards the strong influence that perceptive, ongoing diagnosis of student thinking has on a teacher's instructional moves and student learning (Black & Wiliam, 1998; Cowie & Bell, 1999; Hammer, 1997) Assessment that occurs moment-to-moment in classroom activities concerns, fundamentally, teachers' attention to ideas and reasoning (Ball, 1993; Sadler, 1998). There is clear consensus in the science education literature that teachers must listen and respond to the substance of student thinking (NRC, 2007). Our premise here is simply that assessment requires attention: Teachers can only assess student reasoning if they are paying attention to it.

A second reason to care about teacher attention is its effect on student attention: If a teacher is paying attention to the substance of student thinking, students are more likely to pay attention to that substance (Warren & Rosebery, 1995). For this paper, we take it as a second premise that learning science involves learning to attend to — and to assess — ideas and reasoning. Thus we care about teacher attention not only for the information it provides teachers but also for how it models a key aspect of scientific reasoning for students.

Focusing Novice Teachers' Attention on Student Thinking

Current science education reform emphasizes “student-centered” curriculum and instruction (NRC, 1996, 2000). At its core, this agenda involves meaningful engagement with ideas and reasoning. We know that all students come to school with the resources for learning science, and their progress in learning science depends largely on teachers’ attention to these resources for understanding and using scientific knowledge, for reasoning scientifically, and for participating in scientific practices and discourse (NRC, 2007).

Teacher preparation, however, remains largely teacher-centered. “Methods” courses focus on the things teachers do, from instructional methods to management strategies, and programs emphasize self-reflection and identity formation (Adams & Krockover, 1997; Freese, 2006). Certainly, such courses may engage novice teachers meaningfully with ideas and reasoning, and it is important for teachers to reflect on their roles. Our argument, which we develop in the paper, is that these approaches *direct* teachers’ attention to themselves and their own actions, at the cost of attention to their students’ reasoning.

A teacher-centered approach is strongly influenced by stage-based accounts of teacher development (Berliner, 1988; Fuller, 1969; Fuller & Bown, 1975; Kagan, 1992). From this perspective, novices, like Kay, need standard routines that integrate classroom management and instruction *before they can attend to student learning*, and a focus on oneself is a “necessary and crucial element in the first stage of teacher development.” (Kagan, 1992)

Rigid stage-based accounts of development have been losing ground in general throughout cognitive and developmental psychology (Metz, 1995; Siegler, 1996), and

contemporary research suggests a more flexible account of the developmental process. This more flexible approach suggests that many factors affect teacher development, including biography, experience, context, personality, and beliefs (Loughran, 2006). Furthermore, some innovative teacher education programs use case studies to engage novices in reflection on student thinking in context (Darling-Hammond & Snyder, 2000). Nevertheless, program design is often still predicated on the assumption that teachers concerns about their own actions and identity must be confronted first, before teachers can attend to student thinking (Freese, 2006; Loughran, 2006; Vicente, 1998).

We have three purposes in this paper: First, we hope to contribute to the empirical study of how to help novice teachers' attend to student thinking, by illustrating what should constitute evidence of that attention; along the way we provide case study evidence of novice abilities. Second, we argue that some of the difficulty novice (and experienced) teachers have in attending to student thinking derives from institutional contexts that direct their attention elsewhere. Finally, we propose an approach to teacher education with a core emphasis on cultivating attention to student thinking.

In the next section, we present the arguments from the stage-based perspective and some challenges to these arguments. In the subsequent section, we present evidence from our work with novice teachers, which adds to the empirical case against stage-based accounts, and, we argue, suggests an alternative explanation for the observations cited within the stage-based literature. We do not dispute the evidence that novice teachers *typically* focus on themselves and their behavior rather than on student thinking. Rather, we dispute the notion that they *must* focus on themselves in order to become ready to focus on student thinking.

Research on Novice Teacher Attention

We begin with a review of the literature promoting accounts of developmental stages in teacher education, and then we turn to a review of the challenges to those accounts.

Stage-Based Views from the Teacher Development Literature

For some time, research on teacher development has pursued a stage-based account of teacher attention (Berliner, 1988; Fuller, 1969; Fuller & Bown, 1975). This framework remains influential in the assumptions researchers make and the implications for teacher education that they infer (Dori & Herscovitz, 2005; Freese, 2006; Loughran, 2006; Vicente, 1998).

Kagan (1992) reviewed 40 naturalistic learning-to-teach studies published between 1987 and 1991 with the central goal of constructing a model to describe the professional growth of novice and beginning teachers. The resultant model described preservice and first-year teaching as belonging to a single developmental stage in which novices:

1. acquire knowledge of pupils
2. use that knowledge to modify and reconstruct their personal images of self as teacher
3. develop standard procedural routines that integrate classroom management and instruction (Kagan, 1992, p.129)

Thus preservice teachers arrive with beliefs and images based on their experiences as students. As they begin to interact with students, novice teachers acquire knowledge of students, such as of the diversity in their readiness to learn, which they use to reconstruct their images of themselves as teachers. During this process, they tend to focus on their own behaviors. Once they have “resolved” an image of themselves, novice

teachers can shift attention to the design of instruction and analysis of what students are learning.

The body of research shows, Kagan argued, that the initial focus on self is a “necessary and crucial element in the first stage of teacher development” (Kagan, 1992). Attempts by university faculty or supervisors to abort this period of inward focus may be counterproductive, since novices need a clear image of themselves as teachers in order to begin the process of reconstruction. Among the studies that Kagan reviewed were several that suggested that novice teachers who fail to reconstruct their images of self as teacher may encounter frustrations that drive them out of teaching (e.g., Bullough, 1991).

This early stage of teaching is also spent developing standardized routines for integrating classroom management and instruction. *Only when these routines are in place can novices begin to focus on student learning* (Kagan, 1992). The notion that mastery of organizational routines is a prerequisite for attending to student learning has become conventional wisdom in teacher education, and is often assumed in published research. For example:

A teacher’s career path starts when the teacher struggles to survive consistent daily routines of teaching. It continues in stages of relative stability, when the teacher is ready to introduce innovations and changes in his/her traditional teaching...”(Dori & Herscovitz, 2005)

In the time since Kagan’s (1992) review, teacher development has moved away from a rigid stage-based view of teacher development. Nevertheless, it is still argued that there is a development of issues of "concern" (i.e., issues of identity, and the establishment of routines) that teacher educators must address and should "bring to the fore" rather than "waiting for them" to arise (Loughran, 2006). Teacher education programs often focus novices’ attention inward, for example encouraging them to write

“self-study” reflections about their teaching. Focusing novices’ attention on themselves assumes that novices need to resolve issues with themselves before they can focus on student thinking (e.g., Freese, 2006).

Challenges to Stage-Based Views of Teacher Development

Stage-based models of novice teacher development have been challenged on theoretical and empirical grounds. Because of the prominence of Kagan’s (1992) review, it has been the proximal target for much of the criticism.

Grossman (1992) argued that Kagan’s review omitted literature that demonstrated preservice secondary teachers’ abilities to think deeply about how to teach their subject matter to students before establishing classroom routines (Grossman & Richert, 1988; Shulman, 1987; Wilson & Wineburg, 1988). While the preservice teachers in these studies did attend to issues of identity and classroom survival, “these concerns did not prevent them from reflecting deeply on issues related to the content of teaching” (Grossman, 1992).

Davis (2006) analyzed the reflective journal entries of preservice elementary teachers as they designed and taught lessons in a school-based practicum experience prior to a practice teaching semester. Her analysis of journal entries showed that the prospective teachers were able to attend to the substance of their students’ thinking as they reflected back on lessons. While some have found teachers’ reflections on student learning to be primarily focused on students’ interest and motivation (e.g., Abell, Bryan, & Anderson, 1998), these results showed new teachers’ can attend to student learning in more substantive ways.

Darling-Hammond and Snyder (2000) described several teacher education programs that used case studies of students and classrooms, artifacts of practice, exhibitions of teaching performance, and problem-based inquiries to try to capture important attributes of teaching and reasoning about teaching in context. They argue that these assignments help beginning teachers to better understand the effects of their actions and better meet the needs of their students.

One line of evidence challenging the early emphasis on self-reflection and identity formation in teacher education is cited in Kagan's review. Shapiro (1991) interviewed 23 preservice secondary teachers throughout a methods course and classroom practicum, and found that the teachers began to see themselves as teachers as they interacted with students. This study, and others like it, support Kagan's claim that novices reconstruct their identity as they interact with and gain knowledge of students. They do not, however, suggest that novices must focus inwardly in their preservice teacher education programs. In fact, they suggest the opposite; it is precisely by focusing on student learning that preservice teachers reconstruct their identities.

Further challenges to stage theories focus on what happens with experience. Stage models imply that having developed classroom routines that work, experienced teachers will flexibly adjust their routines when they appear not to be working (e.g., Berliner, 1988). Evidence shows otherwise: Teachers often become satisfied with their teaching and less likely to question their chosen routines as their careers progress (Grossman, 1992).

An argument central to our conjecture below is that stage theories take little account of institutional systems. A number of researchers have argued that teacher

attention is largely organized by elements of the institutional system in which teachers work, including reform priorities, standards and assessments, local professional communities and their tools, and institutionalized norms of student and teacher relationships (Coburn, 2004; Cohen, 1990; Herbst, 2003; Jenkins, 2000; McLaughlin & Talbert, 2001; Rop, 2002; Settlage & Meadows, 2002).

In this study, we add to theoretical and empirical work that questions assumptions of stage theories of teacher development. First, we provide several examples of novice teachers attending to student thinking in classrooms *while teaching*, and we use these examples to articulate what we mean by attention to student thinking. Second, we suggest an alternative theoretical explanation for novice teachers' frequent struggle to attend to student learning, arguing that these patterns arise at least in part out of how the systems of public school teaching and conventional teacher education programs organize novice teachers' attention. Finally, we argue that the evolving arguments against the assumptions of stage-based accounts suggest a different approach to teacher education, one in which teacher attention to student thinking is prioritized.

Novices' Attention to Student Thinking

There is evidence in the literature that novices can attend to student thinking when examining records of practice outside of class (Darling-Hammond & Snyder, 2000; Davis, 2006). We have collected such evidence as well (see also Appendix B).

Advocates of a developmental perspective could argue, however, that their account concerns what takes place during instruction. Our primary purpose here is to present evidence of novices' attention to student thinking in real-time, during their

teaching. We then turn to case studies of interns who struggled or failed to attend to student thinking, and we offer an alternative account of their difficulties.

Research Context and Methods

The data for the study is from the 2006-7 graduate initial teacher certification program at an Eastern state university. Most candidates in the program work as paid part-time teachers, or “interns,” in a local school district while they take their courses; a few follow a more traditional student teaching model in which they progressively increase their leadership of classes throughout the school year. In 2006-7, there were nine paid interns in the program; they are the focus for this study.

The program includes science pedagogy seminars that emphasize the substance of student thinking. During seminars, which begin in the summer prior to their teaching placements and continue through the year, interns examine records of practice primarily with respect to evidence of student reasoning, first drawing on existing examples and then collecting their own (Hammer, 2000b; Hammer & van Zee, 2006; Sherin & Han, 2004). Their assignments include the preparation of case studies from their classes, at least one of which must include video the candidate selects and transcribes for presentation in seminar.

In addition, interns are supervised five times each at their schools. The first author shared responsibility for supervision with another staff member; he made 1-5 observations per intern. Supervisory visits and follow-up conversations also emphasize the substance of student reasoning, as evident in class. The science pedagogy courses are the only ones that systematically focus candidates’ attention on student thinking, as one might expect: the substance of that thinking is specific to science.

The data for this study include (1) video recordings, 1-3 classes per intern, prepared as part of their seminar assignments, (2) field notes from the first author's in-class observations, 1-5 observations per intern, (3) the teacher interns' papers in their science pedagogy seminars, taught by the first author, and (4) the teacher interns' remarks during seminar discussions and in interviews, gathered from field notes and recorded on videotape. From these data sources, we have selected examples from four of the nine interns, whom we identify by the pseudonyms Scott, Susan, Emma, and Kay. We chose these four interns because they represent the range we observed across the nine; we provide brief descriptions of data for the remaining five. See Appendix B for further documentation.

For analyses of classes from field notes or video, we consider it evidence of attention to student thinking when the intern notices and responds to a student's idea. The response may be the intern's asking the student or other students to explain or elaborate on the reasoning, rephrasing the idea herself, or shifting the flow of classroom activity in a way that addresses the idea. We also consider it evidence when an intern later reports noticing an idea during class when she identifies it specifically, even if she did not overtly respond at the time. It is not evidence, however, if the intern notices or responds only to correctness; the response or report must focus on the sense of the idea from the student's perspective.

Although not the emphasis here, we note that similar criteria apply to our analyses of written assignments: We consider it evidence when an intern makes a claim about student reasoning that is supported by evidence in the data—that is, in the video, transcript, or student written work. Again, it is not sufficient for the claim simply to

identify whether the student is correct or incorrect; the claim and support must concern the sense of the student's thinking from the student's perspective.

The examples we present illustrate our application of these criteria, with respect to classroom observations and video and to interns' written reflections on these classroom episodes.

Early Attention to the Substance of Student Thinking

We begin with Scott and Susan, who needed little help in focusing their attention on student thinking. We then turn to Emma, who seemed to shift her attention toward student thinking over the course of the year, and Kay, who did not.

Scott

Scott was teaching three sections of high school biology in a public school. The following took place in October of his first semester teaching; it is based on field notes from the first author's observations.

Scott had filled a plastic bottle with water and frozen it to demonstrate that water expands when it freezes. (The water level rises in the bottle.) One student, Cindy, asked, "If something frozen expands, does it always expand to the same amount?" Scott asked her if she could explain more about what she meant, and she asked if she could draw something on the board. She drew six bottles on the board like the bottle in the demonstration. She labeled two bottles as soda, two as water, and two as juice. She indicated that one of each pair would be frozen, and she wanted to know, in which would the level of the liquid rise the most?

Scott told her that it was a great question, and he asked her what her "instinct" was. Cindy said that she didn't know, and Scott turned to the rest of the class and said,

“Let’s open it up. What do you guys think? If they start at the same level, which will rise the most?”

Several students said they would all be different, although no one offered an explanation. Scott asked if anyone thought they would all be the same. Princess thought the water would not rise as high as the soda, and the order would be “soda, juice, then water, ‘cause soda has caffeine in it.” Scott asked her what caffeine had to do with it. “I don’t know,” she said, “It has to do with science.”

Scott continued to push students to come up with explanations for why they thought the three liquids would rise to different levels. Kathy thought that the juice would be lowest, but could not explain why. Another student didn’t offer a prediction, but pointed out that soda was “mushy” when it froze and water was “hard.” Other students agreed that this would influence the outcome, although no one was really sure how it would affect it. Someone mentioned that the class could do an experiment to test the various predictions.

Scott talked about this class during the seminar. He said that he initially let Cindy come up to the board because she often had good ideas, but was not always engaged, and he wanted to keep her engaged in the class discussion. He was very impressed with her question, pointing out that she had designed a controlled experiment without being directed. He also pointed out that students were able to draw on their everyday experience to think about the problem, like the student who observed that soda is “mushy,” while water is “hard.”

The evidence of Scott's attention to student thinking includes his request to Cindy to explain her original idea and, when she had clarified her question, his using that question as the focus for the next several minutes of conversation.

Susan

The following is based on a lesson Susan videotaped and analyzed for the science pedagogy seminar. The lesson took place in November of her first semester teaching, at the same school as Scott; the two split a full-time schedule for their paid internships.

Like Kay in the example that opened this article, Susan was teaching a lesson on mitosis, but her approach was quite different:

My goal for the lesson was for students to come to an understanding of the cell cycle through exploration and discussion, rather than direct instruction. I wanted the students to construct their own understanding of the cell cycle process. I anticipated that this approach would produce really creative responses.

The students had no prior instruction on cell division. Susan began by showing a five second animation of a cell splitting into two and had the students discuss two questions in small groups: "Why do cells need to divide?" and "How do cells divide?" After about 15 minutes, Susan brought the class back together. What follows is a transcript of the discussion about the "Why" question, and Susan's reflection.

1. Susan: Okay, let's go Addie and Jill—what reasons did you come up with for why cells need to divide?
2. Addie: So that there are always good cells and new cells and so that there are always more cells when cells die
3. Charles: Cells escape from your body.
4. Susan: How do cells escape from our bodies?
5. Charles: Ummm, like urine, spit, semen, tears, blood.
6. Nat: Like if you cut yourself
7. Charles: Anything that exits your body.
8. Claudio: Isn't dead skin cells
9. Nat: Growth
10. Susan: So let's get some of these up (on the board)...Nat, what'd you say?
11. Nat: Growth

12. Susan: So when we grow—
13. Nat: You need more cells, those cells need to break up and create more so that people grow. That's how we get taller.

We see evidence of Susan's attention to student thinking when she asks Charles to explain how cells escape from our bodies (4) and when she asks Nat to repeat what he had said (10) and to elaborate on his use of the word "growth" (12). We also see evidence of attention to student thinking in Susan's written reflection on this exchange:

Right after Addie, Charles said something about cells "escaping from our body." Examples that Charles gave of cells "escaping from our body" were urine, spit, semen, tears, blood. I thought that this was a great response (that we needed to replace cells which we lost), and am so intrigued by the word "escape." I wonder if Charles had an idea that, in general, cells were trying to escape, but something was somehow keeping them in²².

Susan's statement that "I thought that this was a great response" is further evidence she noticed Charles's idea in the moment. Her subsequent wondering about the word "escape" illustrates what we take as evidence of an intern's ability to interpret student ideas from records of practice.

These examples illustrate evidence of interns' attention to student thinking during class. For four other interns, like Scott and Susan, there is evidence from video or field observations within the first few months of their starting to teach. For two other interns, we did not see evidence of that attention until the spring semester. In all, however, the evidence shows eight of the nine interns in our program were attending to student thinking within their first year of teaching, during their classes as well as in their out-of-class reflections (see Appendix B). Several of the teachers, including Scott and Susan, did seem to be contending with their roles as teachers and management of the classroom, but these concerns did not prevent them from attending to student thinking. In

²² We don't agree with Susan's interpretation here, but she does *have* an interpretation.

interviews, both Scott and Susan identified attention to student thinking as the foundation of their teaching, and they credited the science pedagogy course sequence for focusing their attention in this way.

In the next section, we argue that part of the dynamic of the interns' attention reflects their involvement in two larger systems — the school and the credential program.

An Alternative Account of Early Difficulties

As we reviewed above, stage-based accounts hold that attention to student thinking is a later stage of teacher development, necessarily following the earlier steps of identity formation and mastery of classroom routines. In the previous section, we provided evidence of novices' early attention to student thinking, contributing to the case against accounts of developmental limitations. In this section, we offer an alternative theoretical account for why interns do or do not attend to student thinking.

In particular, we argue that the systems in which teachers operate direct their attention in various ways, and in general the systems they find in their school placements direct their attention to their own behavior, to classroom management, and to curricular fidelity. In contrast, we designed our science pedagogy courses specifically to direct attention to the substance of student thinking. We draw on observations of two interns, Kay and Emma, who split a full-time position in seventh and eighth grade science at the same middle school.

Emma was one of the two interns for whom we did not see attention to student thinking until the spring. Kay was the only intern for whom we never saw that attention. Their cases provide evidence of influence by the respective systems of the school and program.

Emma

Throughout most of the year, Emma was trying to attend student thinking to guide her teaching. She told university supervisors and school administration that she valued “discourse” and “inquiry,” and she was occasionally able to engage students in substantive conversations about scientific phenomena. Frequently, however, her class was disorganized and loud, and she had difficulty moving through lessons in a focused manner. Indeed, Emma fit the standard pattern of struggling at first with classroom management.

Her video case study in February illustrates both her coming to attend to student thinking as well as the tensions she felt about doing so. The students were discussing what happened when she dropped an Alka-Seltzer tablet into a cup of water. Emma had previously explained the definition of chemical change, as a change in which “a new substance is created.” Now she wanted to see whether they could apply that definition to the demonstration.

1. Emma: So I have Alka-Seltzer and I add water to it. Is that a chemical reaction?
2. Students: No... no... yes... no... yes
3. Emma: (to students who said yes) So, okay, so why is it a chemical reaction?
4. Charles: (unrecognizable)
5. Emma: You are saying that the bubbles dissolving is a chemical reaction.
6. Charles: Yes
7. John: Because the Alka-Seltzer is mixing in the water
8. Emma: Because you're getting a mixture. Okay.
9. Alice: Because if it's creating bubbles then it's creating something new
10. David: No... I have a statement. It's just letting all the air out.
11. Emma: Okay. So you think it's because it's letting all the air out.
12. David: Yes

The evidence of Emma's attention to the substance of student thinking includes her reflecting students' ideas back to the class so that they could be considered by others

(5, 8), and similarly with David's disagreement (11). Additionally, Emma used this brief exchange as an opportunity to pursue the students' idea that bubbles were a sign of a chemical reaction. There was further evidence in what she wrote later:

My inclination was to probe the students' association with bubbles and reactions. Hence, I expanded on the original example with an additional visualization. This time I took a bottle of cranberry juice and shook it to create bubbles....

[David thought] you could simply see the bubbles more easily when you added water. The water was "letting the bubbles escape from the tablet." David believed that bubbles were already in the tablet and were trapped. I am unsure if he meant this as a physical or chemical reaction though.

Emma's uncertainty over whether David considered the release of the bubbles a physical or chemical change was an example of something she described more generally:

[O]n the video, I noticed a lot more assertions I could have probed to understand student thinking. However, we did not have enough time with those students I did probe. Hence, I again find myself facing the conundrum of getting through the curriculum as opposed to allowing the students to think independently.

In this way, Emma expressed a tension in objectives reflecting the different agendas of the systems in which she participated. On the one hand, Emma was learning to participate in the practices of the system represented by the credentialing program, which drew specific attention to student thinking, and required evidence of student thinking for course assignments. On the other hand, she was learning to participate in the system represented by her school. Under pressure from the science department and administration to keep up with the curriculum, Emma's attention was divided. While she saw the value in attending to student thinking, and asking students to articulate their ideas, she was always aware of the time she was taking away from coverage of the curriculum. Emma contrasted "getting through the curriculum" with "allowing students

to think independently,” suggesting that she experienced curricular expectations as a barrier to desirable learning outcomes.

Kay

Kay’s attention was not so divided. By her accounts and by the observations and video data of her work, she attended primarily to classroom management, student behavior, and the correctness of students’ answers judged against the canon. The snippet from her class at the beginning of this article was one example. Another was in a lesson on meteorology, when she asked for a volunteer to explain what an “isobar” was. Briana responded that isobars were “lines on a map joining the same air pressure.” “Joining?” replied Kay. “Or connecting,” said Briana. Asked later what she thought of Briana’s initial response, Kay indicated that she wanted Briana to use the word “connecting” instead of “joining,” because connecting was the word that Kay had used in defining the term isobar for the students. In all, Kay noticed and responded to the fidelity of students’ language to the curricular versions; she did not probe for or notice evidence of student understanding, such as of how Briana understood the concept of a line of constant air pressure.

It was only when specifically pressed to comment on the substance of student thinking, in person during seminar discussions or in supervisor meetings, that Kay showed she was able to do so. That she could respond to direct requests — “what do you think the student might have been thinking” — suggests she, too, had nascent abilities, but there was not evidence of her using them.

Systemic Influences on Attention

Why did Emma come to attend to student thinking but Kay did not? There are many factors that could influence interns' attention to student thinking, including their academic experiences, epistemological stances toward science and learning, and participation in the systemic contexts (or, most likely, some complex dynamic of these and other contributing factors). We are interested to understand how different teachers' abilities to attend to student thinking emerge, but an in-depth exploration into the complex dynamic around each candidate is beyond the focus of this paper. Here we focus primarily on the role of the systemic contexts in which teaching is learned.

Kay, in fact, was the only intern to enter the program who did not take the program seminar in the summer before, taught by the first author. Rather, Kay had completed a more traditional initial pedagogy class focused on curricular fidelity and classroom management, and it satisfied the same formal requirement. In other words, when Kay began teaching, there was no tension of objectives or competing influences on her teaching; her course work and the school directed her attention toward similar issues. As Kay began teaching, her attention was on student behavior and curricular fidelity, and this was only supported by the school system itself.

Emma did, in fact, struggle with classroom management, and for the school system that was the over-riding issue. While university faculty and supervisors were concerned about Kay, the school administration was much more concerned with Emma. The assistant principal recognized that Kay's classroom was highly rigid and presented little opportunity for students to articulate their ideas, but she was gravely concerned with Emma's classroom management difficulties. She appeared to assume that Kay would learn to attend to student thinking, possibly influenced by developmental accounts, but

treated Emma's management difficulties as a more serious problem. While Kay was left alone, in and out of the classroom, Emma was directed to meet with a staff development person daily to work on organizing her lessons, improving her presentation, and managing student behavior. Her continuing endeavors to engage her students' inquiry and listen and respond to their ideas were not prioritized in these sessions.

This example suggests that the system surrounding public school teaching prioritizes other concerns (i.e., classroom management and content coverage) over attention to student thinking. In this public school context, Kay's difficulty in attending to student thinking was a minor concern, sending the message to Kay that her practice was appropriate, and, possibly, helping to stabilize her stance toward students and teaching. Viewed alongside the evidence that other novice teachers (e.g., Scott, Susan, and Emma) were able to attend to the substance of their students' thinking, Kay's difficulty, and the lack of concern by the administration, supports reinterpretation of stage-based theories of teacher development, particularly the role of context in shaping what novice teachers do (Loughran, 2006).

We do not doubt in the slightest that it was important for Emma to learn strategies of classroom management. What we challenge are practices of focusing on management and curriculum to the exclusion of substance, as well as the contention that she should first develop routines before she tries to hear and respond to student ideas.

Implications for Teacher Education and Learning to Teach

Evidence from our case studies adds to existing arguments that teachers' attention to student thinking is complex and context-sensitive. In this section, we argue

that this finding has implications both for how we design teacher education and how we understand learning to teach.

While we see some examples of novice teachers (e.g., Kay) struggling to attend to student thinking, we have presented evidence that many novice teachers can begin to attend to student thinking early in their teaching careers. This finding has important implications for teacher education. If it is possible even for some novice teachers to attend to student thinking, then we should make this an explicit agenda in science teacher education, by structuring activities and assignments that give them practice in attending to student thinking. Attending to student thinking is an important first step in providing responsive instruction that can help students construct understanding of scientific concepts, reason scientifically, appreciate the nature of science, and engage in scientific practices.

Absent other influences on their attention, beginning teachers may focus their attention on themselves and their behavior (as suggested by the teacher development literature) rather than on their students, and may thus not draw upon their nascent abilities for attending to others. Teacher education programs that focus novices' attention on themselves, through practices such as "self-study" papers, may feed into this pattern. We take a different approach in our science pedagogy course sequence, designing our courses to amplify attention to student thinking by having novice teachers watch videotape of classrooms and analyze data from their own and others' classrooms with an eye toward what students are thinking as they participate in science classes. We also encourage teacher candidates to identify themselves as responsive teachers, who listen to student ideas. Participation in these practices apparently supported novices such as Emma in

learning to attend to student thinking in real-time, in the classroom. Teacher education should support and amplify novice teachers' nascent abilities to attend to the substance of student thinking.

We have argued that one major reason that novice teachers struggle to attend to student ideas and reasoning is their participation in the social and institutional systems of public schooling, which prioritize classroom management and curricular coverage. As participants both as students and teachers in these systems, novice teachers learn teaching routines that focus on these priorities. For example, Kay's use of "triadic dialogue" can be thought of as a routine that functions to help the teacher to manage an orderly classroom and maintain authority as the holder of "correct" knowledge.

Routines themselves are not a problem. All teachers form routines in learning to teach. Emma used a routine of "reflecting" students' meaning back to them for further comment. This "reflective toss" (Van Zee & Minstrell, 1997), is a powerful routine for attending to student thinking. The reflective toss was modeled in the science pedagogy courses, and many of the interns who were successful at attending to student thinking engaged in this kind of dialogue with their students. The point is that routines should be learned from within a framing of teaching as attention to student thinking. We argue that if attention to student thinking is not prioritized until after novices begin to construct routines (as suggested by Kagan, 1992), then novices may construct routines that distract from attention to student thinking.

In short, the systems of traditional science teacher education and public school teaching fail to build on teachers' nascent abilities to attend to student thinking, encouraging routines that are focused on other priorities. A teacher who is not

predisposed to think of science teaching in terms of attention to student thinking will not necessarily reconsider her practice on her own without outside support.

The institutional and social systems of public schooling are themselves complex. Teachers' participation in local communities of practice in their academic departments, for example, can strongly influence their attention (McLaughlin & Talbert, 2001; Siskin, 1990). Strong professional relationships, co-planning, and co-teaching with others focused on attention to student thinking may help support novices in learning to attend to student thinking. Scott and Susan, for example, shared a classroom, met daily to plan together, and jointly reflected on lessons in their classrooms. By contrast, Emma and Kay did not have a close professional relationship, and they were not able to offer each other that level of support.

In conclusion, our empirical findings support challenges to stage-based theories of novice teacher development (Davis, 2006; Grossman, 1992) and provide evidence of novice science teachers attending to student thinking from their earliest experiences in the classroom. The evidence suggests an alternative explanation for the observation that novices often fail to attend to student thinking. This is largely a reflection of the ways in which the systems of public school teaching distract from attention to the substance of student thinking, and not inherent developmental limitations of novices. We suggest further exploration into the abilities of novice science teachers in order to better understand the complex dynamic that shapes novices' attention, and to further inform teacher education practices that can amplify novices' attention to the substance of student thinking.

Chapter 5: Understanding Teachers' Attention in the Classroom²³

Introduction

The exchange below occurred in a 10th grade biology class following the presentation of a computer simulation demonstrating how natural selection is thought to have occurred among peppered moths in England during the Industrial Revolution. The simulation illustrated that dark colored moths became more abundant than light colored moths, presumably because their color camouflaged them against the backdrop of the soot-stained trees, protecting them from predation. After showing the simulation, the teacher (Ms. Hawkins²⁴) engaged her students in conversation:

1. Ms. Hawkins: How do you think that this dark moth came about, the very first one? Edwin? Why do you think it changed it?
2. Edwin: Mutation
3. Ms. Hawkins: Ok, so he said it could be a mutation, something in the genes could get changed, and it would cause the moths to get dark. Ok, Good. Ok, so, this goes along the lines of, um, the moths just didn't think that, "Oh! Let me turn dark!" Right? Do they think that?
4. Student: No
5. Ms. Hawkins: No, ok. Catherine?
6. Catherine: I have a question, do you know how they said I think 90% of the moths in England now are dark...So since the first dark moth, did like the other ones think they're more attractive, and that's how they made more and more and more?
7. Ms. Hawkins: Well, it goes along with Edwin's, and Bethany's idea that a mutation most likely has occurred.
8. Catherine: Oh...ok

We focus here on how Ms. Hawkins *attended to* Catherine's question in line 6.

Catherine poses a mechanistic question about how the dark color genes spread throughout the moth population. Ms. Hawkins' immediate response suggests that she may not have

²³ A version of this chapter is presently being submitted as a paper to the Journal of Research in Science Teaching, in collaboration with Janet Coffey and David Hammer.

²⁴ All names in this manuscript are pseudonyms. The teacher is the fourth author; in the final manuscript we will use her real name.

heard a mechanistic element in Catherine's reasoning, or even the emphasis on sexual selection, in the moment, even though she was able to discuss possible interpretations of the question during a follow-up interview.

Did Ms. Hawkins simply not understand Catherine's question? Did she understand the question and choose not to pursue the comment so as to not confuse other students? Alternatively, was she distracted by her attention to whether or not her students "got" the main ideas and used vocabulary terms intended for the lesson? Perhaps the answer lies in some combination of the above.

Second guessing a teacher's move hardly seems worthwhile. However, we argue that trying to better understanding a teacher's move, in particular what draws and demands her attention, could be productive. What a teacher attends to in the classroom – even in informal interactions – matters. It matters in terms of the nature and type of feedback teachers provide. It matters in terms of what it marks to students as being worthy of attention in the subject area. In short, it matters for students' science learning. If teachers are to support students' abilities to understand and use conceptual knowledge, reason scientifically, and participate in scientific practices, as science education reform documents suggest they should (NRC, 2007), teachers must attend to the substance of students' thinking.

Examples like the one from Ms. Hawkins' classroom motivate the research questions we take up in this paper: *To what do science teachers attend in the classroom? And, what shapes this attention?* We describe an episode from Ms. Hawkins' class in order to speak to these questions. We use Ms. Hawkins' and her students' actions and language in the classroom and Ms. Hawkins' reflections gleaned in interviews about the

class to explore what she was *explicitly* attending to in the moment, while teaching. Subsequently, we draw on data collected during hundreds of hours of classroom observations, teacher interviews, conversations among teachers in a professional development setting, and reviews of curriculum and assessment tools available to teachers in Ms. Hawkins' district, to construct a theoretical argument that teachers' attention within the classroom is largely organized by the institutional systems in which science teaching is situated. Although we ground our argument in Ms. Hawkins' classroom, this paper is not solely about Ms. Hawkins' attention. Rather, we explore how the systems in which teachers work shape their attention. In order to make the connection between a teacher's classroom and the larger system within which she teaches, we consider the multiple accountabilities teachers face and how these become consequential for day-to-day science teaching. We conclude by discussing implications for teacher education and professional development.

Everyday Assessment -- An Issue of Teacher Attention

Before we proceed, it is worth establishing why we care about teacher attention in the first place. Research has begun to conceptualize assessment as an everyday classroom activity in which students and teachers participate (Atkin & Coffey, 2003; Cowie & Bell, 1999; NRC, 1996, 2001), and a growing body of work points towards the strong influence that perceptive, ongoing diagnosis of student thinking has on a teacher's instructional moves and student learning (Black & Wiliam, 1998; Cowie & Bell, 1999; Hammer, 1997). The more responsive teacher feedback is to students, the more useful it can be for both teachers and students. Assessment that occurs moment-to-moment in

classroom activities concerns, fundamentally, teachers' attention to student ideas and reasoning (Ball, 1993; Sadler, 1998).

The question arises, attention *to what*? What aspects of student thinking are teachers attuned? In the class described in the opening example, for instance, Ms. Hawkins appeared to be attending to many things. One primary focus appeared to be on her students' use of terminology. With her attention focused on use of the term *mutation*, she overlooked what students understood about what a mutation is, how a mutation can cause a moth to be a different color, or how a single mutation could lead to the spread of a physical trait throughout a population. We are not arguing that a teacher cannot attend to multiple things at once, but, in this snippet of interaction, it appears that her primary focus on students' use of the term *mutation* may have contributed to her not attending to the substance inherent in Catherine's question, which concerned how a mutation could spread through a population.

Consensus exists in science education literature that listening and responding to the substance of student thinking and recognizing and responding to their engagement in scientific practices are important aspects of teaching science (NRC, 2007). After all, ideas and reasoning are the stuff of science. In order to support students' science learning, teachers need to prioritize and be responsive to the meaningful substance of student ideas and reasoning in their classroom. This, then, becomes *the what*, not students' use of particular terminology. Our premise here is simply that assessment requires attention: Teachers can only meaningfully assess that which they notice and attend.

We return briefly to the opening example to consider what attention to student ideas and reasoning might look like in the classroom. We could imagine other responses

that would suggest the teacher had heard students' reasoning and ideas. For example, the teacher could have asked Edwin to elaborate on what he meant by his response, "Mutation," or have asked Catherine to elaborate on her question. She could have tossed out a question to the class asking how the mechanism embedded in Catherine's question differed from Edwin's idea of mutation. In perhaps subtle ways, these moves, among others, may have indicated that a teacher was actively attending to the substance of her students' ideas and reasoning, and not primarily monitoring for use of correct terminology.

As we stated, we do not see attention to various foci as necessarily mutually exclusive. In other words, if a teacher attends primarily to one thing, they can attend to other things as well. We see some evidence that Ms. Hawkins' was attending to student reasoning in the example above. In response to Edwin's answer of "mutation", she remarks to the class that the moths "didn't just didn't think that, 'Oh! Let me turn dark! Right?'" This seems to suggest that she wants to hear more about how mutations occur; she is looking for a mechanism. However, teachers cannot attend to everything in a classroom. Often, it appears teachers have orientations towards a particular type of thing, and this can serve as a selective filter for what gets and does not get explicit attention.

One reason to consider what teachers attend to is in light of the everyday assessment literature that underscores the importance of close attention to student ideas for guiding instructional moves and teacher feedback. Not unrelated, another reason to care about teacher attention is its effect on student attention: If a teacher is paying attention to the substance of student thinking, students are more likely to pay attention to that substance (Warren & Rosebery, 1995). After uncovering what Edwin meant by way

of “mutation,” if the teacher were to ask Catherine or the class how the mechanism in Catherine’s question was similar to or different than what Edwin meant by “mutation”, she would help focus their attention on consideration of reasoning. In doing so, she would help send a message to students about the importance of reasoning in science. As we noted above, Ms. Hawkins begins to achieve this when she asked if the moths could just think they wanted to change color. For this paper, we take it as another premise that learning science involves learning to attend to — and to assess — ideas and reasoning. Therefore, we care about teacher attention not only for the information it provides teachers but also for what it emphasizes and how it models to students key aspects of scientific reasoning and ideas about the nature of science.

Existing Research on Teachers’ Attention

Much of the existing research on teacher attention involves the study of teachers outside of the classroom, when watching video of classrooms or reviewing other records of classroom practice. Much less has explored teachers’ attention while actually teaching. Below we share findings about teachers’ attention from both perspectives.

Teachers’ Attention When Reviewing Records of Classroom Practice

The predominant body of literature discussing teachers’ attention comes from mathematics education research and uses the related term “noticing” (Jacobs et al., 2007; Sherin & Han, 2004; van Es & Sherin, 2006). Van Es and Sherin (2006) propose that the skill of noticing consists of (a) identifying what is important in a teaching situation and (b) drawing on one’s knowledge of teaching and learning to reason about the situation. In this sense, noticing depends both on teachers’ ability to focus their attention on “what

is significant in a complex situation” (p. 125) and draw on their “pedagogical content knowledge” (Shulman, 1987) of students, subject matter, and the school context to reason and interpret what they notice. Despite efforts to decompose aspects of noticing into particular skills (e.g., Jacobs et al., 2007), these aspects are co-constitutive. That is, teachers are constrained in focusing their attention by relevant background knowledge that helps them to interpret classroom events as significant. Likewise, it is impossible for teachers to interpret or reason about something upon which they do not focus their attention. We see our work as relevant to this discussion in the literature, although much of this work explores what teachers attend to while looking at videotape and other records of teaching.

There is evidence that even experienced teachers initially have difficulty focusing on the substance of student thinking in their content area when investigating records of practice such as videotape, transcripts of classroom events, and student work (Hammer, 2000b; Sandoval et al., 2002; Sherin & Han, 2004). This might suggest that these teachers lack pedagogical content knowledge or cannot pay close attention to their students, but other possible explanations exist as well. First, like practitioners in other fields, teachers’ attention is largely tacit (Schon, 1983). For example, in conversations with a group of physics teachers around records of practice, Hammer (2000b) found that teachers’ attention was frequently drawn to the actions of the teacher. He pointed out, however, that comments about teacher action often served to convey an interpretation about students’ understanding. These interpretations were usually implicit, and teachers lacked the language to talk about them. From this study, he concluded that teachers have

the ability to attend to student thinking, but are not accustomed to practices of talking about student thinking.

Second, teachers are not accustomed to focusing primarily on the substance of their students' disciplinary thinking. In any classroom, there are multiple things that may capture teacher attention: Are students engaged? Is the teacher being equitable to all students' participation? How is the class progressing with respect to the curricular goals? (Hammer & Schifter, 2001)

Since attending to the substance of student thinking has not been a regular aspect of teachers' practices, professional development efforts in both science and mathematics education have sought to focus conversations about records of classroom practice around the substance of student thinking. Research has shown that these efforts, designed to help teachers get into the habit of attending to the substance of student thinking and developing their abilities to hear and interpret students' ideas, have helped many teachers become more sophisticated in hearing and interpreting student thinking (Hammer & Schifter, 2001; Sherin & Han, 2004).

Evidence exists from both the science and mathematics education literature that teachers can attend to the substance of students' thinking while reviewing records of practice, or at least that they can learn to do so with support and professional development. In this paper, we are more concerned with how science teachers attend to student thinking *while teaching*. We now turn to that body of literature.

Teachers' Attention During Instruction

The focus on teachers' attention in examining records of practice is important, as it is generally assumed that teachers cannot attend to student thinking in the classroom if

they cannot do it when examining records of practice (Jacobs et al., 2007). The reverse is not necessarily true, however; we cannot presume that teachers can attend to student thinking *in situ* just because they can do so upon reflection with colleagues.

There are studies that have proven illuminative in this area. Work by Ball (1993), Lambert (2001), and Hammer (1997), for examples, have highlighted what they as classroom teachers noticed in terms of student thinking, how they made sense of student remarks and work, and how this informed their instructional moves. We would argue, however, that these descriptions, while rich, do not capture – nor do they claim to – a range of “typical”. These researchers taught as part of a larger research agenda and in many ways, sat outside the confines of the school systems in which they worked. In this sense, their teaching contexts did not reflect that of a typical classroom teacher, although they offer insights to better understanding the complexities of teaching and its inherent decision-making.

While there is little work in science education that directly addresses what science teachers attend to during classroom instruction, existing studies suggest that teacher attention is divided among numerous possible foci; student thinking is not always a central priority. Literature documents that teachers may attend to how to manage instructional time and cover the curriculum (Jenkins, 2000; Rop, 2002; Settlage & Meadows, 2002). Other work notes teachers’ attentiveness to issues of student engagement or interest (Olitsky, 2007). Our work, among others, points to teacher attention to the recognition of correct vocabulary, or repetition of some canonically correct idea as reified by the curriculum (Gearhart et al., 2006; Levin, Hammer, &

Coffey, in press). We situate this study within this gap in the research, directly exploring what science teachers attend to in the classroom, while teaching.

Unpacking Teachers' Attention in the Classroom

In the following sections, we present the data from Ms. Hawkins' class and analyze how she attends to the student thinking in evidence. We also draw on other data sources to triangulate our findings and to move the focus beyond Ms. Hawkins.

Research Context and Methods

The data for this paper were collected during the 2005-2006 and 2006-2007 school years. We observed over 100 hours of biology teaching in Ms. Hawkins' school and throughout the school district during this span of data collection. Along with seven other teachers in the district (three from her school) and university faculty and graduate students, Ms. Hawkins participated in a collaborative research program focused on better understanding teachers' modifications of curriculum. The classroom of each teacher in the group was observed and videotaped at least four times a year; classrooms in Ms. Hawkins' school were each videotaped at least six times, and observed (with detailed written field notes) at least two additional times. We selected the example from Ms. Hawkins' class as representative of the teaching we observed, particularly with respect to what she attended to while teaching.

The data for this paper include (1) the video recording from Ms. Hawkins' class, (2) audio recording of Ms. Hawkins' comments about the class in an interview with the first author, (3) audio recordings of interviews with other biology teachers in Ms. Hawkins' school, (4) the first authors' field notes as a participant observer (Becker &

Geer, 1982) during the 2005-2006 school year, teaching biology at the same school as Ms. Hawkins, and (5) video recording of teachers in the research group discussing the video of Ms. Hawkins' class. This last data source provides insight into the socially-shared aspects of teachers' attention, and reveals the range of possible foci of attention that are articulated among a group of teachers operating within the social norms of the group (Herbst & Chazan, 2003). Selection and analysis of this data is also informed by the larger corpus of data from the research and professional development project.

For analyses of classes from field notes or video, we consider it evidence of attention to the substance of student thinking when a teacher notices and responds to a student's idea. Such responses can take on a variety of forms. The response may be the teacher asking students to explain or elaborate reasoning, rephrasing the idea herself, or shifting the flow of classroom activity in a way that addresses the idea. We also consider it evidence when a teacher later reports noticing an idea during class when she identifies it specifically, even if she did not overtly respond at the time. It is not evidence of attention to the substance of student thinking, however, if the teacher notices or responds *only* to correctness; the response or report must focus on the sense of the student's idea. Elsewhere, we have provided other specific examples of what we consider evidence of attention to student thinking (Levin et al., in press). In this study, we move beyond discussing *whether* a teacher can attend meaningfully to students' ideas and reasoning in the classroom to consider *what* she attends to when listening to students' ideas' and reasoning, and what influences that attention. We are interested in exploring the dynamics of teachers' attention, which includes exploring the conditions that exist when teachers are attending to the substance of student thinking, and subsequently, when their

attention is pulled away to other priorities. As part of this, we seek to understand their commitments of attention – when and what is sustained? What is deliberate, and what is more episodic?

“Why Do Giraffes Have Long Necks?” An Example from Ms. Hawkins’ Class

The following example captures an activity that occurred in Ms. Hawkins’ class at the beginning of the unit on evolution, prior to the peppered moth simulation and discussion that opened this paper. As a warm-up²⁵, Ms. Hawkins asked students to provide a written response to the question “Why do giraffes have long necks?”, which she also rephrased as “How did they get those long necks?”²⁶ She framed the goal of the activity to her class as “just finding out what you [students] think” and emphasized that there were no “right or wrong answer(s),” which she repeated several times as they completed the warm-up.

As students finished writing, she collected their responses and read through them quickly. She returned papers to four of the students. In the follow-up interview, Ms. Hawkins discussed her intention in doing this: She quickly picked out two papers that she thought espoused Lamarckian²⁷ theory and two that she thought were aligned with Darwinian views. She said that she wanted students to read their ideas aloud to compare the competing ideas and so that they could see that “other people have had these ideas before.” In the sections below, we present transcripts from the classroom conversation in

²⁵ In other school districts, the same kind of activity goes by different names, i.e., “drill”, “activator”

²⁶ These distinct questions are significant in the kinds of responses they activate. This discussion is beyond the scope of this paper. Briefly, there is evidence that “why” questions may activate teleological responses (need as a rationale for change), while “how” questions are more likely to activate mechanistic responses (Abrams, Southerland, & Cummins, 2001).

²⁷ Prior to Charles Darwin and Alfred Russell Wallace’s simultaneous publication of the theory of natural selection, a prominent theory of evolution was that of Jean-Baptiste de Lamarck, who argued that adaptive traits acquired during the life of an organism were inherited, thus ultimately leading to changes in species over time.

two snippets with accompanying interview data. These snippets and her comments ground our discussion about the nature of Ms. Hawkins' attention in the classroom.

Snippet 1: Nathan & Carrie

1. Ms. Hawkins: ...So, I'd like to hear your ideas, okay? ...Carrie, could you go ahead and tell us your idea? How did giraffes get long necks?
2. Carrie: Giraffes have really long legs, so they can't bend down to get grass, so they needed they needed the leaves of off the trees, so they reached up for a really long time until they had long necks.
3. Ms. Hawkins: So, did everyone hear her idea?
4. Students: No, what'd she say?
5. Ms. Hawkins: Okay, so can you just real quick summarize what you said?
6. Carrie: I said that since the giraffes have really long legs even though they had short necks, they couldn't reach the grass, so they needed the leaves so they reached up for a really long time from trees and they stretched up for a really long time till they got long necks.
7. Ms. Hawkins: Okay, so how many of you guys thought that idea?
8. Student: That they stretched out their necks.
9. Ms. Hawkins: Okay, so they stretched and they stretched and they stretched until they could finally reach the trees. Okay, that's a good idea, but I'd like to another student...Nathan, go ahead and read us what you wrote.
10. Nathan: I think the giraffe got a longer neck cause then he can get to his food.
[inaudible]
11. Ms. Hawkins: Is that what you wrote?
12. Nathan: yea.
13. Ms. Hawkins: It is? Okay. Why did you think that?
14. Student: What'd he say?
15. Ms. Hawkins: Why did you think that? ...Okay, so that they can eat, because if they don't stretch out there then...
16. Student: [inaudible]
17. Ms. Hawkins: Say it again? The trees are too tall, so either the trees need to shrink or the giraffe needs to grow his neck. Is that what you thought? Okay, that's kind of similar to what Carrie said.

In an interview Ms. Hawkins explained she selected Carrie's and Nathan's responses to represent a Lamarckian view of evolution. In response to the prompt, "*How do you think the modern-day giraffe got its long neck from short-necked ancestors?*" the two students wrote the following:

Nathan: *I think that the giraffe got his Long (sic) neck because they needed for they can eat from the tall trees.*

Carrie: *Giraffes have really long legs so they can't bend down to get the grass so they needed the leaves on the trees so they reached up for many years until they were just born like that and they can now eat from the trees.*

When asked in the interview to talk about ideas that stood out for her, Ms.

Hawkins mentioned Nathan's idea, but not Carrie's.

Researcher: Yeah, so what is it about Nathan's idea that stands out for you?

Ms. Hawkins: Umm...well I...well, he recognizes that they need to eat. So, you know, that's an important part of, you know, they wouldn't just be stretching their necks for the heck of it...you know, they need to eat, so they need to survive. So it's kind of tying in the, "in order to survive they need to have these long necks." But, just get that, the whole Lamarckian idea and presenting that to the class. So, I don't know if I do, but hopefully maybe they're referring when I say, "this guy Lamarck had this idea that's kind of similar to what Nathan and Carrie were thinking." And, umm...So, setting it up so they're you guys aren't the first ones to think this, you know? These two guys thought what Nathan and Carrie thought...

We see evidence in this snippet that Ms. Hawkins was able to attend to the substance of student ideas, both in class and upon reflection. She asked Carrie to repeat her idea so everyone in the class could hear it (3,5), and she asked Nathan follow-up questions to get a better understanding of what he was saying (13,15). As we will discuss below, however, we see evidence in both the classroom snippet and in her interview that Ms. Hawkins' primary attention was not on the substance of the students' ideas and reasoning.

Snippet 2: Hannah & Bethany (& Catherine)

After hearing from Nathan and Carrie, Ms. Hawkins then asked Hannah and Bethany to read their respective responses. Bethany's written response was misplaced so we are unable to include it verbatim here; Hannah wrote:

I think the Giraffe got long neck from short-necked ancestors because of there evolution. The giraffe environment started to change so they started to change to

adapt to the environment and to survive. Because tree (sic) are long they need a long neck to reach the food.

18. Ms. Hawkins: Hannah, can you go ahead and read us what you wrote.
19. Hannah: I think they have a long neck because they started evolving so they could survive in their environment.
20. Ms. Hawkins: Okay. What do you mean they needed to, needed to evolve?
21. Hannah: Like since I was gonna say...maybe the environment started changing and they need to survive, and in order to survive they needed to get their necks to be longer?
22. Ms. Hawkins: Okay, so they all talked to each other and said hey you need to grow your neck? How did it happen then?
23. Hannah: Maybe the stretching thing?
24. Ms. Hawkins: Oh, you think the stretching thing? Okay, Bethany can you read us what you wrote?

In the interview, Ms. Hawkins expressed surprise that Hannah had fallen back on the “stretching” explanation. She selected Hannah’s paper because she saw mention of the changing environment and the term *evolution*. She had assumed Hannah would provide an example of a Darwinian explanation. Hannah’s response was the first thing she mentioned when, after re-watching the tape of the discussion, she was asked if there were any student ideas in particular that she noticed:

Ms. Hawkins: Umm...well I guess, Hannah, what she said, but didn’t say. I mean, she read off her paper, but then when I guess she was asked to explain, she didn’t really elaborate. Her idea was more Darwinian. Umm...

Researcher: So what about her ideas is more Darwinian? And less Lamarckian?

Ms. Hawkins: Umm...so the environment started to change. So they started to change to adapt to the environment. So coming up with that idea that you know, in order to survive they’re going to have to have some kind of characteristic about them that’s going to allow them to survive in that changing environment.

Ms. Hawkins stated that Hannah “had the terms” and she “thought she was trying to say the right thing.” She admitted that she only did a cursory read of the responses before selecting them. She explained that she just “rushed through, I flipped through them. I was like, okay, they have evolution, adapt, and I just asked them to read theirs.”

Ms. Hawkins next asked Bethany to read her response.

25. Bethany: Um I said that the giraffe probably adjusted to their environment [inaudible] by a genetic gene that was passed through each generation.
26. Ms. Hawkins: Ohhh! (*raising voice*) Can you maybe say it in um uh/
27. Bethany: I think it's the same thing as everyone else said.
28. Ms. Hawkins: You think it's the same thing as everyone else says? See I'm thinking it's something different.
29. Bethany: Because you use adaptation
30. Ms. Hawkins: Okay, what do you mean by adaptation?
31. Bethany: Like...I don't know
32. Ms. Hawkins: Why do giraffes need long necks? Okay, so that they can eat. Now you said that they came from, uh they evolved from these short-necked giraffes that were their ancestors. So how do they go from these genes where there were short neck genes, to getting long neck genes...What did you say Bethany?
33. Bethany: I said a mutation
34. Ms. Hawkins: Oh a mutation? What do you mean, a mutation?
35. Bethany: an extra chromosome or something that caused their neck to be longer maybe...
36. Ms. Hawkins: Oh, okay, maybe not an extra chromosome, but maybe a change in their DNA that coded for longer necks. Um, Catherine?
37. Catherine: Maybe there were other giraffes that had long necks and they met the short neck giraffes and maybe they had short and long neck babies which led to...
38. Ms. Hawkins: Ohhh! okay so that's going back to our um when we were talking about genetics and doing the Punnett square crosses. So you were kind of getting your thinking from there
39. Catherine: I just felt like saying that.
40. Ms. Hawkins: Oh so you just felt like saying that? Okay, good. Well, so I'm liking, I'm liking your ideas. And, um, actually your ideas have been proposed. Okay? You guys aren't the first ones to think of this. Okay. The first idea, we um we have this guy named Lamarck who thought that if the giraffes needed to reach the trees, they just stretched their necks, and stretch 'em and stretch 'em and stretch 'em, and then when they have babies, all their babies would have long necks because they stretched them so their babies are gonna have long necks. Okay? And that's kind of what I think a few of you guys raised your hands and you thought that might be an idea. Right?

Bethany's response lacked a mechanism by which these genetic differences might lead to the evolution of long necks. When Catherine introduced an idea that sounded mechanistic and plausible (Line 40), Ms. Hawkins used it as an opportunity to bring the activity to a close, categorizing the ideas as Lamarckian and Darwinian.

After this snippet, Ms. Hawkins moved into a detailed explanation of Darwinian theory of natural selection. Most of her students took notes. At the end of her explanation, she came back around to the Lamarckian ideas expressed earlier in the class, this time explicitly identifying Lamarckian ideas as incorrect.

41. Ms. Hawkins: Some of you guys proposed the idea that the giraffe stretched their necks. ...That would be kind of the same as me saying 'if Ms Hawkins dyed her hair blonde, then her children are going to have blonde hair.'
42. Student: Do you think that will happen?...no, no right?
43. Ms. Hawkins: Do *you* think that would happen?
44. Students: no, no...you can't do that. /No I don't think so
45. Ms. Hawkins: Why would that not happen?
46. Student: Because you can't change your genes.
47. Ms. Hawkins: ohh...Is my blonde hair inherited or fake.
48. Students: fake
49. Ms. Hawkins: Fake right? We're not gonna lie here, okay? So, so it kind of goes with the idea, that Lamarck's idea, you guys were talking about the giraffes that if they just stretch their necks, they're gonna pass that trait on. That's false.

Again, we see evidence in this snippet and in the interview response that Ms. Hawkins was *able* to attend to student thinking, and actively sought to elicit student reasoning. For example, she asked Hannah for greater elaboration on what she meant by "they needed to evolve" (21) and asked her to explain "how" it happened. She also asked Bethany to explain what she meant by a "mutation" (34). Furthermore, as she described in the interview, she noticed that Hannah's response was different from what she had expected based on the words Hannah used. As we will discuss below, we see evidence of the ways in which Ms. Hawkins' attention was oriented throughout the classroom activity. For the most part, it was not on the substance of the students' ideas or reasoning; it was on conceptual correctness, marked by use of the relevant scientific terminology.

To What Do Teachers Attend in the Classroom?

In the following sections, we use the example of the activity in Ms. Hawkins' class and her comments about the activity to address our first research question, "To what do teachers attend in the classroom?" We have chosen this example strategically, as it is representative of the teaching we see, and provides a window into several different categories of teachers' attention that we have observed regularly in more than two years of observing biology teaching in Ms. Hawkins' school and school district. We also include examples from the teachers' conversations about this and other classes, to explore how others in the community share the focus and orientation of Ms. Hawkins' attention.

The ten-minutes of class activity represented by these two snippets occurred in April (2005-2006), at the outset of the class period, and at the very beginning of the unit on evolution. This was Ms. Hawkins' first year as part of the research and professional development project, which focused on teachers' moves with respect to curricular decision-making. Project participation at this point entailed biweekly meetings with a group of 8 other high school biology teachers to share and discuss video snippets of classroom practice. The intent of the first year was to gather baseline data on the modifications teacher made to curriculum and underlying influences that informed them. Evidence in this snippet suggests that Ms. Hawkins was paying attention to her students' ideas to begin a conversation about natural selection. For examples, she used student ideas to structure the discussion, and she probed students to explain more when their explanations seemed incomplete or unclear. A key question remains, however: how was Ms. Hawkins' attention oriented while listening to the students' ideas? We discuss this question below.

Correct conceptual understanding and misconceptions

Ms. Hawkins' attention to her students' thinking in this activity was drawn primarily toward her perceived accuracy of her students' explanations for the evolution of the giraffe, i.e., whether her students' ideas were Darwinian (correct) or Lamarckian (incorrect "misconceptions"). This is supported by Ms. Hawkins' own testimony in the interview:

So, by asking the question I wanted to see where they were coming from. And to see how many of them were Lamarckian. ...To see how much I was going to already have to break that misconception...I was just thinking about all the evolution misconceptions that there are and trying to put them on the table and we can talk about them and introducing it before I introduced Darwin.

Evidence from the transcript also supports this assertion that Ms. Hawkins' attention was focused on whether her students had a correct or a misconception. She structured the activity so that the "Lamarckian" ideas were identified first, to set up the contrast for the ideas that seemed more Darwinian. Bethany's idea, which introduced the language of genetics, was the last idea chosen, and Catherine's contribution pointed to the beginnings of a correct explanation for the evolution of long-necked giraffes. Ms. Hawkins focused on what it was about Bethany's idea that was different, and along with Catherine's contribution, it set up a direct explanation of the canonical mechanism of natural selection. Despite assurances to students that there were no right or wrong answers (most likely intended to mean that students would not be graded on their explanations), Ms. Hawkins ultimately explained that the Lamarckian ideas were wrong (49).

Ms. Hawkins' differential verbal responses to Lamarckian and Darwinian ideas belie a motive to differentiate the correct from the misconceived. In lines 12 and 20, for

example, Ms. Hawkins responded to Carrie and Nathan's ideas respectively, with a neutral "Okay," even calling Carrie's idea a "good idea." By contrast, her reaction to Bethany's idea was quite different, she exclaimed, "Ohhh!," with her voice rising (Line 29; her voice rise is very noticeable on the video and audio tape) and made sure that the class recognized it as a different idea when Bethany tried to claim that "it's the same thing that everyone else said" (30 and 31). In the interview, Ms. Hawkins explained why Bethany's idea stood out for her:

Well, I think, it tells me that they're kind of thinking on the right track. That it's not like, you just umm...you know, if you're born with blue eyes, it's not just by random chance. Like ...it ties back to DNA.

Correct use of terminology

Students' use of terminology can be difficult to tease apart from their conceptual understanding. In addition to attending to the correctness or incorrectness of students' ideas, Ms. Hawkins also attended to students' use of vocabulary. For example, she initially misinterpreted Hannah's idea as she quickly flipped through the students' responses because Hannah's response contained terms and phrases (i.e. "evolving", "the environment started changing" and "need to survive") that led her to believe that Hannah's account was Darwinian in nature. Hannah's explanation in class suggested that she considers the "stretching thing" (lines 24-26) to be the mechanism behind the evolution and adaptation of the giraffe's neck. In attending to whether Hannah had the appropriate vocabulary words to signal a Darwinian explanation, Ms. Hawkins appeared to neglect consideration of whether Hannah's response included a Darwinian mechanism; she learned during the discussion that Hannah held a more Lamarckian conception.

Similarly, Ms. Hawkins chose Bethany to share her response because the use of terminology related to genetics caught her eye, leading her to believe that Bethany was “on the right track.” During the class, she responded to Bethany’s use of the term “genetic gene” by asking her to “say it in um, uh—.” Based on her response when Bethany later comes out with the term “mutation”, we interpret her initial response as an attempt to elicit the target scientific vocabulary, “mutation.” The misplacement of Bethany’s initial written response makes it difficult to know whether she did indeed have a more Darwinian explanation, but her claim that she was saying, “the same thing as everyone else said,” suggests that she may not have, and that it was simply her use of terms related to genetics that captured Ms. Hawkins’ attention. Alternatively, Bethany may have had a Darwinian explanation, but was hesitant to disagree with what others in the class seemed to be saying.

Common Foci of Attention among Biology Teachers in the District

Patterns we see with Ms. Hawkins, reflected in these snippets, echo observations of other teachers and classrooms in our study. While attention moved among a variety of other foci -- including student engagement, and (occasionally) student reasoning -- attention to correct conceptual knowledge and repetition of vocabulary were often central and generally sustained.

The focus on conceptual correctness and incorrectness and use of vocabulary also emerged when teachers watched videotape of classrooms or examined student work. Frequently, in these conversations, we found teachers focus on students’ correct use of terminology in answering questions without focusing on the substance of student reasoning in support of those answers or students’ conceptual understanding of the

terminology they were using. As we said before, the two foci quickly become entwined. Students' use of terminology very easily became a proxy for conceptual understanding. Teachers noticed, for example, that students were able to give the correct answer regarding the role of mitosis in our bodies ("for growth and to repair damage"), but seemed initially unfazed that all the students were using precisely the same phrase and that none of their work or comments provided additional evidence of their understanding of what exactly that meant. Only after discussion in the group did they see this uniformity as problematic. While they could engage in close analysis with peers, they did not frequently do so in the classroom.

We saw this pattern of conflating the use of scientific terminology and understanding when the cohort of biology teachers discussed the above transcript from Ms. Hawkins' class. Teachers noticed what Bethany said, and spontaneously began talking about it, without being prompted.

1. Nancy: Bethany, no she has the idea, but then she says 'I think the same as everyone else...
2. Lisa (Ms. Hawkins): Right! Right.
3. Nancy: You think she really just was like spouting something she didn't understand...or?
4. Facilitator/D: Wait what idea did she have before?
5. Adam: That mutation, a mutation that's causing it

The conversation moved off of a discussion of Bethany's idea before one of the facilitators brought it back.

36. Facilitator/J: So can we get back to the transcript?...Bethany, so in Bethany, in 49, 'I said, that the giraffe had probably adjusted to their environment by a genetic gene that was passed through generations,' and we're all saying that, that she 'gets it'?
37. Adam: But then she's afraid to own it.
38. Facilitator/D: What does she get?
39. Adam: That's its a, it's a series of, it's the mutations that were being passed from generation to generation

40. Facilitator/D: And how does that, so you, you understand here, her understanding of how that corresponds to the giraffes evolving a long neck?
41. Adam: Yea. [She says] "Probably adjusted to it by a genetic gene that was passed through each generation," And then later, she is, she says mutation without anyone else ever mentioning it. She just, she doesn't come up with that adaptation,
42. Nancy: But does she, I mean she's throwing out the words, I mean she's you know...and she, she says "I think the same thing as everyone else" but does she really get what all those words mean [inaudible]
43. Adam: I think she has an idea.
44. Facilitator/J: Definitely/
45. Adam: But she's afraid to, to go with it.
46. Facilitator/J: So an idea of a/
47. Adam: a correct idea. That it's, it's the genetic generation to generation thing, not a stretch your neck and then you have babies with longer necks.

We see evidence in this transcript that other teachers in the group (not unlike Ms. Hawkins) assumed that Bethany had “a correct idea” (47) primarily because of her use of the term “mutation” (5). Adam for example, points to Bethany’s use of the term mutation to suggest that she had a correct idea. Only after being prompted by the facilitator (36) did Adam make a claim that her correct idea was in her reasoning that the mutation is passed from generation to generation, and he contrasted this with the incorrect Lamarckian idea (47). While some teachers questioned whether Bethany really “got it” or not (e.g. Nancy in 3,42), no one pointed out that Bethany’s explanation did not account for how all giraffes ended up with long necks (i.e., selection) nor suggested that they needed to hear more in order to draw any conclusions about what she understood with respect to the evolution of the giraffe.

We have argued here that teachers’ attention is primarily focused on conceptual correctness and target vocabulary, and that vocabulary often serves as a proxy for conceptual understanding. Certainly, conceptual correctness and correct use of vocabulary are important. However, we are concerned with how attention to these things distracts attention to other important aspects of science learning. In the next section, we

again consider Ms. Hawkins' class, to explore other aspects of student thinking that frequently were overlooked.

To What Else Might Teachers Attend?

In structuring the activity to categorize and contrast the students' ideas, and attending to the correctness of the ideas primarily via the vocabulary used, Ms. Hawkins' attention was distracted from other important aspects of her students' scientific thinking, most notably, their scientific reasoning and participation in scientific argumentation.

Scientific reasoning

The focus on conceptual correctness and appropriate terminology frequently distracts teachers from attending to the substance of students' scientific reasoning. We saw one example of this in the opening exchange, where Ms. Hawkins neglected to notice what Catherine was asking about the coloring of moths, and instead invoked the term "mutation," which was central to the explanation she was asking students to construct.

We see similar examples in the full transcript of the class and in Ms. Hawkins' reflection on the class. For example, she identified both Carrie's and Nathan's ideas as similar to what "this guy Lamarck had," even though there were important differences in the kinds of reasoning among the two students. Although Carrie's idea was teleological (the change happened because the giraffes "needed to reach the trees"), it also included features of a mechanism, in that she talked about a process (stretching) by which the change might occur, which would involve the inheritance of acquired characteristics. Nathan's response did not include a process; he simply stated that the need caused the change.

We asked Ms. Hawkins what ideas she noticed that were not correct, intending to see what Ms. Hawkins might notice in students' reasoning beyond whether their ideas were correct or incorrect. She might have given Carrie's response as an example, which would suggest that she noticed that Carrie had the beginnings of a mechanism in her response. Instead, she chose Nathan's. Nathan's idea may have stood out for her because on some intuitive level she noticed that it lacked something (possibly because it lacked a process), and in fact, during class she probed his response more deeply than she did Carrie's²⁸. Nevertheless, her classification of the two ideas together, and her response to the interview question, both suggest that her attention was not on her students' ability to produce mechanistic explanations *beyond whether or not they were the correct (i.e., Darwinian) mechanistic explanations*. Similarly, based on Ms. Hawkins' explication of her goals for the activity, probing Bethany and Hannah about their ideas was merely intended to more fully categorize the ideas as Darwinian or Lamarckian, not to highlight the value of mechanistic responses. If she were attending to reasoning, differences between mechanistic and non-mechanistic explanations may become something students should understand. In this case, we might have seen her ask students to account for the ways in which the explanations differed, or even explicitly point out to students the differences inherent in the various explanations.

Participation in argumentation

Ms. Hawkins' attention to the conceptual correctness and correct vocabulary also distracted from her attention to opportunities to engage students in argumentation. Although the beginnings of two very different kinds of explanations for the evolution of the giraffe's neck came up in the class, Ms. Hawkins did not take advantage of

²⁸ We will discuss this in more detail in a later section.

opportunities for students to argue for or against these possibilities. For example, when Carrie read her explanation, Ms. Hawkins said, “Okay, so how many of you guys thought that idea?” If she were attending to opportunities for her students to inquire, we might have expected her to ask a different kind of question rather than asking for just a show of hands in agreement, such as, “What do the rest of you think of that explanation?” and asking other students to provide evidence and reasoning to argue for or against the explanation. Ultimately, Ms. Hawkins provided the evidence herself that the Lamarckian explanation was false, by drawing students to the observation that her blond hair would not be inherited.

In describing these other possible foci of attention, we do not mean to suggest that teachers never attend to these things. As we discuss below, we believe there is evidence here of Ms. Hawkins’ nascent abilities to attend to these types of student reasoning. In other classrooms we see moments of teachers probing and pushing on reasoning, encouraging students to do the same, and engaging students in argumentation. However, these moments are more episodic and fleeting, only occasionally sustained for any meaningful length of time. The important point we wish to make here is that the dominant foci of correct conceptual knowledge and, by proxy, correct terminology overshadow and out compete other possible foci. How can we explain this, particularly since we have instances of teachers meaningfully attending to the substance of ideas and reasoning? In the following sections we attempt to do this by considering our second question, “What shapes teachers’ attention?” and construct a theoretical argument that teachers’ attention can be best understood as situated within the institutional systems in which they work.

Situating Teachers' Attention in Institutional Systems: Considering Teachers' Multiple Accountabilities

Below we argue that in many significant ways Ms. Hawkins' attention is a reflection of the broader institutional system in which she works. While we focused primarily on Ms. Hawkins' classroom in the first part of this paper to highlight issues of attention, we do not see her attention as our *unit of analysis* here (McDermott, Goldman, & Varenne, 2006)²⁹. Our analytical focus here is on the system. We use Ms. Hawkins, and the pulls and draws on her attention, to better understand the system in which she and other secondary biology teachers work. Insight into this system then informs our understanding of Ms. Hawkins', and other teachers', attention. This perspective guides our exploration of how elements of the system shape teachers' attention.

Ms. Hawkins works in a large, diverse district in the midst of a large metropolitan area. Along with all the science teachers, she is faced with multiple and often competing responsibilities and demands. For one, she is expected to help her students reach certain levels of understanding of biological concepts and principles, which are articulated and communicated to her through a district curriculum and various standards documents, and measured through student performance on standardized, high-stakes tests. She is also responsible for implementing other district policies, such as a literacy initiative and district-wide grading guidelines. Furthermore, she is a member of a large science department and one of seven teachers on the school's biology team. Together with her colleagues, she works on the specifics of curriculum implementation and participates in

29 McDermott et al., (2006) present a cultural analysis as one that, "takes individuals seriously by focusing on their environments and rarely allows a single person to bear the undue burden of being targeted, accused, labeled, explained, worried about, remediate or even rehabilitated without an account of the conditions in which he or she lives."

student placement decision-making. She corresponds about student performance with parents and students, as well as with her colleagues and school administration.

To consider how this setting with these demands influences teachers' work, and attention, we draw on theories of knowledge and learning that hold that an individual's cognition cannot be disentangled from the sociocultural context in which it exists and interacts (Lave, 1993; Lave & Wenger, 1991; Varenne & McDermott, 1999; Wenger, 1998; Wertsch, 1991). We refer to "systems" as the term is used to refer to systems of interacting, often mutually reinforcing, continuously evolving contextual elements that guide and constrain individual action and cognition (Conrad, 2006; Engestrom, 2000; Jacobson & Wilensky, 2006; Kaput et al., 1999; Lemke, 1997; Weick, 1976).

While we take a theoretical stance that what a teacher attends to in the classroom cannot be fully understood without understanding the institutional system in which she works, others might (and do) argue that teacher attention is primarily a reflection of cognitive properties of the individual. That is, a teacher's attention is largely constrained by matters such as her subject matter content knowledge or her beliefs or expectations for her students. Before we begin to look more closely at the influences of the broader system, we return to the example of Ms. Hawkins to confront this characteristics-of-the-individual argument. Then, we turn to an explication of the ways in which institutional systems, and in particular the multiple accountability systems, work to organize teachers' attention.

Spotlighting the Individual – Consideration of Teachers' Subject Matter and Pedagogical Content Knowledge

As we suggested, one could argue that issues of attention primarily reside within an individual teacher. Here we focus on a teacher's content and pedagogical content knowledge in particular, as we see it is most relevant for this example. Few would take issue that when teaching science, a teacher's knowledge of the subject matter matters (NRC, 2007). Furthermore, a large body of literature suggests that teachers' pedagogical content knowledge, the subject matter knowledge particularly suited for instruction in particular content areas, is also central to teaching (e.g., Adams & Krockover, 1997; Loughran, Mulhall, & Berry, 2004; Shulman, 1986, 1987)

One might interpret Ms. Hawkins' attention to her students thinking in this example in terms of her knowledge or understanding of science. For example, earlier in this paper we argued that she lumped Carrie and Nathan's ideas together because she was attending to the contrast between correct (Darwinian) explanations and misconceptions. Perhaps she doesn't *know* that Lamarckian explanations and teleological explanations are different, that mechanistic explanations are more scientific, or perhaps she doesn't understand that it is important for students' to understand these distinctions. In the case of any of the above contingencies, she may have clustered the ideas together not only because they are non-Darwinian, but also because she recognized them as fundamentally *the same*.

This analysis falls short on several grounds. Attributing her move to a lack of depth in content or pedagogical content knowledge does not fully account for the various ways that Ms. Hawkins responded to Carrie's and Nathan's ideas during the class discussion. While she accepted Carrie's response without further questioning, she probed Nathan's idea until he agreed that the evolution of the giraffe's neck occurred by

“stretching.” Although Ms. Hawkins may not have been explicitly attending to the differences between mechanistic and non-mechanistic thinking in this instance, her response suggested that she may have had some intuitive awareness that Nathan’s idea was different in nature than Carrie’s, and thus probed him until she elicited some sense of mechanism. We see a similar move in the opening snippet in response to Edwin’s answer of “mutation”; Ms. Hawkins appears to be encouraging students to consider a mechanistic explanation for how the mutation would occur. A view of her attention in this episode as a reflection of her lack of content or pedagogical content knowledge provides no account of her understandings, however nascent, of the differences between mechanistic and non-mechanistic explanations, or her move to elicit this type of reasoning from her student. A very plausible explanation would be that she simply lacked the recognition or vocabulary to identify why Nathan’s idea was “more wrong” than Carrie’s and, as such, required further probing.

Additional evidence demonstrates that Ms. Hawkins’ *can* attend to the substance of students’ reasoning, although she often appears distracted from it in the moment. For example, she initially attended to Hannah’s response in terms of vocabulary usage that signaled a Darwinian explanation. Although Ms. Hawkins attention was initially keyed to this vocabulary, when she pushed Hannah to elaborate on her explanation, she did notice that Hannah was not using the terms in the context of Darwinian reasoning. Moreover, we have ample data from teacher meetings where Ms. Hawkins engaged in fine-grained analysis of student reasoning in ways that demonstrated a fairly sophisticated depth of content knowledge. In this cohort conversation, Ms. Hawkins pointed out Catherine’s idea of sexual selection in the opening exchange. In a written

case to accompany this snippet of classroom data, Ms. Hawkins' analysis of student remarks and relevant written work concluded that most of the students' responses could not easily be classified as either Lamarckian or Darwinian, but more often had characteristics of both.

Another problem arising from simply associating Ms. Hawkins' attention with a lack of content or pedagogical content knowledge is its failure to explain how this same pattern of teacher attention occurred repeatedly in classrooms in her school and throughout the district. In our work with more than twenty-five high school science teachers, over the course of more than two school years, the example of Ms. Hawkins is more typical than not. In her same school, for example, we have data of another biology teacher explicitly commenting on students' mechanistic reasoning during class, but still remaining predominantly oriented to students' correct use of vocabulary and repetition of correct conceptual knowledge.

We do not deny that Ms. Hawkins' content and pedagogical content knowledge play some role in shaping her attention. We challenge the notion, however, that these factors alone explain her teaching. We take issue with a perspective that *limits* an explanation of the organization of teachers' attention to a property of the individual. Ms. Hawkins may lack the language for differentiating and making explicit the distinctions between scientific and non-scientific explanations; she may even have limited understanding of the importance of students' reasoning and participation in argumentation in developing scientific proficiency, after all, teacher education programs rarely prepare science teachers to fully understand important aspects of students' thinking (NRC, 2007). However, focusing solely on characteristics of Ms. Hawkins overlooks

how other aspects of the system in which she teaches influences her attention in the classroom.

While we do not doubt the importance of content and pedagogical content knowledge for teaching science, we are concerned here with the ways in which the institutional system supports and constrains teachers' abilities for attending to deep conceptual knowledge *and* student reasoning and participation in scientific discourse. In the following sections, we explore several elements of the system in which Ms. Hawkins teaches and consider how these elements could work to shape attention.

Considering Teachers' Multiple Accountabilities

In the era of federal legislation intended to ensure greater accountability, the term has come to mean "a count of ability" as measured by student performance on external tests. While dominating current discourse and practice, this is only part of a teachers' accountability picture.

As a window into the dynamics of the system, we consider the multiple accountabilities Ms. Hawkins and her colleagues face – to students, to standards, to curriculum, to colleagues, to parents, to state mandates, and, to the science they are teaching. A lens of accountability allows us to move beyond the individual teacher to consider the relationships among the individuals to the system and to others within the systems. In order to account for the work of the system, we look at the accountability structures in place, and examine how these can influence teacher attention. We use the term accountability broadly, to consider how teachers negotiate the tensions brought on by their obligation or willingness to accept responsibility to various entities. To whom,

or to what, are teachers accountable, and how do these accountability structures shape what teachers attend to in the classroom?

Our research suggests three areas of accountability that appear particularly salient in shaping patterns of teacher attention: those that accompany the pressures of high-stakes tests, including state indicators and the district-wide curriculum, the influence of local professional communities, and those associated with needs and expectations of students. While we focus here separately on various accountability relationships facing Ms. Hawkins and other teachers in her school and district, we do not claim that these are the *only* things that shape attention; and, we assume that multiple influences interact in complex ways.

High-stakes tests, state indicators and district-wide curriculum

How do features of the institutional context, such as high-stakes tests and standardized curriculum, shape teachers' attention? In the state where Ms. Hawkins teaches, students must take a High-School Assessment (HSA) exam in biology in order to graduate from high school. Scores feed into schools' Annual Yearly Progress (AYP) rating, which is reported in adherence with federal *No Child Left Behind* legislation. Additionally, all students take semester and final exams created and administered by the district, which count toward their semester grades. The district-mandated curriculum articulates the specific content students are expected to know for the final examination. Performance on the first semester final is seen as a strong indicator of student performance on the Biology HSA. Coverage of the content presented in the curriculum is, therefore, thought to be imperative to help students pass the high stakes tests.

In light of such pressures, Ms. Hawkins and her colleagues frequently comment on the importance of the HSA and the district finals in focusing their attention in their classes. When asked in an interview to discuss her goals, another biology teacher at Ms. Hawkins' school commented on the influence of this system of testing:

... the mandate to get the students to pass these tests definitely weighs in heavier than most in what I do. Like, when I'm planning a lesson or doing a day-to-day, you know, all my little assessments are geared toward conditioning them for those tests, you know writing tests, other assessment that are comparable ... I feel like that motivates a lot of what I do.

In addition to talking about "conditioning" her students for the tests, this teacher also often referred to the need to "procure" test scores. Her language implies that while she might choose to attend to a variety of things in teaching her classes, the focus on test scores played an important role in shaping her attention.

In what ways do the pressure of the high stakes tests and the coverage of curriculum manifest themselves to shape teacher attention in the ways instantiated by the example from Ms. Hawkins' class? To begin with, consider Ms. Hawkins' attention to students' correct use of vocabulary. Although some of the items on the high-stakes tests require more extensive reasoning, many of the items are fundamentally dependent on students remembering vocabulary terms and associating them with particular concepts. For example, in the section of the curriculum that corresponds to the activity in Ms. Hawkins' class, one of the principal "assessed indicators" (objectives) is for students to *identify examples of adaptations*. To meet this indicator, according to curriculum material, students must know the term *adaptation* and recognize examples of it. On the suggested end-of-unit test found in the curriculum, we find the following question:

Mammals living in extremely cold climates have thick fur and a layer of fat to insulate them from the cold. Which of these terms best describes these characteristics?

- A adaptations**
- B alterations**
- C recombinations**
- D translations**

It's not difficult to imagine a student could understand that structural elements of animals' bodies (i.e., thick fur) are related to their function (insulation), yet not know the word *adaptation*. Students could understand adaptation, but simply get the question wrong on the test because they do not know the vocabulary word. In this context, it's not surprising that Ms. Hawkins initially attends to Hannah's response as correct because she "had the terms" (in particular, "adapt"). After all, even if Hannah does not have a Darwinian conception of evolution, her use of the term adaptation would serve her well on the test question.

Correct use of vocabulary is not only an implied part of the curriculum, it is explicitly stated as a goal in the rubric that is published by the state for grading student responses to Brief-Constructed Responses (BCRs) found on the state assessment. This same rubric is used on the district tests. This rubric is found in the district curriculum and posted in teachers' classrooms. Teachers are encouraged to show and discuss the rubric with their students, and emphasize the "accurate use of terms" on every BCR students write in class (which they do for practice) and on tests. While the intended criteria clearly states "accurate use", we see many examples where what is implemented (and even rewarded in the rubric grading) emphasizes the term "*use*", often leaving accuracy – or understanding - obscured.

The high-stakes tests and standardized curriculum also give rise to a dichotomy of

“correct” responses and “misconceptions.” The district curriculum purports to support an “inquiry-based” approach to teaching life science concepts and underlying principles. Students are asked to “explore” phenomena first, before they (or the teacher) explains the concepts and principles. The giraffe question posed by Ms. Hawkins’ is a “pre-assessment,” described in the curriculum as intended to “measure a student’s knowledge and skills of the unit to be taught,” and to “determine the appropriate content and pacing of instruction for individual students” (district curriculum).

The curriculum does not state that the teacher should directly explain natural selection to students (as Ms. Hawkins did at the end of the above example), but curriculum documents note that pre-assessments are good opportunities to “clear up misconceptions and highlight understanding” (district curriculum). It is not unreasonable for a teacher to try to confront misconceptions by noting their incorrectness and providing the correct conception. (After examining student work from this day’s lesson, including student exit cards, Ms. Hawkins concluded that few students actually “changed” their minds about how giraffes evolved, despite her explanations.) Nowhere does the curriculum guide suggest that students inquire deeply into alternative conceptions, to argue among themselves, using evidence to support their arguments and to confront counter-claims. Considering what the curriculum affords, it is not surprising that teacher attention is predominantly oriented toward conceptual correctness and the dismantling of misconceptions and not toward substantive student inquiry or deep conceptual understanding.

Local professional community

Research suggests that teachers' professional communities also influence attention (McLaughlin & Talbert, 2001; Rop, 2002; Siskin, 1990). Teachers in Ms. Hawkins' district are involved in a number of formal professional communities, including district-level content cohorts organized for professional development, grade-level teams in the schools, academic departments, and smaller content-specific teams within the academic departments. Observations and interviews point to the small content specific teams as particularly important in shaping teachers' attention. Next we look at the "biology team" in Ms. Hawkins' school and explore how this kind of local professional community can contribute to the ways in which biology teachers' attend to student thinking.

High school biology teams were formed in the district to support teachers' preparation for the Biology HSA and district tests. According to the district website, "If we want our students to do well on the HSA, our locally developed tests need to mirror what students will see on state and national tests (use the language, vocabulary, and format)." As additional policies and procedures were handed down from the school and the district (i.e., a school-wide literacy initiative and a district-wide grading policy) the biology team at Ms. Hawkins' school was charged with making collective decisions about how to institute these policies. The biology team produced a common syllabus to conform to the district grading policy and met during science department meetings to decide how to respond to school policies (like the literacy initiative). The team also met monthly to make decisions about the pace of the curriculum, construct common unit tests, and decide what activities to use. A member of the team described team meetings:

There's sort of a check-in, there's a logistical component as far as where is everybody in the current unit? When do people anticipate starting the next?

Trying to keep people on the same page, um, logistical component with any shared labs, discussing set-up, breakdown, sometimes the sharing of strategies for upcoming units or discussion of common misconceptions or anticipated problems....Um, a discussion of test scores, there's always a discussion of scores of sorts and a push towards um, or, with the sort of HSA as being this underlying goal...and strategies towards improving the scores.

Team members also occasionally took professional leave to plan collaboratively, a practice encouraged by the science department head. For example, around the time of the class described in this paper, Ms. Hawkins and another teacher took professional leave to collect and organize sample HSA questions from the publicly available examples, with the intention of using the questions in their classrooms to get their students ready for the test.

Teachers on the team also informally shared activities and instruction, talking during lunch, before or after classes, or simply putting worksheets and other prepared activities into colleagues' mailboxes. Instructional strategies sometimes spread around the team and made their way into teachers' classes. Attention to vocabulary use is not only a reflection of a climate of testing and accountability, but, subsequently, supported and propelled within the local professional community.

The biology team also supports attention to conceptual correctness. A particularly interesting example relates to the lesson on natural selection that is described in this paper. The question that Ms. Hawkins presented to her students, "How did giraffes get long necks?" was described differently in the curriculum guide. In the guide, the question showed a picture of a horse and a picture of a giraffe and asked students to think about how the giraffe, which descended from an animal "like a horse," might have evolved a long neck. Emily, the biology team leader, objected to the original question. She wrote an e-mail to the district's curriculum coordinator, arguing that the question

promoted a significant misconception of evolution³⁰. No one on the biology team at Ms. Hawkins' school uses the question as it is recommended in the curriculum guide; everyone uses the form of the question as Ms. Hawkins asked it. This is not a bad thing. The giraffe question *is* a better question, as it helps students to understand that life on earth may have been at one time very different from what we have come to expect today, and that modern species evolved from ancestral species that are no longer in existence. Nevertheless, the point is that activities promoted in the curriculum are not simply enacted in teachers' classes, but are filtered through the biology team, which itself promotes a focus on conceptual correctness. On one level, this may be a desirable aim. Yet, when it occurs in the absence of attention to underlying reasoning, the nature and depth of understanding becomes difficult to ascertain.

Expectations of and for students

We argue that teachers' accountability to their students also influence teachers' attention, often pointing it to correctness and vocabulary use. An aspect of this involves students' expectations of schooling. As long-term participants in schools, students come to secondary science class with particular expectations of student and teacher roles in the classroom. In the example from Ms. Hawkins' class, students were expected to provide some ideas, and then the teacher was expected to tell the students the correct answer. Routinely, we hear students respond to open-ended questions in class with common phrases like, "Can't you just tell us the answer?" or, "if you know the answer, why are you making us do this?" The pervasiveness of such comments is a testament to how deeply ingrained these expected roles are.

³⁰ The idea that one extant organism could have evolved from another extant organism (i.e., humans come from monkeys).

Teachers also report wanting to engage student interest and a hope for fostering within them an appreciation, and in some cases, a love of the subject matter. With new laws governing that all students need to pass the state exam, teachers also feel accountable for helping their students achieve an adequate score. The tensions among these different accountabilities to students do not go unnoticed by the teachers. As one teacher said in an interview:

I mean, yeah, I want my kids to pass the HSA because I know they're not going to graduate if they don't, but I also want them to have faith in me as a teacher and come into this class engaged and trusting that what they're learning is—I don't know, that they're going to be set up for success.

At other times, this same teacher discussed her sense of accountability to help students be successful in life beyond their achievement in science class, by helping them to become interested in learning. While teachers often described their accountability to their students in terms of helping their students to prepare for the test, there was also a common sense, as this teacher mentioned, that engaging students was important for preparing them for life beyond the classroom.

Our research suggests that teachers are accountable to their districts and their schools, which expect them to teach to certain tests, using particular curriculum, and to produce certain kinds of student achievement. It also suggests that teachers are accountable to local professional communities to share resources and responsibilities and to move through the curriculum in particular ways. Furthermore, teachers are accountable to students, to help them to develop interest and participate in science in ways that will allow them to learn content, achieve good scores, and graduate.

Within the context of this system of accountabilities, we argue that Ms. Hawkins' teaching is appropriate and, by many measures, good. She engaged her students in

important questions that are relevant to biology content, she worked to help them to develop the content and vocabulary that they needed to achieve on high-stakes tests, and she worked collaboratively and effectively with other members of the community. Her class provides an example of what a science class looks like when a teacher works hard to do what the system tells her to do. An important piece is missing in the scenario and the accompanying description. Ms. Hawkins is a science teacher, and on a very fundamental level, she has responsibilities to this subject matter.

Where is the Accountability to Science?

At this point in our analysis, we are left with a lingering question. In what ways are the system and the kind of teaching it promotes accountable to the discipline of science? We have shown Ms. Hawkins attending primarily to conceptual correctness and vocabulary, and our data suggests that this pattern is quite typical. It's less clear that teachers regularly attend to students' substantive scientific reasoning, or students' productive resources for thinking about science or engaging in scientific practices. By this, we do not intend to suggest that teachers *cannot* attend to these things. Rather, we argue that most teachers have abilities to attend to students' substantive scientific reasoning or participation in scientific practice, but that the system within which they operate fails to support these abilities, as it prioritizes other concerns (see also Levin et al., in press). Of course, this lack of attention is neither explicit nor deliberate. In fact, some may argue that the testing and curriculum systems put in place are intended to ensure that all students receive quality science instruction. However, as implemented, they appear to undermine any substantive attention on actual science.

We draw on a sound metaphor to highlight this phenomenon. Imagine a teacher receiving radio signals from a variety of sources that compete for her attention. She receives messages about the importance of standards-based curriculum and high stakes assessment (Jenkins, 2000; Settlage & Meadows, 2002), which may be sustained or modified at the level of her school or within her academic department (McLaughlin & Talbert, 2001; Rop, 2002; Siskin, 1990). She receives messages from her past, her own experiences, both as a teacher and as a student, that tell her what to expect and what to do (Windschitl, 2002). She may receive messages from students about their expectations for her behavior, based on their own prior experience within classrooms (Herbst, 2003). How do these signals interact and interfere with each other to shape a teacher's attention, and, importantly, how (and when) do they afford her the opportunity to attend to the substance of student thinking?

If we consider the volume of the signals that the teacher is receiving, many of the signals are *amplified* by the system such that teachers hear them most loudly, drowning out the sounds of productive student reasoning and participation in inquiry. We think that science teachers have all sorts of abilities for hearing these sounds; absent other influences on their attention, however, teachers are most likely to pay attention to the signals for which the system tells them to listen--those signals for which they are the most accountable to hear.

Implications for Teacher Education and Professional Development

Our argument has important implications for teacher education and professional development. If the system in which teachers work fails to amplify attention to students' productive scientific thinking and practice, than teacher education and professional

development must turn up this signal. They must create the type of feedback loop that will sustain attention to the substance of student thinking.

One mechanism through which science pedagogy courses and professional development programs can help teachers (and prospective teachers) develop their abilities to attend to student thinking is by engaging them in practices that explicitly frame teaching in terms of attention to student thinking beyond the correctness of ideas and repetition of vocabulary. In other words, helping teachers learn to *listen* carefully to their students ideas and reasoning. Having teachers watch videotape of classrooms and analyze data from their own and others' classrooms with an eye toward what students are thinking, for example, can help teachers to develop these abilities (Hammer, 2000b; Hammer & van Zee, 2006; Sherin & Han, 2004). In our own work with teachers involved in the research and professional development project in which Ms. Hawkins participated, we have noted shifts, albeit at times subtle, in their attention. We suggest that engaging teachers and prospective teachers in attending to student thinking upon reflection can support it happening later *in situ*.

Limitations

In this paper, we have tried to make the case that the example from Ms. Hawkins' class provides evidence of the categories of things that teachers attend to in their classroom teaching and the things that shape and constrain their attention. As a single classroom example, it has obvious limitations. One teacher's experience cannot be generalized to all teachers. Individual characteristics, such as degree of education, content knowledge, experience in scientific practice, personal epistemological commitments, and identity certainly play a role in style and substance. Ms. Hawkins is a

highly organized and disciplined person who structures her classes such that she covers all of the material in a regularly-paced fashion in time for the final exams. Other members of the biology team identify her as “our pacemaker” who keeps others to a regular calendar of when to give tests, do certain labs, etc.³¹ Other teachers might take more time to provide opportunities for student inquiry. Yet, observations of classrooms in the school, across the district, and in other districts, reveal similar patterns and trends. And, evidence presented here strongly suggests that regardless of Ms. Hawkins’ personal knowledge, position, or personality, elements of the system afford the categories of attention to student thinking that we observe.

³¹ In fact, Ms. Hawkins was chosen to be the biology team leader in the school year after this class was recorded.

Chapter 6: Teachers' Attention to Student Thinking Contributes to a Classroom Culture that Affords Student Participation in Inquiry

Introduction

In the previous chapter, I used the example from Ms. Hawkins' class to address my first two research questions: To what do teachers attend in the classroom, while teaching, and what shapes teachers' attention? I argued that secondary science teachers' primarily attend to "correct" conceptual knowledge and target vocabulary as a proxy for correctness, and I showed how the institutional systems of public school biology teaching organize attention to these foci. While I did not explicitly address my third question in that chapter, (how is teachers' attention consequential for what occurs in the science classroom?), the data suggest that teachers' focus on target vocabulary and conceptual correctness can stifle productive opportunities for students to participate in classroom inquiry.

Consider again, for example, the exchange shown in the introduction in the previous chapter.

9. Ms. Hawkins: How do you think that this dark moth came about, the very first one? Edwin? Why do you think it changed it?
10. Edwin: Mutation
11. Ms. Hawkins: Ok, so he said it could be a mutation, something in the genes could get changed, and it would cause the moths to get dark. Ok, Good. Ok, so, this goes along the lines of, um, the moths just didn't think that, "Oh! Let me turn dark!" Right? Do they think that?
12. Student: No
13. Ms. Hawkins: No, ok. Catherine?
14. Catherine: I have a question, do you know how they said I think 90% of the moths in England now are dark...So since the first dark moth, did like the other ones think they're more attractive, and that's how they made more and more and more?
15. Ms. Hawkins: Well, it goes along with Edwin's, and Bethany's idea that a mutation most likely has occurred.
16. Catherine: Oh...ok

The class had already conducted a simulation that introduced the mechanism of natural selection as an explanation for the spread of dark color in the moths (i.e., the dark color camouflaged them against the dark trees) yet Catherine’s question raised another possibility of *how* a mutation might spread through a population; novel traits might provide a selective advantage by making those who exhibit the trait more sexually attractive, thus improving their relative reproductive success and spreading their genes through the population. For whatever reason, Ms. Hawkins did not respond to the substance of Catherine’s question, but instead told Catherine that, “It goes along with Edwin’s, and Bethany’s idea that a mutation most likely has occurred.” In doing so, Ms. Hawkins amplified the message most often heard by students in science classrooms: that the object of science classroom activity is to arrive at *the correct answer* using scientific terminology. If she were to have asked Catherine or the class how the mechanism in Catherine’s question was similar to or different from what Edwin meant by “mutation”, she may have helped focus the class’ attention on consideration of reasoning. And, in doing so, may have helped send a message to students about the importance of reasoning in science. The exchange represents a missed opportunity to encourage students to inquire into alternative explanations for a phenomenon, and possibly to engage in scientific argumentation. Essentially, Ms. Hawkins’ response to Catherine shut down any further consideration of the idea, and the exchange ended with Catherine’s capitulation, “Oh...okay.”

As I discussed in Chapter 1, there is evidence in the literature that when teachers pay attention to the substance of student thinking, students are more likely to pay

attention to that substance (e.g., Hammer, 1997; Warren & Rosebery, 1995). In this chapter, I contribute to that evidence by presenting the classroom of another teacher, Ms. Brown, who frequently demonstrated skill in attending to student thinking. As a counter-example to the case of Ms. Hawkins' class, this case study allows for a consideration of what teachers' attention to student thinking affords in terms of opportunities for students' meaningful science learning. I will draw on evidence from Ms. Brown's classroom, and theoretical perspectives on classroom culture, to argue that when teachers primarily attend to the substance of student reasoning and participation in scientific practice, they can facilitate student inquiry by contributing to a classroom culture that affords student participation in practices of inquiry practices.

In the sections that follow, I discuss what I mean by inquiry and introduce the theoretical lens that I am using for understanding how a classroom culture that affords student inquiry comes to be. I then provide empirical evidence to show how Ms. Brown's attention to the substance of student thinking draws students' attention to that substance, and how it can contribute to a classroom culture that affords student participation in inquiry.

What is Scientific Inquiry?

Scientific inquiry refers to inquiry as it is practiced by scientists (NRC, 2000). Science curriculum reform promotes attention to inquiry (NRC, 1996), but how do scientists practice inquiry? What should it mean for students to "do inquiry" in the secondary science classroom? Normative views of science, in science education and history and philosophy of science, emphasize inquiry as model-based or mechanism-based reasoning in the pursuit of coherent causal explanations (Darden, 1991; Driver,

Leach, Millar, & Scott, 1996; Hammer, 2004; Machamer, Darden, & Craver, 2000; Nersessian, 1994). The work of scientists is in building and testing theories using models and exploring hypothetical mechanisms (Windschitl & Thompson, 2006). For example, Watson and Crick's theoretical structure of DNA used Rosalind Franklin's experimental X-Ray crystallography work to produce a model consistent with contemporary models of molecular bonding (Watson, 1968). The resulting model led them to propose a hypothetical mechanism for DNA replication (Watson & Crick, 1953). The development of the model of DNA led to explosive developments in understandings of molecular biology.

While different scholars emphasize different aspects of scientific reasoning, the centrality of reasoning in practices of inquiry is not disputed. Model-based reasoning refers to “an integrative reasoning process that employs analogical and visual modeling and thought experimentation in creating and transforming informal representations of problems” (Nersessian, 1994). Mechanistic reasoning refers to reasoning about the entities and activities involved in phenomena, reasoning about starting and ending points of phenomena, and “forward and backward chaining”—reasoning from knowledge of one event forward to other events and backward to antecedents (Machamer et al., 2000). As seen in the Watson and Crick example, both forms of reasoning are important aspects of scientific inquiry.

In general, views of scientific inquiry have changed over the last century, moving away from “naïve empiricism,” which fails to acknowledge the role of theory in reasoning about observations, toward a view of inquiry as reasoning with and about theories in all aspects of scientific work. Additionally, contemporary literatures about

inquiry emphasize the importance of coherent argumentation (Driver, Newton, & Osborne, 2000; Kuhn, 1993). Scientists generate knowledge claims by drawing on evidence to argue for or against explanations for phenomena. Arguments are composed of data, claims, warrants that justify the connections between the data and the claims, and the basic assumptions that provide justification for particular warrants. More complex arguments include qualifiers, which specify the limitations of the claim, and rebuttals, which specify the conditions under which the claim will not be true (Toulmin, 1958).

Inquiry has become such a loaded and misunderstood term in science education³² that a recent report by the National Research Council (NRC) avoided the term altogether, instead emphasizing the use of conceptual knowledge, reasoning abilities, epistemological understandings, and participation in specialized practices and social discourse that characterize scientific proficiency (NRC, 2007)³³. Developing proficiency in science means developing proficiency across these dimensions; I take these as fundamental to inquiry. Students inquire when they use conceptual knowledge and reasoning in the pursuit of coherent causal explanations and arguments (Driver et al.,

³² Historically, in schools, inquiry has been conflated with application of “the scientific method”. This perspective is promoted by textbooks and science curricular documents (Rudolph, 2003) and its application in classrooms can undermine opportunities for students to participate in authentic inquiry as conceptualized in history and philosophy of science (Tang, Coffey, Levin, Honda, & Elby, 2007). Science education reform documents have made great efforts to promote inquiry as it is practiced by scientists, but these efforts have often contributed to confusion among teachers and teacher educators over what constitutes inquiry (Anderson, 2002). The National Science Education Standards (NSES) states that “Inquiry into authentic questions generated from student experiences is the central strategy for teaching science” (NRC, 1996). Ultimately, inquiry is described in a variety of ways in the NSES and the NSES Inquiry Supplement (NRC, 2000): as a teaching strategy, as a general method of thinking, and as a reflection of scientific practice—“science as inquiry.” The NSES view of inquiry has been criticized both in terms of the many ways that it can be interpreted (Anderson, 2002) and in terms of its emphasis on empirical investigation over theoretical aspects of inquiry (Hammer, Russ, Mikeska, & Scherr, in press).

³³ In the few places where the term inquiry is used in this report, it refers to the methodology of experimentation that is usually associated with “the scientific method.”

2000; Hammer et al., in press), and productive student inquiry rests on productive epistemological understandings of inquiry (Driver et al., 1996).

There is growing attention to social practices of scientific inquiry and to students' participation in these practices (NRC, 2007). In practice, scientific reasoning and argumentation occur within a social context (Driver et al., 2000; Latour & Woolgar, 1986). Recognition of the social nature of scientists' work has contributed to a "practice turn" in studies of science: the recognition that scientific work occurs in communities which are important in negotiating how scientific research proceeds, as participants assume roles in relation to assessment of ideas (Ford & Forman, 2006). The practice turn influences how the work of scientists is conceptualized. Argumentation, for example, is seen not simply as a solitary rational process of marshalling evidence for or against theoretical explanations, but as a practice in which scientists participate with others in the social context and in which meaning is made at the level of interaction with others (Driver et al., 2000). In communities of scientific practice, scientists argue for the purpose of persuading colleagues of the validity of ideas and critiquing those ideas (Ford & Forman, 2006; Latour & Woolgar, 1986). Even scientists engaged in solitary work assume social roles when reasoning through scientific arguments. Situated in the communities of scientific practice, they internalize the norms of the culture and the ways in which scientific knowledge has been generated, critiqued, and revised. Science education reform calls for science classroom practices that resemble such disciplinary practices. In the following section, I discuss what it might mean for students to participate in scientific practices, and the role teachers' attention plays in fostering such practices.

What is the Role of Teachers' Attention in Fostering Classroom Practices of Inquiry?

Scientific practices of inquiry involve the reasoning common among participants, and the norms and discursive practices that serve as their tools for argumentation (Ford & Forman, 2006; Latour & Woolgar, 1986; Lemke, 1990). School science rarely reflects scientific practice, however. For example, students are rarely asked to argue, and there is rarely any guidance in *how* to argue scientifically. Everyday argumentation, as it is often practiced among students is often quite different from scientific argumentation (Kuhn, 1993); rather than involving claims, evidence, and warrants, it often involves participants arguing about their opinions, and the measure of a good arguer is usually based on the volume of a person's voice or the persistence of their stance. But students have social and epistemological resources for understanding argumentation in a more scientific sense (Hammer et al., in press). It is assumed that students *can* argue scientifically, but that there are rarely opportunities for them to do so in schools (Driver et al., 2000; NRC, 2007). The discontinuity between everyday practices among students in classrooms and scientific practices (exemplified here by practices of argumentation) calls for specific guidance by teachers to engage students in classroom practices of inquiry that resemble scientific practices of inquiry. In this way, it is argued, teachers contribute to a classroom culture in which scientific inquiry can thrive (NRC, 2007). Most fundamentally, in order for teachers' to provide such guidance, they must attend to the substance of students' thinking and participation in scientific practices as they arise in the classroom.

There is evidence that specific guidance can be productive for engaging students' scientific practices. For example, Herrenkohl and Guerra (1998) explored how directly teaching specific roles to elementary students could scaffold productive scientific

argumentation. Students were taught to respond to other students' experimental results from investigations by asking for clarification about methods and theories, challenging claims, and questioning the relationships among the theories and the data. When students took on these particular roles in discussing others' investigations, there was evidence of greater negotiation of shared understanding, monitoring of comprehension, challenges to arguments, and efforts to coordinate theory and evidence.

There is also evidence that students can develop and negotiate norms for classroom inquiry and can hold themselves and others accountable to these norms. Lucas et al., (2005) made the development, critique, and revision of norms for inquiry an ongoing topic over the course of an academic year in a sixth grade classroom. Students discussed classroom criteria for evaluating what counted as a good scientific question and what they understood persuasive evidence to be. These criteria were used as a reference for students as they worked in teams to pursue inquiry into questions about pond ecology. The criteria changed over time; as new ideas arose, students began to argue about and alter the criteria. For example, students argued that they should add to the criteria of a good question. Specifically, some students proposed that a good question should be inspired by other findings and should inspire new questions.

Evidence, thus, also exists showing that students can productively engage in practices of inquiry in the science classroom, especially when classroom activity is explicitly organized around such practices (see also Lehrer & Schauble, 2004; Warren, Bellanger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001; Warren & Rosebery, 1995). It is assumed that guiding the classroom and organizing instructional activities is the role of the teacher, but most studies have taken place in classrooms that were

specifically designed by outside researchers to promote engagement in inquiry. In taking the teacher out of the equation, these studies fail to consider how the teachers' attention in moment-to-moment interaction with students contributes to classroom culture organized around inquiry. I make the theoretical assumption that classroom culture is built out of the moment-to-moment interactions among teacher and students, and the teacher's attention is an important element of those interactions. I will argue here, using theoretical ideas and empirical evidence from Ms. Brown's class, that teachers' attention to student thinking and participation in moment-to-moment interaction contributes to a classroom culture that can support students' participation in inquiry. I am offering a way of exploring how classroom culture develops, by focusing on teachers' attention in the classroom and the related discourse among teacher and students. I turn now to an explanation of the theoretical lens I use to emphasize the important role of teachers' attention in contributing to the classroom culture.

A Classroom Culture that Affords Student Inquiry

A focus on cultural practices of the classroom draws attention to the organization of the activity system of the classroom as an appropriate unit of analysis (Gallego, Cole, & LCHC, 2001; Valli & Chambliss, 2007). People engaged in sociocultural activity, such as the teacher and students in a classroom, are organized around particular goals or "objects" (Engestrom, 1987), which specify the ultimate goal for the activity. The object provides the group's "motive," which refers to the intention that drives the subject or subjects to pursue the object. The collective motive sets the specifics of what is important to address in that activity and constrains and affords suitable behavior (Wertsch, 1991). This motive serves to define the "degrees of freedom" for cognition

and behavior in the activity (Kaput et al., 1999). Because the teacher plays an important role in establishing the objects and motives in the classroom, a focus on her action (and attention) as an analytical unit provides insight into the overall culture of the classroom (Valli & Chambliss, 2007). It is important therefore, to understand how the orientation of her attention can function to contribute to organization of the culture of the classroom.

Pursuit of the object in the classroom is organized by the individuals (i.e. the teacher and students) engaged in the pursuit, the broader communities to which participants are accountable, and the tools these individuals and communities use (Gallego et al., 2001). In research on classroom culture, tools may refer to tangible tools used in the classroom (such as worksheets, curricular documents, and artifacts of classroom practice—i.e., tools used for scientific measurement, objects central to demonstrations, etc.), but they may also refer to conceptual tools or discourse practices that mediate the object. For example, Lemke (1990) refers to *triadic dialog* as a central form of discourse that serves as a cultural tool for pursuing the objects of traditional science classrooms. This form of discourse, which has also been referred to as an “Initiate-Respond-Evaluate” (IRE) form (Mehan, 1978) consists of the teacher asking questions with known answers, the students responding with bids for the correct answer, and the teacher evaluating the response in terms of their consistency with the known answer. This discourse pattern mediates the objects of most classrooms; it maintains the rules for interaction that identify the teacher as the authority, and it provides easy opportunity for the teacher to quickly and easily evaluate students in terms of correctness. The previous chapter describes how Ms. Hawkins and her students’ attention, their discourse patterns, as well as the broader communities in which Ms. Hawkins

participates, organize a classroom culture around objects of conceptual correctness and target vocabulary.

In classrooms in which the object is scientific inquiry, discourse may proceed quite differently. For example, van Zee & Minstrell (1997) have pointed to a different discourse pattern, referred to as a “reflective toss” in which the teacher simply repeats a student’s statement, thereby creating opportunities for both the particular student and the students collectively to consider the merits of the idea suggested, before it is evaluated by the teacher. This discourse can do much to mediate the pursuit of inquiry. It can force students to respond with more detailed accounts of their reasoning and help students to recognize that articulation of one’s reasoning is an important part of scientific practice. It can help to establish a classroom practice of attention to ideas and cue students to pay closer attention to their own and others’ ideas. Furthermore, it can mediate the pursuit of inquiry by distracting from a focus of accountability to the teacher as the authority and the arbiter of good or correct ideas.

In considering inquiry within the activity system of Ms. Brown’s classroom, I have looked to see when teachers and students are engaged in pursuit of coherent, causal explanations for phenomena, participating in scientific practices of argumentation, and generally framing the activity in terms of sense-making. What is the object that supports the organization of the classroom? What cultural tools mediate pursuit of the object? How can the teachers’ attention mediate pursuit of the object? In the following sections, I present the data from Ms. Brown’s class in order to argue that, when teachers attend primarily to the substance of student thinking, they can contribute to a classroom culture that affords student participation in inquiry.

Teacher Attention to Student Thinking: Supporting Classroom Inquiry

In the sections below, I draw on data from three of Ms. Brown's classes, a class in an evolution unit during her student teaching, and two others from her first semester of full-time teaching: One around the topic of ecological succession and one focused on diffusion and osmosis. These transcripts are accompanied by examples of Ms. Brown's written and oral reflections.

Research Context and Method

To explore how Ms. Brown attended to student thinking and the consequences for classroom inquiry, I present data from Ms. Brown's classroom over the course of two academic years. During the 2005-6 academic year, Ms. Brown was a teacher candidate in the Masters Certification Program (MCERT) described in chapter 4. During this time, she followed a traditional student teaching model, working at the school where Ms. Hawkins and I were teaching. In the first semester, she worked part-time in my class and part-time in Ms. Hawkins' class, helping us both with planning, instruction, and grading. In the second semester, she worked exclusively in Ms. Hawkins' classroom, taking progressively increasing leadership of the classroom throughout the semester.

During the 2006-7 academic year, Ms. Brown worked as a biology teacher in the same school, and participated in the Mod Squad biology cohort. The data for this case study include (1) video recordings of Ms. Brown's classes from both years (2) Ms. Brown's analysis of classroom video as part of her science pedagogy course assignments in the MCERT, (3) Ms. Brown's comments during discussions about her own and others' classrooms in the Mod Squad biology cohort meetings.

As in the previous chapters, I take it as evidence of attention to student thinking when a teacher notices and responds to a student's idea. The response may be the teacher's asking the student or other students to explain or elaborate on the reasoning, rephrasing the idea herself, or shifting the flow of classroom activity in a way that addresses the idea.

As shown in the previous chapter, it frequently appears that teachers attention is oriented primarily toward a particular type of thing (such as correct vocabulary as highlighted by the curriculum) and this orientation can serve as a selective filter for what gets explicit attention. A teacher's primary focus on correct content and vocabulary may distract her from noticing the substance of students' ideas, or even noticing when the substance is not articulated. Conversely, a teacher who is also oriented to the substance of students' ideas may be expected to listen for that substance and probe when it is not in evidence. In this chapter, I also consider what the evidence suggests about the orientation of Ms. Brown's attention, and how this attention is sustained in the classroom. Evidence of this orientation includes consideration of what Ms. Brown was focusing on throughout these conversations. Taken out of context, some of Ms. Brown's instructional moves could be interpreted as evidence of attention to conceptual correctness and misconceptions, but as part of an overall pattern, they support an interpretation that she is focused on attending to the substance of students' ideas.

I have chosen to base this argument in Ms. Brown's teaching primarily because there is consistent evidence of her attending to students' reasoning and participation in scientific practices beyond whether or not students used correct vocabulary or articulated correct concepts. Exploring Ms. Brown's case affords the opportunity to consider how a

teacher's attention to students' thinking can contribute to a classroom culture that can support student inquiry. I consider it evidence of a classroom culture of inquiry when students are collaboratively engaged in constructing coherent mechanistic arguments, participating in scientific discourse focused on the quality of scientific ideas, or otherwise participating in efforts to make sense of the ideas that arise.

Evolution

During the second semester of 2005-6, Ms. Brown took responsibility for half of Ms. Hawkins' course load, teaching three sections of introductory high school biology. She videotaped, transcribed, and analyzed a whole-class discussion in one of her classes for a science pedagogy course assignment. Notably, this is the same question that Ms. Hawkins posed to her class in the previous chapter, and this discussion occurred at the same time as that discussion, in another of Ms. Hawkins' classes that was being taught by Ms. Brown.

To start the discussion, Ms. Brown gave each student a slip of paper that asked "How do you think the modern-day giraffe got its long neck from short-necked ancestors?" She asked the students to take about five minutes to think about the question and write a response, collected the cards and read through them quickly, then returned the cards to students and began the discussion.

1. Ms. Brown: Tasha what do you think?
2. Tasha: I think it was a mutation.
3. Ms. Brown: What do you mean a mutation?
4. Tasha: I don't know, something happened and their DNA got messed up...so one had a long neck.
5. Ms. Brown: OK so does this mutation all happen at once?
6. Tasha: Well like for one of them (inaudible) then they have more offspring with long necks.
7. Louis: What did she say?

8. Ms. Brown: She said that she thinks it's a mutation
9. Louis: What else?
10. Ms. Brown: The mutation in the genes so then they had a longer neck. Right, Tasha?
11. Tasha: Yeah
12. Louis: Only the ones with a long neck...uh...were the ones that can survive
13. Ms. Brown: Only the ones with long necks survived?
14. Louis: They survived better.
15. Ms. Brown: They survived better, why Louis?
16. Louis: Because they could reach the trees or whatever to get food.
17. Ms. Brown: To get food, OK...so we have this one idea that maybe a mutation took place which caused them to have long necks, right? So they...and Louis said so they could reach the food in the trees they could live longer.

There is evidence of Ms. Brown's attention to student thinking in reiterating what students said back to them and requesting further explanation and elaboration. She asked Tasha to elaborate what she meant by a mutation (3,5) and repeated Tasha's idea (8,10). She similarly asked Louis for further explanation of his reasoning (13, 15), and in line 17 she summarized to the class the two student ideas she had heard.

Ms. Brown then asked if anyone else had an idea.

18. Ms. Brown: OK...Sharon.
19. Sharon: Could they like adapt by stretching...like try and stretch it.
20. Ms. Brown: They tried to stretch it, so, so...
21. Louis: They adapted.
22. Ms. Brown: They adapted, so Sharon say a little bit more about stretching their necks.
23. Sharon: I don't know they might have tried to stretch their necks to get food in the trees and the longer they stretched it, they adapted to it.
24. Ms. Brown: So, this is another idea, so we have two different ideas. Both of our ideas, kind of, we've talked about the trees. Right? The ones survived that were able to get the food out of the trees. So Sharon's idea that she is proposing is that maybe the giraffes just kept stretching their necks, right. They couldn't reach the leaves in the trees so they just kept stretching and stretching and over time because they stretched their necks so much they got longer. Is that right? Is that what you were saying?
25. Sharon: So could that change their DNA?

Again, Ms. Brown focused on the sense of the student's reasoning. Here, for example, she repeated Sharon's idea that the giraffes "tried to stretch it," and used a subtle verbal cue "so, so..." to prompt Sharon to elaborate. Note that in this instance and in the previous one, Ms. Brown explicitly worked to elaborate and press students to elaborate their ideas independent of whether the ideas would ultimately turn out to be correct. In line 24, she gave a simple summary of the two ideas and the respective lines of reasoning that supported them.

In her analysis of this exchange for her science pedagogy course, Ms. Brown recognized the value of Sharon's question (25), and she was particularly impressed that Sharon was the one who brought it up.

I really liked it when Sharon proposes this Lamarckian idea of giraffes stretching their necks to obtain food. She presents this idea to the class and then almost immediately asks, "So could that change their DNA?" I love this! I was so surprised when she asked that question because I was not expecting it at all. I thought eventually this question would arise, but I didn't expect it to happen so soon, or to come from the person who proposed the Lamarckian idea.

While Ms. Brown expected the argument against Lamarckian mechanisms to arise, she did not expect someone who articulated the Lamarckian idea to question it. She could have marked Sharon's objection as correct and explained why. Instead, she posed the idea to the rest of the class.

26. Ms. Brown: Good point. Could that change their DNA?

27. Louis: No.

28. Ms. Brown: No, why not?

29. Louis: Because that's something that changed after they were born.

30. Ross: Cuz they wasn't born like that.

Here there are two forms of evidence of Ms. Brown's attention to student thinking: Her response during class, reflecting Sharon's question back to everyone else, asking others to consider and argue for or against Lamarckian mechanisms, as well as her

statements later about what she saw at the time. It is particularly impressive that Ms. Brown did this, in light of evidence that Ms. Hawkins, a more experienced teacher working from the same materials, directly explained that Lamarckian ideas were incorrect, while providing the students little space to argue for or against them.

Here we can also see how Ms. Brown's attention to students' thinking supports inquiry by creating opportunities for students to articulate mechanistic explanations. For example, Ms. Brown pressed Tasha on her meaning of the word "mutation" (3), making it possible for all of the students to hear what Tasha meant. Explaining that she meant that "something happened and their DNA got messed up," (4) Tasha introduced the possible starting conditions of the evolutionary mechanism at work. As Ms. Brown probed further (5), asking if the mutation "happens all at once," Tasha provided more detail of her reasoning, introducing the important process of "hav[ing] more offspring" into her explanation.

Over time, Ms. Brown's attention to students' mechanistic explanations may focus students' attention on the importance of mechanistic explanations in science. Louis may already understand that single vocabulary words are not sufficient for scientific explanations. In response to his question about what Tasha said (7), Ms. Brown said that she thought it was a mutation (8), and Louis pressed Ms. Brown to say "what else" (9) Tasha said. It might be argued that Louis simply pressed Ms. Brown to say "what else" because he heard Tasha say something else, and not because he knew that her explanation required more. Either way, it is clear that Louis knew that he needed to hear all of Tasha's explanation before he decided if he agreed or not. Once Ms. Brown repeated what Tasha said, Louis noted his agreement, and added to Tasha's mechanistic

explanation by noting that the long-necked giraffes could survive better because they could reach the leaves to get food (12-16).

When Ms. Brown summarized what Tasha and Louis said as “one idea” and asked if anyone else had an idea, she contributed to a classroom culture of inquiry by creating opportunities (or “making space”) for other students to articulate their reasoning and making space for students to argue with ideas. Sharon responded with the stretching idea (19), and elaborated to provide a fuller mechanistic account when Ms. Brown asked her to “say a little bit more” (23). Additionally, when Ms. Brown repeated Sharon’s idea and checked with Sharon to see if she had repeated the idea correctly, she created an opportunity for students to consider the two ideas and decide which had the most merit. It is possible that hearing her own idea back is what led Sharon to question the idea (25). Ms. Brown’s repetition of Sharon’s question (26) provided the opportunity for Louis and Ross to argue it couldn’t change their DNA because it’s “something that changed after they were born,” and “they wasn’t born like that.” (29, 30)

Succession

After earning her teaching certification, Ms. Brown was hired to teach biology in the school where she had done her student teaching. Early in October, Ms. Hawkins designed a lesson for the biology team to use to teach succession while remaining accountable to a reading initiative being aggressively pursued by the school³⁴. At this point, Ms. Brown had joined the Mod Squad biology cohort, and I continued to observe and videotape her classroom.

³⁴ It would have been nice to have video of Ms. Hawkins doing this same activity, as she was the one who designed it. Did she also “make space” for students to debate the order of the phrases, as Ms. Brown did?

The following transcript comes from this lesson. Ms. Brown gave students a stack of phrases from a narrative of a piece they were going to read about the Mount St. Helens eruption and subsequent recolonization of the ecosystem. Each pair of students had a collection of strips of paper that read as follows.

- volcano erupted
- Washington State on May 18, 1980
- it appeared to be totally lifeless
- 50 species of wildflowers, shrubs, and trees have returned
- 500 times the force of the Hiroshima atomic blast
- unpredictable
- the lake looked almost undisturbed
- species would recover, and then others would, along a particular order.

Students worked in pairs trying to predict the order of the narrative. After several minutes, Ms. Brown called the class back together and asked who had an idea about how the lines should be put in order. Students offered up responses, one line at a time. No one read through their entire series, so Ms. Brown called on Robbie to read how he and his partner had arranged their strips.

1. Robbie: In Washington State, on May 18, 1980, unpredictable volcano erupted...five-hundred times the force of the Hiroshima atomic blast. The lake looked almost destroyed—disturbed.
2. Ms. Brown: Undisturbed.
3. Robbie: Yeah, undisturbed...it appeared to be totally lifeless. Species would recover and others were unharmed or—150 species of wildflowers, shr—
4. Ms. Brown: shrubs
5. Robbie: shrubs and trees have returned.
6. Ms. Brown: Okay, so anybody else have a different order? Anybody think theirs should go a little differently? Tezeta?
7. Tezeta: Oh, I said unpredictable volcano erupted, five hundred times the force of the Hiroshima atomic blast. In Washington State on May 18th, 1980, the lake looked almost undisturbed. It appeared to be totally lifeless. Species were recovered and others were unharmed [inaudible]. 150 species of wildflowers, shrubs, and trees have returned.
8. Ms. Brown: Okay, so um, anybody else? Allie?
9. Allie: In Washington State on May 18th 1980 an unpredictable volcano erupted five hundred times the force of Hiroshima atomic blast. The lake appeared undisturbed. Species recovered and others were unharmed

[inaudible] 150 species of wildflowers, shrubs and trees have returned. It appeared to be totally lifeless.

10. Robbie: That sounds good.
11. Ms. Brown: Okay, that sounds good?
12. Robbie: Sounds good. Not as good as mine, but it sounds good.
13. Ms. Brown: What's different between your two?
14. Robbie: She has "it appeared to be totally lifeless" at the end, and I have it like when I talk about species.
15. Allie: He talked about like what it was [inaudible] but [inaudible] my statement was it appeared to be totally lifeless.
16. Ms. Brown: Okay, so wait, explain that again. You put it at the end why Allie?
17. Allie: Because, you know how at the beginning like it destroyed everything
18. Ms. Brown: Right.
19. Allie: At the end, it got better and then it had a statement that said the whole thing it appeared to be totally lifeless until everything had grown back.
20. Ms. Brown: Okay. so you, you put it at the end just because you kind of were summarizing, is that what you're saying. And Robbie where did you put it?
21. Robbie: Before I talked about species.
22. Ms. Brown: Okay, and why would you put it before?

Robbie and Allie disagreed on the order in which they put the phrases:

Robbie argued for this order

- Washington State on May 18, 1980
- unpredictable
- volcano erupted
- 500 times the force of the Hiroshima atomic blast
- the lake looked almost undisturbed
- it appeared to be totally lifeless
- species would recover, and then others would, along a particular order.
- 50 species of wildflowers, shrubs, and trees have returned

...and Allie argued for this order

- Washington State on May 18, 1980
- unpredictable
- volcano erupted
- 500 times the force of the Hiroshima atomic blast
- the lake looked almost undisturbed
- species would recover, and then others would along a particular order.
- 50 species of wildflowers, shrubs, and trees have returned
- it appeared to be totally lifeless

Robbie did not really explain why he had put the “totally lifeless” line earlier. Attending to the differences in Robbie and Allie’s ordering, Ms. Brown had an opportunity to assess their reasoning. While she didn’t learn Robbie’s reasons for his objection that his was “better” than Allie’s, she learned quite a bit about Allie’s, who appeared to be arguing that the line went at the end to show that it *had* appeared to be totally lifeless *until* everything had grown back.

There is also evidence here of Ms. Brown paying attention to opportunities for students to participate in practices of argumentation. She took advantage of Robbie’s statement that Allie’s was “not as good as mine” to ask how the two summaries were different (13), asked Allie to explain her reasoning (16), and then asked Robbie to explain his (20). Ms. Brown talked about the disagreement between Robbie and Allie in the Mod Squad biology cohort group, noting that Robbie was willing to take Allie on, despite Allie's status in the classroom as "the smart one."

Like, it’s a known fact in my class, like everyone’s like, "Oh ask Ashley, she knows the answer." "Ask Allie." Like it’s this big joke, but I mean, [Robbie] was sure of his answer, ... when she read her list, and he was like, "That sounds pretty good," he’s like "That’s a good one, but mine’s better." ...and it wasn’t just that he was being cocky. I think that he was really, like, "No!" You know? ...

As the discussion in her class continued, Ms. Brown pressed more students to participate in the argument, which helped the class move toward consensus on this point.

- 41 Ms. Brown: Does anybody else...um, did anybody else put theirs that it looks like this before talking about the species returning? Yes, Mavis why did you put it before?
- 42 Mavis: Because even though, at the end, even though all this happens, species still returned.
- 43 Ms. Brown: It’s what it looked like before right? Okay, so you put it before
- 44 Mavis: Because it was lifeless and then they returned.
- 45 Ms. Brown: Because it was lifeless and then they returned. Okay, Brianna?

46 Brianna: It was, we put it after the volcano erupted because well, a volcano erupted and then there would be like no animals and no stuff and it would be lifeless.

47 Student: Oooh!

48 Ms. Brown: Okay, good. So it's, it's totally lifeless right after the volcano erupts, correct? Okay, that's a good place for it.

Again, we have evidence that Ms. Brown was attending to students' ideas, as she repeated Mavis' reasoning that "it was lifeless and *then it* returned," (45). Brianna, who had her hand up, explained that she and her partner had put it after the volcano erupted, and not at the end, because "a volcano erupted *and then* there would be like no animals and no stuff and it would be lifeless." Ms Brown repeated Brianna's idea as well (48).

Thus, Ms. Brown was attending to students' reasoning and opportunities to participate in argumentation, which facilitated further reasoning and participation by the students. It might be argued that the argument was not a substantive scientific one, but rather one in which students were arguing over the predicted wording of the sequence. This may explain why Allie did not continue to argue her point. Perhaps she understood that the argument that the volcano erupted *and then* it appeared lifeless (Brianna) *and then* the species returned (Mavis) was not fundamentally different from her own argument that that the line went at the end to show that it *had* appeared to be totally lifeless *until* everything had grown back.

The point here is not to show that the students were engaged in a scientific argument *per se*, but to show that Ms. Brown's attention to the substance of student thinking supported students' participation in sense-making discourse. Although students argued about the appropriate sequence of the words, they approached the activity in terms of what made sense to them based on their understanding of volcanoes and living things.

I take students' participation in this kind of sense-making discourse to be an important aspect of scientific practices of inquiry.

Furthermore, I take this as a good example of how teachers' attention to the substance of students thinking can contribute to a classroom culture that supports inquiry, because the teachers' attention to substance provides opportunities for students to consider the substance of others ideas, and encourages students to engage in this practice. Ms. Brown made space for student to practice making claims, listening to others' claims, and choosing among alternatives. In this way, she provided students with excellent practice in participating in the kind of discourse that characterizes classrooms explicitly designed to promote scientific inquiry (e.g., Warren & Rosebery, 1995) .

Osmosis

In November of that same semester, I recorded another of Ms. Brown's classes during the unit on cells. The class had discussed osmosis and diffusion and done laboratory activities to explore these two phenomena. Ms. Brown began the class with a warm-up activity asking students to define osmosis and diffusion. Following this brief review of the terminology, Ms. Brown showed students a stanza from Samuel Taylor Coleridge's *Rime of the Ancient Mariner*:

*Water, water, everywhere,
And all the boards did shrink;
Water, water, everywhere,
Nor any drop to drink.*

Ms. Brown told the students that the poem had been written from the point of view of someone on the ocean. Without prompting, Jeffrey offered an interpretation of the poem.

1. Jeffrey: You can't drink the water, 'cause that's salt water.
2. Ms. Brown: Okay, so, shhh, alright, so let's talk about this. Jeffrey, go ahead.
3. Jeffrey: They can't drink the water 'cause it's like...salt water.
4. Student: Salt water.
5. Ms. Brown: Salt water, okay, so why can't they drink it? What does this have to do with anything?

Several students began talking at once. Lara spoke up loudly.

1. Lara: Doesn't it have to do with osmosis though?
2. Ms. Brown: Okay, so what does it have to do with osmosis?
3. Lara: Meaning, uh, the water—
4. Ms. Brown: You guys, listen! Shhh.
5. Lara: Like, doesn't it kinda mean, like the water inside the boards left out the boards and then it shrank
6. Ms. Brown: Why would it do that?
7. Lara: I...(shakes her head)
8. Ms. Brown: Okay, so Lara's saying that the water in the boards left out of the boards, which made them shrink. Okay. The water--the boards, he's talking about what?...What are the boards that he's talking about?
9. Lara: Like on the boat.
10. Ms. Brown: Like on the boat, right. On the boat, so why...why did they, why did the water leave?
11. Ryan: The boards had a higher concentration of water on the boat

The discussion continued, with many of the students agreeing that the water would have “left out of the boards” as Lara suggested if the concentration of the water was higher in the boards on the boat than outside in the ocean. Lara was not satisfied with this explanation, however, and she spoke up.

26. Lara: But the ocean was—
27. Ms. Brown: The ocean is what? No--go ahead
28. Lara: The ocean is water
29. Ms. Brown: Right
30. Lara: So how does the board have more water than the ocean?
31. Ms. Brown: Okay. Remember when we did the egg-speriment and we put the...

In the snippets of transcript above, there is evidence of Ms. Brown’s attention to the students’ reasoning when she asked students why they can’t drink salt water (5),

asked Lara what it had to do with osmosis (9), and asked the class why the water would “leave out of the boards” as Lara suggested (13, 17). Not only did Ms. Brown’s attention to students’ reasoning support Ryan’s reasoning that there was a “higher concentration of water *on the boat*” (than in the ocean), it also set up a situation that Lara thought needed explaining. In these ways, Ms. Brown’s attention to students’ ideas led to further opportunities for students to reason.

Ms. Brown then tried to relate students understanding to an earlier demonstration. She mentioned the “egg-speriment” in which she had shown students what happens when an egg, after the shell is dissolved, is placed in salt water (the egg shrinks as water moves across the osmotic gradient). Many students began talking at once, recalling the demonstration.

40. Ms. Brown: Okay, listen...We're talking about--we know that the boards are shrinking, and we're--the idea is that there--something's moving from a high to a low concentration, and the idea was proposed that the water, it's moving, but Lara and maybe other people want to know how the water can move out of the boards and into the ocean when the ocean's all water...so my question for you is, think about the experiment we did, and we had that egg, and we put it in the vegetable oil, right? Was it completely submerged in that oil?

Ms. Brown reoriented students to the current discussion, and established what the class had determined, her use of the third-person plural “we” sending the message that the class was together working toward a solution. She summarized the idea that was proposed, and noted Lara’s objection. Drawing the attention to another demonstration students had seen she created an opportunity to further articulate their understandings of osmosis as it related to the poem. Again, Ms. Brown’s attention was geared toward having students make sense of the poem in light of their understandings of how water

moves. She did not draw students' attention to the terminology of osmosis until the end of the discussion (not shown here).

41. Lara: Yes.
42. Ms. Brown: So was there more liquid in the egg or what it was in?
43. Lara: Outside of the egg.
44. Ms. Brown: Outside. There was more liquid.
45. Lara: Oh. It doesn't mean that there was more water in vegetable oil than there was in the egg.
46. Ms. Brown: Good. So what's different about--maybe what's different about the water in the board and the water in the ocean?
47. Lara: Maybe it's two different kinds of water.

Lara directly answered Ms. Brown's question (correctly) that there was more *liquid* outside of the egg (43), and Ms. Brown repeated Lara's assertion (44). Lara realized that this didn't mean that there was more *water* outside of the egg, implying that she knew that the more important question was where there was a greater concentration of *water* (45). Seizing on Lara's realization, Ms. Brown asked what was different about the water in the boards and in the ocean, which led Lara to reason that maybe it was "two different kinds of water" (47). Attending to this statement, Ms. Brown asked Lara "like what?" and when Lara said she didn't know, Ms. Brown opened the question up to the rest of the class. Before anyone else could speak, Lara broke in with another idea.

48. Lara: Maybe one's fresh water and one's salt water.
49. Ms. Brown: Okay, and he's in the ocean, right? What kind of water Rick is in the ocean?
50. Rick: Salt water
51. Lara: Oh I get it, because the salt doesn't have as much, never mind.
52. Ms. Brown: No no no, go ahead, talk it out.
53. Lara: I was just gonna say 'cause the salt doesn't have as much water as the fresh water would because the salt absorbs it a little bit.

Lara was apparently continuing to think about the evolving explanation, and as Ms. Brown probed students to differentiate between the "two different kinds of water," she began to construct a fuller explanation. She tried to back off on explaining what she

understood (56), but Ms. Brown pressed her to “talk it out.” (57). Lara explained that there was more fresh water in the boards because the salt in the ocean “absorbs [the water] a little bit.”

Again, the evidence in this exchange suggests that Ms. Brown was attending to students’ reasoning, taking the opportunity to move them to apply what they had learned about the movement of water to their interpretation of the poem. Furthermore, we see evidence that the orientation of Ms. Brown’s attention not only helped her to assess what students did and did not understand about osmosis, but also provided opportunities for students to reason further. In this case, her attention to Lara’s arguments helped Lara to construct a mechanistic explanation that made sense to her. We have additional evidence of Ms. Brown and other teachers in her school and in the district attending to students’ reasoning and participation, and evidence that this orientation of attention created further opportunities for students in these classrooms to reason and participate in scientific practices. As I will discuss, I take this as further evidence that teachers’ attention to the substance of students’ reasoning can have positive consequences for students’ participation in inquiry.

Consequences of Teachers’ Attention to the Substance of Student Thinking

In the sections below, I discuss how, when teachers attend to the substance of student thinking, they amplify attention to the substance of ideas. In doing so, they contribute to a classroom culture that can afford student participation in inquiry.

Amplification of Attention to Substance

As I have shown in earlier chapters, while teachers can attend to the substance of student thinking, the school system and traditional teacher education and professional development often focus on other priorities, such as the coverage of conceptual content and correct vocabulary as its proxy, and fail to support teachers' abilities to attend to substance. For these reasons, I have used the term "amplification" to argue that teacher education and professional development should focus efforts on helping teachers to attend to student thinking. At the level of the school system, amplification of teachers' attention to student thinking is fundamental to combating the systemic priorities that can inhibit teachers from supporting students' science learning.

Amplification can also be applied to the level of the classroom. When, for example, a teacher attends primarily to vocabulary (as Ms. Hawkins did in the opening snippet), she draws students' attention to the importance of vocabulary. As a result, students often respond to teachers' questions with single-word repetitions of vocabulary, as Edwin did in the opening example. As these kinds of exchanges repeat and accumulate over time, attention to vocabulary is amplified. By contrast, when teachers attend to the substance of student thinking, they draw students' attention to the importance of articulating their ideas, which can lead to more articulation of ideas. The more ideas students articulate, the more opportunities teachers' have to attend to their ideas and further draw students' attention to the importance of discussing ideas. This "feedback loop" can lead to greater and greater attention to ideas. Thus amplification of teachers' attention to the substance of student thinking leads to amplification of students' attention to ideas.

Attending to Substance Contributes to a Classroom Culture That Can Foster Inquiry

Attending to and assessing the value of ideas is fundamental to what might be called a “culture” of scientific practice. In order to reason with and about ideas and engage in argumentation, scientists (and students) must pay attention to the substance of those ideas. In scientific practice, the object is to consider the substance of ideas, to distinguish the relative merits of ideas, and to focus on those ideas that are most coherent, sensible, and consistent with evidence. As described in the previous chapter, however, the object of science classrooms is closely associated with the objects of the broader educational systems—knowing correct ideas and vocabulary as reified by high-stakes tests. The motive to pursue this object provides little space for inquiry to occur; the activity is simply not framed as a sense-making endeavor.

As a central participant in the classroom, the teacher plays an important role in shaping the discourse and contributing to the object of the classroom (Valli & Chambliss, 2007), and thus what she attends to helps to shape the culture of the classroom. When teachers attend to the substance of student thinking, they contribute to objects and tools of classroom activity that more closely resemble those of scientific practice. By asking students to explain their reasoning and to choose among alternative ideas (for example) the teacher supports a motive to attend to the substance of ideas and to consider whether or not they make sense. The evidence here supports other research suggesting that teachers’ attention to the substance of students’ thinking can contribute to a classroom culture that fosters student inquiry (e.g., Warren & Rosebery, 1995). While there are examples in the literature that show how such a culture can develop in classrooms in which practices of inquiry are explicitly scaffolded (e.g., Herrenkohl & Guerra, 1998;

Lucas et al., 2005), I argue here that the simple act of a teacher attending closely to the substance of students' thinking in everyday practice can contribute to similar ends.

Limitations and Areas for Future Research

I do not claim that the data included in this paper demonstrates that Ms. Brown's students are consistently participating in classroom inquiry and practices of assessment of ideas. First, my data is drawn from only three different classes, and thus does not show how the students' attention, nor the object of a particular classroom, shifts over the course of the year. Secondly, in some cases, (e.g., the example from the osmosis class), the data primarily shows how Ms. Brown's attention supports only a few (or even just one as in the case of Lara in the osmosis class) students' inquiry.

My data does show how a teachers' attention to student thinking can support students' attention to ideas, which is crucial to the development of practices of assessment of ideas and the establishment of a classroom culture that can foster inquiry. Thus, while I cannot make definitive causal claims about the role of teachers' attention in the development of a culture of classroom inquiry, my data does suggest that the teachers' attention plays an important role and that focusing on the role of teachers' attention is a productive way to understand how a culture of classroom inquiry can develop in science class. This is an area ripe for further study. In the future, I hope to observe a single classroom over the course of a year in which a teacher attends to student thinking and works to promote norms for practices of assessment of ideas and classroom inquiry. With this data, I will be able to make stronger claims about how a teachers' attention to the substance of student thinking contributes to the development of a classroom culture that can foster inquiry.

This chapter suggests another area for future research that deals not with the consequences of teachers' attention, but the issues of variation in teachers' attention. Whereas the example from Ms. Hawkins' class is representative of the ways in which teachers commonly attend to "correct" conceptual knowledge and target vocabulary as a proxy for correctness, the examples from Ms. Brown's class suggest that some teachers are able to frequently and consistently attend to the substance of student thinking despite the systemic constraints³⁵. In the next chapter, I will return to the fundamental question that arose in the case study of the MCERT program (Chapter 4) and again here: If the institutional system exerts the influence on teaching argued in the previous chapter, how, then, within the same system, can we account for both the teachers who regularly attend to the substance of student thinking and those who are more frequently distracted by conceptual correctness and vocabulary?

³⁵ This is not to suggest that only some teachers *can* attend to the substance of student thinking, only that some have a greater tendency to do so consistently and regularly in the context of the systemic constraints. As I described in the previous chapter, evidence demonstrates that Ms. Hawkins can (in the particular class shown as well as in other classes in the data set) meaningfully attend to the substance of student ideas and reasoning, although she is frequently distracted by competing accountabilities to the various elements of the system. This raises the question of within-subject variation, which is another area for future research: *When* do teachers attend to the substance of student thinking and when do they not?

Chapter 7: Findings, Implications, and Areas for Future Research

In this chapter, I discuss findings and implications from the collection and analysis of data reported in Chapters 4, 5, and 6. In particular, I focus on implications for teacher education, professional development, and theory development, as well as delineate areas for future research.

Summary of Findings

This study has shown that teachers can attend to the substance of student thinking, but are often more likely to attend primarily to conceptual correctness and target vocabulary. My data suggests that this pattern reflects the ways in which teachers' accountabilities to systemic influences shapes their attention. I also argue that *when* teachers attend to the substance of student thinking, it can have positive consequences for students' science learning.

Teachers Can Attend to Student Thinking

Teachers, even novice teachers, can attend to the substance of student thinking while teaching. In the same way that people, in everyday conversation, have the ability to focus on and try to understand other peoples' ideas, teachers have abilities to focus on and try to understand the meaning that students are trying to make with scientific content. For example, in Chapter 5, I described how Ms. Hawkins selected Hannah's answer to the question, *How do you think the modern-day giraffe got its long neck from short-necked ancestors*, to introduce Darwinian ideas into the discussion. She did this, she said, because she flipped through, and saw the words "evolve" and "adapt" and assumed that Hannah had the right idea. In class, however, Ms. Hawkins asked Hannah about a

phrase she'd used about giraffes *needing* long necks to eat the leaves on trees. Hannah responded "Maybe the environment started changing and they need to survive, and in order to survive they needed to get their necks to be longer? When Ms. Hawkins pressed her for a mechanism, Hannah suggested it might be "the stretching thing" that someone had said earlier. In attending to the substance Hannah's explanation, in terms of the language she was using and the mechanism she might imagine, Ms. Hawkins learned that Hannah had quite a different idea, one Ms. Hawkins would characterize as "Lamarckian."

Teachers Often Attend to Correctness of Ideas and Target Vocabulary

The above example illustrates another theme throughout my data. While teachers *can* attend to the substance of student thinking, they often are more likely to attend to students' ideas in terms of the correctness or incorrectness of the ideas, and they frequently attend to target vocabulary as a proxy for correct ideas. Thus, Ms. Hawkins was distracted throughout the class by whether students were using words like "evolution," "adapt," and particularly "mutation," and she was focused on picking out and identifying the correct answers and the "misconceptions." Other examples from classroom transcripts and field notes show something similar occurring with the ways in which Ms. Hawkins, Ms. Turner, and Ms. Vai and some of the MCERT interns taught the "Well-Designed Investigation." Evidence from these classes, and in other data generated from the Mod Squad project (Tang et al., 2007) shows teachers primarily attending to students' correct understanding of the sequence of the steps, and the recognition of key vocabulary such as "independent variable," "dependent variable," "control," and "constants."

Institutional Context Influences Teachers' Attention

My data suggests that the pattern of attending primarily to conceptual correctness and target vocabulary reflects the ways in which teachers' accountabilities to institutional, local, and classroom systems organize and constrain attention. The High School Assessment (HSA) in biology emphasizes these foci, and the local professional community continuously reproduces and reifies them. Furthermore, teachers' accountability to student expectations of science class, based on the history of student and teacher interactions, highlights the importance of correct answers and correct terminology. With all of these accountabilities emphasizing similar foci, attention to these foci is amplified, and attention to the substance of students' thinking is often drowned out.

Teachers' Attention to Meaningful Substance Contributes to Scientific Inquiry

Despite these conditions and their influence on what teachers attend to in class, there is evidence of some teachers, such as Ms. Brown, who are frequently able to attend to the substance of their students' thinking during class, as I described in Chapter 6. Data from Ms. Brown's class shows that when a teacher attends to the substance of student thinking, students attend to their own and others' ideas. As attention to ideas is amplified, a classroom culture may develop that can support and sustain student inquiry. This latter claim is a much more tentative than the others, and it is an important area for future research. In the sections below, I discuss this and other areas of future research and implications for teacher education and professional development.

Implications and Areas for Future Research

This research has implications for teacher education and professional development, and it suggests avenues for future research in these areas. There are also contributions to our theoretical understandings of individual activity within broader systems.

Implications for Teacher Education

Science education reform promotes teachers' attention to the substance of student thinking (NRC, 2007). The finding from Chapter 4, that even novice teachers can attend to the substance of student thinking, has important implications for teacher education. If it is possible even for some novice teachers to attend to student thinking, then we should make this an explicit agenda in science teacher education, by structuring activities and assignments that give novices practice in attending to student thinking. Attending to student thinking is an important first step in providing responsive instruction that can help students construct understanding of scientific concepts, reason scientifically, appreciate the nature of science, and engage in scientific practices.

The MCERT science pedagogy course sequence was designed to amplify attention to student thinking by having novice teachers watch videotape of classrooms and collaboratively analyze student thinking from their own and others' classrooms, with an eye toward what students are thinking as they participate in science classes. We also encourage teacher candidates to identify themselves as responsive teachers, who listen to student ideas, and we model discursive tools that can support attention to student thinking. The MCERT program may be seen as an alternate system to the institutional systems in which most teachers work, one that can support a framing of teaching in terms of listening to and understanding students' ideas.

There is some evidence that the MCERT program is successful in supporting such a framing. This evidence exists both in the examples of novice teachers successfully attending to student thinking (in the case of Ms. Brown, even after leaving the program) and in interviews and spontaneous comments that some of these teachers have made about their teaching in relation to the MCERT program. For example, in the third year of the Mod Squad project, Susan and two other graduates of the MCERT program joined the biology cohort. In one of the summer meetings, there was a conversation about the difficulty in attending to student thinking in light of the numerous other systemic pressures. Susan said she didn't really understand what the problem was, because attending to student thinking was "how I learned to teach." Approaching teaching from within a framing of attention to student thinking, Susan didn't see a conflict between the priorities of the system and the focus on student thinking.

Research on the MCERT program continues, and there are two main avenues for further study. First, it will be important to collect more systematic data on how the discourse and practices of the MCERT science cohort amplify attention over time, and if and how novices' attention to student thinking changes over time as a result of participation in this system. What practices are most significant for supporting teachers' attention to student thinking? How do participants in the MCERT program work collaboratively to develop a framing of teaching on these terms?

Second, there is evidence that despite similar systemic circumstances, some novices have a greater tendency than others to attend to the substance of student thinking. How can we understand this variation? This same question of variation appears in examining the case studies of Ms. Hawkins and Ms. Brown. In the case of Ms. Brown and Ms. Hawkins, it may be that Ms. Brown's experience in the MCERT program helped

her to frame teaching differently than the way it was framed by the institutional systems, and thus helped her to recognize the “degrees of freedom” that were afforded by the institutional system.

But what if Ms. Brown had not been in the MCERT program? Would she still attend to student thinking? The factors that shape and constrain individual teachers’ attention is an area for future research. Most likely, how individuals’ frame their teaching is dependent not only on the institutional system and the system in which they learned to teach, but on a more complex stew of pedagogical content and context knowledge and the ways in which individuals’ identify with the educational systems and with other systems. A framework for understanding this variation would have to be able to explain those teachers in the MCERT program who rarely attended to student thinking; it would have to be able to explain teachers who were not in the MCERT program, but were frequently able to attend to student thinking. Understanding this variation would mean conceptually expanding on the systems perspective to focus at the level of the individual³⁶ in relation to the system. Methodologically, it would call for in-depth case studies of individual teachers, to understand the factors that contribute to a teacher’s framing of teaching in terms of attending to student thinking.

Why should we care about understanding this variation? We should care because we want to know how to help teachers frame teaching in terms of attending to student thinking. We should care for the same reason that we should care as secondary science teachers to understand the variation in our students’ learning. We should care because it will inform our instruction and our program design. It will help us to learn the

³⁶ In Appendix C, I provide an example to demonstrate how I am beginning to think about expanding the framework to account for this variation.

difficulties that teachers may encounter in attending to student thinking, and how to help them overcome them.

Implications for Professional Development

The argument in Chapter 5, that experienced teachers can attend to the substance of student thinking, but are frequently distracted by their accountabilities to institutional systems, has similar implications for professional development. If the system in which teachers work fails to amplify attention to students' productive scientific thinking and practice, then this is an important role for professional development. One way to help teachers develop their abilities to attend to student thinking is to engage them in practices that explicitly frame teaching on these terms.

As the Mod Squad project comes to a close, there is evidence that some teachers may have begun to shift the focus of their attention while teaching. An important area of future research is to understand how the Mod Squad project has helped teachers to reframe their teaching and develop their abilities to really listen to and understand students' ideas. Furthermore, we must begin to explore how to support teachers once they have begun to attend to student ideas while teaching. Some of the same teachers in the Mod Squad program who are learning to attend to student thinking are already asking "now what?" questions: many are not sure what to do with much of the student reasoning that they hear. Further research is needed to understand how to help teachers use their understanding of student reasoning to respond in the moment and make pedagogical decisions.

A related area of research is to determine whether and how it makes a difference *when* teachers are introduced to practices that prioritize attention to student thinking. It may

be that it is important to introduce teachers to such practices *before* they have begun to teach in a system that distracts from attention to student thinking. That is, the framing of teaching as amplified by the institutional system may be powerful enough to “block” teachers from appropriating an alternate framing. Conversely, teachers may be able to adopt such a framing if introduced to practices of attending to student thinking later. How is learning to attend different, for example, for Ms. Hawkins, Ms. Brown, Susan, or any of the other novice and more experienced teachers included in this study? Case studies of teachers who are introduced to practices of learning to attend at different stages of their career might also help to elucidate those factors that contribute to this variation.

In considering the potential of teacher education and professional development to amplify attention to student thinking, it would be useful to know what it takes to help teachers sustain a framing of teaching in terms of attention to student thinking. For example, Ms. Brown and several other graduates of the MCERT program have continued to work with us in the Mod Squad project, where a framing of teaching as attention to student thinking is continuously being reproduced and reified. The project is coming to a close, however, and it raises the question: how sustainable is such a framing, in light of the system of accountabilities as I describe in Chapter 5? As I have argued, there is little about the institutional systems of schools that systematically supports teachers’ attention to student thinking. Without outside support, can teachers continue to be successful at attending to student thinking?

Perhaps, in some cases, the answer is yes. Maybe for some teachers the exposure to a new way of framing teaching can be a transformative experience, around which they can begin to reframe their practice in a sustainable way. Considering the multiple ways in which institutional systems distract from attention to student thinking, however, it is likely that many teachers would need continued outside support. My research suggests that such

support might be most productive if it is situated within the context of the institutional system itself, particularly in teachers' local professional communities.

My research contributes to literature suggesting that teachers' participation in strong local professional communities can influence their attention (McLaughlin & Talbert, 2001; Siskin, 1990). In considering teachers' accountabilities to local professional communities, I have looked at how Ms. Hawkins' accountability to the "strong" Springfield biology team helped to reinforce signals that shaped her attention in particular ways. The "strength" of a community refers to dimensions of cooperation and collegiality, and does not necessarily mean that a community is engaged in a pursuit that is accountable to the discipline. In the case of the biology team at Springfield, while the community is strong, it is still primarily accountable to the priorities of the institutional system, and its practices continue to revolve around students' achievement on high-stakes tests. For example, under direction from the administration, the biology team at Springfield now engages in a sort of educational "triage" (Settlage & Meadows, 2002) where they identify those students who have earned marginal grades on the first semester final exam, considered a predictor of success on the HSA, and remediate those students only with after school tutoring sessions.

A local professional community *could* be engaged in collective practices of attending to student thinking, however. For example, Sarah and Scott, while they were in the MCERT program, were also working together at the same school, planning and reflecting on lessons together, collecting artifacts of their classrooms, and analyzing their students' thinking. It would be interesting to organize a cohort of teachers within a single school (like the Springfield biology team, for instance) and engage them in practices of attending to student thinking as we have done in the MCERT program and in the Mod Squad project. This could give some insight into the power of local professional communities to affect

change within the system, and an image into the classrooms in which such change might be consequential. It may be possible to amplify attention to student thinking from inside the institutional system.

Implications for Research on the Consequences of Teachers' Attention

My data suggests that teachers' attention to student thinking supports a classroom culture that can foster inquiry. In making this claim I have shown how teachers' attention to ideas draws students' attention to ideas and can lead to practices of scientific discourse, argumentation, and sense-making. My data is limited, however, in that I did not observe Ms. Brown's class everyday, over the course of a period of time, nor did I interview students. Without this data, I am limited in claims I can make about the extent to which these types of practices are typical and particular to a class in which teachers' attend to student thinking, and I'm limited in my knowledge of how students understand what they're doing in such a class. Furthermore, I have little way of understanding, if, and how, classroom cultures change over time as attention to student thinking is amplified. This is an important area of future research. We³⁷ intend to pursue this area by focusing in on the classroom of another teacher, Susan (the MCERT graduate discussed earlier, who is currently a participant in the Mod Squad project) who regularly frames her teaching in terms of understanding students' ideas, and is frequently successful at attending to student thinking. Daily observations, classroom artifacts, and interviews with students will provide a more detailed picture of the culture of a classroom in which a teacher frequently attends to the substance of student thinking and draws students' attention to ideas.

³⁷ Mostly Kitty Tang

Theoretical Contributions to Understanding Teaching and Learning to Teach

Finally, this work is situated in theoretical perspectives that seek to understand the relationships among individuals and the systems in which they participate (Holland et al., 1998; Wenger, 1998). In research on science teaching, a lot of work has focused primarily on individual teachers and their knowledge, beliefs, etc. (Cronin-Jones, 1991; Gess-Newsome, 1999). A growing body of work has focused on social and institutional aspects of teachers' participation in learning communities in professional development and within the systems of schooling (Grossman, Windeburg, & Woolworth, 2001; McLaughlin & Talbert, 2001; Purnam & Borko, 1997). It is important to bring these two approaches together in ways that offer insights into how the individual and the system interact. My work contributes to theoretical perspectives that consider the individual within systems, as a lens into the systems, and as an active participant in the objects of the systems. My intent is to add an example to the literature that helps people continue to discuss, debate, and synthesize theoretical frameworks for better understanding teaching and learning-to-teach.

We need such a model because teaching is complex, and teachers' attention will never be quite so simple as a reflection of what's in the teacher's head, nor as simple as a reflection of the institutional pressures surrounding the teaching. As I discussed earlier, we see a great deal of variation in both the MCERT program and in the Mod Squad project in terms of teachers' practices of attending to student thinking, and we see variation even within individual teachers' practice. A theoretical model to account for this variation will contribute greatly to our understanding and design of teacher education and professional development, and is useful in understanding other problems as well. For

instance, we understand little about how teachers use curriculum. If we assume variation in teachers' attention to student thinking, we might expect variation in the ways teachers use curriculum. This perspective may be helpful in improving curriculum design.

Summary

This study suggests the need for teacher education and professional development that frame teaching in terms of listening to and understanding ideas, and support teachers in framing teaching on these terms. Further research is needed, however, to understand variation in teachers' abilities to attend to student thinking, to understand how people learn to attend to student thinking, and to understand how teacher education and professional development can best support teachers in developing their abilities. Furthermore, there is a need for further research to understand the consequences of teachers' attention for student thinking. This work serves as an example to contribute to the theoretical discussion on the interplay between the individual and the social and institutional context.

Appendices

Appendix A: Mod Squad Coding Categories

HSA/standardized exams

Any comment that concerns what is or isn't on the HSAs or other standardized exams, or BCRs (Brief Constructed Responses), which appear on the exams, e.g.

“Unless there's a BCR (on the test), then it really doesn't matter”³⁸

“That's like (score of) 4 on a BCR...you can get things wrong and still get a four”

“I don't remember if it (a BCR) was on a test or just one I gave them”

Indicators/mandated objectives

Any comment that concerns what is or isn't listed as an indicator or other mandated objective, e.g.

“The objective is for them to understand the specific nitrogen bases that pair together”

“Graphing is a big deal because it's in the curriculum”

“The indicator is ‘to be able to read and interpret a graph,’ or something like that.

Activity

Any comment that's about the activity, curriculum, materials; e.g.

“There were a variety of (specimens) at the same table”

“I think it was (a problem with) the activity”

“I think it would be wise to do a paper model for replication”

Teacher actions

Any comment that is about something the teacher did, could do, or might have done, e.g.

“...and I did this with some of mine, when they brought up the wrong one I actually said...”

“...I also think that what you did here was...”

“What do you do with commensalism?”

Student ideas

Any comment that is about some specific student thinking, e.g.

“He's trying to define how they're each benefiting”

“I think she's trying to figure out what the heck would want to eat a sponge”

“I think he meant to say ‘exoskeleton’”

Student engagement

Any comment that is about the students' interest or engagement; e.g.

“I would say that student was really into it!”

“He seems to really like the conversation”

“They seem engaged.”

³⁸ All of these examples come from actual coding.

Student attributes

Any comment about students in general, e.g.:

“They don’t much background knowledge.”

“They are totally obsessed with grades!”

“Are these honors or on-level kids?”

Student Action

Comments that are about specific student actions, e.g.

“I see them drawing it on their papers.”

“I think he’s holding it while she’s explaining.”

“They are looking at samples that had sponges in them.”

Science

Comments that are specifically about the science content, e.g.

“That’s my understanding of what a sea anemone is”

“But polyps aren’t hard; polyps are the soft ones”

“Usually it’s caused by a mutation”

Other

Comments that don’t fit in any of those categories, e.g.

“I’m a little confused about how this matches up” (referring to part of a transcript and a worksheet)

“I photocopied this for you guys.”

“I think it was Nancy” (referring to which student made a comment)

Appendix B: Novice Teachers' Attention to Student Thinking

As discussed in Chapter 4, for four other interns, like Scott and Susan, there was evidence of attention to the substance of student thinking within the first few months of their starting to teach. For one other intern, in addition to Emma, I did not see evidence of that attention until the spring semester. Kay was the only intern for whom I did not observe evidence of attention to the substance of student thinking during the school year. Below, I present the evidence from the five interns not discussed in Chapter 4.

Cathy

Cathy was teaching sixth grade science, splitting her schedule with Anne, another intern. The example below comes from a lesson in November on energy flow in populations, which Cathy presented as a video case study.

The students had already learned about populations, communities, photosynthesis, food chains, and food webs. In this lesson, they read a textbook description of energy pyramids together aloud, stopping for discussion after each paragraph. The transcript below concerns a paragraph stating that the amount of energy captured by organisms decreases dramatically with height in the food pyramid. When Aaron gave his summary that “carnivores don’t need that much energy,” Cathy clarified that the paragraph was stating not that carnivores *need* less energy, but that there is “less available energy for them.” She then used pies as an example and showed how the pies get smaller as one moves up the food chain. Mike then interjected with a question.

1. Mike: Why do the pies get so much smaller?
2. Cathy: Ah, why is this pie so much smaller than this pie?
3. Billy: Because the 10% (unintelligible)
4. Mike: I know, but why do they only pass on 10%? Why can’t they pass on more?
5. Cathy: That’s a great question, who can answer Mike’s question?

6. Billy: They use the rest of the energy to do normal things that they need to do to live.
7. Mike: Why can't they be lazy and pass on more?
8. Billy: Because then they would die, and they wouldn't pass on anything!

Many students' began talking at once. The discussion continued around Mike's question, and it included the following exchange:

16. Cathy: ...Douglas, why is it, even if a snake comes along and swallows the mouse whole, it eats the whole thing, how come it only gets 10% of that mouse's energy, and not the whole 90%
17. Douglas: Because it's dead.
18. Cathy: It's dead? Ok, explain that a little more.

Evidence of Cathy's attention to student thinking includes her acknowledgment and repetition of Mike's question (2) and her posing of the question to the rest of the class (5). Cathy also attended to student thinking by repeating Douglas' words and asking Douglas to elaborate on what he meant by "it's dead" (18).

Cathy commented extensively on this conversation in her write-up:

Mike accepted that each level only passes on 10% of its energy, but he wanted to know *why*. A great mini-discussion developed between Mike and Billy. Mike asked, "Why can't they be lazy and pass on more?" to which Billy responded, "Because then they would die, and they wouldn't pass on anything!" Marc wanted to know if organisms could use less energy and therefore have more to pass on and Ben argued that they need to use this energy in order to live.

When I asked Douglas why the predator only gets 10%, even if the animal is eaten whole, he explained, "Because it's dead...It died, so it doesn't have any energy left." Douglas seemed to think that dead organisms have no energy.

The transcript provides evidence that Cathy was attending to student thinking in the classroom. Her interpretations of Mike, Billy's, and Douglas' ideas provide evidence that she was attending to student thinking in reflection for her course assignments.

Anne

Anne was teaching sixth grade science, splitting a schedule with Cathy. This example also comes from a lesson on energy flow in populations in November, similar to Cathy's example.

The class had been talking about energy flow for several days, having covered food chains and food webs. This lesson was designed to be an introduction to energy periods, and the concept that energy is lost in each successive level of the energy pyramid. Anne showed students a food web, and for a few minutes the class discussed the various roles of the different animals within the food web. Anne then introduced the concept of the energy pyramid and explained that the pyramid was representative not just of the flow of energy, but of the amount of energy transferred at each level. The class discussed the concept that, at each level, 90% of the energy is consumed by the organisms' living activities: moving, growing, reproduction, etc. They discussed how a predator, such as a lion, would not be able to get all of the energy contained within producers, like grass and trees, but would only get their energy through a "first-level consumer" like a giraffe. As Anne continued to review the concept that only 10% of the energy was available at each successive level, Arnold interrupted with a question.

1. Arnold: But Ms. G, they also lose a couple more percent because they don't—it's not like they make the tree disappear, they just take the plants off of it, but not all of them—so it'll just grow back and it'll get its energy back from where it started.
2. Anne: You mean when they're eating the plants?
3. Arnold: Yeah
4. Anne: Well, they're not destroying the plants.
5. Arnold: They're just eating the leaves, which doesn't destroy all of its energy. I mean it probably has like, if we have like "50" energy, we probably only take like 50% of the energy from it.
6. Anne: When you say "we," who do you mean?
7. Arnold: Like the people, or the giraffes, herbivores.
8. Anne: Okay, so whichever first level consumer is going after the plants, you're saying that they'll only get 50% of the energy?

9. Arnold: Well, you might get like 70%, around there, 50 to 80, but not 90 cause they still are a living factor.

Evidence of Anne's attention to Arnold's idea includes her initial question asking if he was referring to when the consumers were eating the producers (2), her rephrasing of his idea that "it's not like they make the tree disappear" (4), her request for clarification of the "we" he was referring to (6), and her question ("You're saying that they'll only get 50% of the energy?") to see if she understood what he was trying to say (8).

In writing up her analysis of the class, Anne commented that Arnold's idea was her "favorite bit of student thinking."

He has a fantastic line of reasoning that herbivores can't really get 100% of the energy that they eat, because they haven't really taken all of the energy from the plant because it can re-grow and "regain" all of the lost energy. This was so interesting to me. I think that in my saying that they herbivores gain 100% of the energy that they consume, he was thinking that I was saying that they plant *loses* 100% of its energy.

Again, the transcript provides evidence that Anne was attending to student thinking in the classroom. Her interpretation of Arnold's idea provides evidence that she was attending to student thinking in reflection for her course assignments.

Leslie

Leslie was teaching an introductory physics course for ninth graders. The following example comes from a class discussion that occurred in early November. Students had begun to work on problems involving one-dimensional motion, and Leslie was introducing the idea of "free fall" situations, in which the acceleration of gravity is constant, in order to see if students could apply the ideas they were learning about one-dimensional motion.

1. Leslie: So I've got some little ball bearings, some steel balls like this, and a ping pong ball. So, if I drop these two at the same time, which will land first?
2. Students: The silver one. The weight. That one. The little one—it's heavier. It has more weight.
3. Leslie: Why do you guys think this will land first?
4. Students: Because it's heavier. They will fall at the same time.
5. Leslie: Let me see the hand of someone who thinks this little ball will fall first and wants to explain why. Sarah?
6. Sarah: Cause it's heavier. The more weight the faster it's going to fall.
7. Leslie: Okay, the more weight the faster. Why?
8. Jordan: Gravity. I've got another think. It's smaller.
9. Isaac: Less surface area.
10. Leslie: Less surface area. Okay, anything else?
11. Norma: Same time
12. Alana: I say that orange one over there
13. Leslie: Okay, why the orange one?
14. Alana: It has less stuff in it.
15. Leslie: Okay, we've got two ideas so far. We've got the idea that this ball will fall faster because it's heavier, and people are suggesting that gravity will make a heavier ball fall faster, and then we've got people who are also saying that this one will fall faster because it's smaller and the air will push on it less. Anything else you guys think will affect it?
16. Isaac: No. How high you drop it?
17. Leslie: How high I drop it?

There was a brief interruption, but Leslie brought the conversation back to the question by reminding students that there was one more idea on the table.

20. Leslie: Alana, why did you think the orange ball would fall first?
21. Alana: Cause it has nothing in it.
22. Leslie: Cause it has nothing in it? Why will that make it fall first?
23. Alana: I just think it's the orange ball because it's light
24. Leslie: Okay, it will fall first because it's light. Does anyone else think the orange ball will fall first?

From here, students brought up the question of whether the two would fall at the same time in a vacuum, as opposed to in a situation in which air resistance was a factor. Leslie continued to listen and respond to students' ideas, and the class eventually tested out their ideas both in the room and inside a vacuum tube.

There is evidence in this short excerpt of Leslie's attention to the substance of student thinking in her repetition of Sarah's statement that the heavier ball would fall faster, and in her request for an explanation (7). Similarly, she probed Alana to explain why she thought the orange one would fall first (13,20), and when Alana said it would fall first because "it has nothing in it," Leslie asked her to explain why that would make the orange ball fall first (22). She also summarized students' ideas, and asked if there was anything else they thought would affect the outcome (15).

In writing up her analysis of this conversation for the science pedagogy course, Leslie wrote the following:

As I expected, most of the students thought that heavier ball would fall faster. When I asked for explanations of this prediction, students said, "It's heavier" and "gravity." Students have some idea that gravity causes heavier objects to fall faster than light ones. I assume that they think that this occurs because gravity pulls down more on heavier objects, which is true, but I would like to know if this is their reasoning. I plan to spend more time on this idea when the class studies forces and can examine the relationship between the force on an object and its acceleration.

As with the other examples, the transcript provides evidence that Leslie was attending to student thinking in the classroom. Her interpretation of the students' idea that gravity pulls down more on heavier objects provides evidence that she was attending to student thinking in reflection for her course assignments. It is worth noting that Leslie recognized the uncertainty of her interpretation, as she stated, "I *assume*³⁹ that they think that this occurs because gravity pulls down more on heavier objects, which is true, but I would like to *know* if this is their reasoning." This provides further evidence that Leslie was attending to student reasoning, as she was able to identify aspects of their reasoning that she did not yet understand.

³⁹ Emphases added

Wes

Wes was teaching a physical science course for 9th graders. In October, he did several demonstrations about static electricity for his students using a Van de Graff generator. Students has already studied charges, and had some awareness that negative and positive charges attract each other, while like charges repel. The demonstrations went as Wes had planned, and the class was able to discuss the concepts that he wanted to introduce. After one of the demonstrations, however, something unusual happened, and Wes used it as an opportunity to engage students in making predictions.

Anton had just finished being part of “the human chain,” a demonstration intended to show how well the human body conducts electricity. He was returning to his seat, and he passed by the Van de Graf generator. When he did so, he held out his hand, expecting to get a shock, but he was not shocked. In fact, the generator fizzled out and stopped working all together while he was near it. Wes transcribed the conversation that followed for the science pedagogy class assignment.

1. Anton: What the hell?
2. Wes: What’s up? (He hadn’t see it)
3. Jenny: (Who was touching the generator at the time) He’s not getting shocked!
4. Wes: Huh...Jenny, take your hand away from the generator a moment. (She did so.) Now, try it again Anton.

Anton tried it again, and again the generator did not work when he was near it.

5. Anton: Oh my god. I’m like the anti-science....This is so weird. Why is that happening?

Wes thought that Anton might be grounded through some pipes running below the floor, so he told Anton to stand on a textbook—a pretty good insulator—and try again.

The same effect happened, however.

6. Wes: Very interesting, here; any possible explanations? Cindy?

Wes allowed the conversation to continue for several minutes, and he solicited explanations from several students. Some were silly (Sally: “Anton is quite clearly the devil!”), but some were more substantive. Cindy suggested that Anton was negatively charged, an idea that Anton repeated with some authority later in the conversation.

Renita suggested that Anton was an insulator.

Wes wrote about the unplanned demonstration and resulting conversation in his analysis for the science pedagogy class.

In this exchange with the class, there are several instances of student thinking at work. An unplanned but legitimate science question, “Why doesn’t Anton get shocked,” becomes momentarily the focus of the entire class. I could not simply dismiss it and move on with the demonstrations, so I started a discussion around it.

The fact that Wes noticed this question and used the next several minutes of the class period constitutes evidence of attention to student thinking during class. As he himself pointed out, he could have just dismissed it as an odd occurrence. Instead, he chose to use it as an opportunity for students to construct explanations.

Jane

Jane was teaching sixth grade. Jane was the only other intern, besides Emma, for whom we did not see evidence of attention to student thinking in class until the second semester. This example comes from a class period in April just before the students did an activity to measure how far a disk that they were pushing would slide across the desk. Students were asked to respond to three questions in their workbooks before the activity, and the class discussed the students’ responses. Jane recorded, transcribed, and analyzed the conversation about one of these questions, and presented the discussion in the science pedagogy course. The question and the accompanying discussion follow:

What do you think stops a disk in motion from staying in motion forever?

10. Jane: Alright, what do you think stops a disk in motion from staying in motion forever? Yes.... Ummmmm.... Kai
11. Kai: Ok. Is this number 2?
12. Jane: Yes.
13. Kai: I think the friction stops it.
14. Jane: Ok. So you think the friction stops it from staying in motion forever?
15. Kai: Yeah.
16. Jane: Who else put something similar? Paul, yes.
17. Paul: I think the friction stops it. No matter how little it has. There is still friction everyone. Like when you are ice skating you go and then you stop. (inaudible)
18. Jane: Did you guys all hear what Paul said?
19. Students: Yes, No
20. Jane: Why don't you repeat yourself Paul, please?
21. Paul: I think that it is friction, because no matter how little friction there is it grows and multiplies like on ice. Like on ice. Like if you are ice skating, no matter what you are doing. Unless you hit a wall. (Inaudible)
22. Student: You have to stop yourself
23. Paul: No
24. Jane: How do you think the friction grows or multiplies?
25. Paul: Like um... like on ice. There is little friction and then it gets stronger and stronger and stronger.
26. Jane: So in your example of ice skating, what do you think is happening to make the friction increase, if the surface is the same?
27. Paul: All this stuff on the ice. All the lines going all over the place (gesturing with his hands).

Evidence of Jane's attention to the substance of student thinking includes her repetition and clarification of Kai's idea (5), and the ways in which she called the class' attention to Paul's idea that the friction force "grows and multiplies,"(9) and pressed Paul to explain how he thought the friction grew and multiplied (15,17). In writing up her case study, Jane noted that she was impressed with Paul's explanation because she saw that he was trying to "relate his ideas with something he knew." She was especially pleased to hear these ideas because she felt that she had learned considerably more about

what Paul thought then she would have from his workbook response alone. In his workbook, he had written, “The friction that slows it down fast then stops it for good.”

Jane’s one regret was that she hadn’t really understood exactly what Paul meant by the force “growing and multiplying,” and she wished he had explained more about it. When the science pedagogy class watched this exchange, everyone noticed Paul’s idea of the friction force “growing and multiplying,” and several of the physics candidates interpreted him as saying that friction continues to build up as the disk moves across the surface. While recognizing that Paul’s idea was different from the way physicists would describe friction, most of the candidates were able to consider the idea beyond its incorrectness. They were impressed with Paul’s reasoning, which fit sensibly with the observation that the disc slows down.

Appendix C: Understanding Variation

A possible avenue of research into this question would be to explore the ways in which teachers' identify, or are identified by others, within different systems that frame teaching differently, and the ways in which these identities support or discourage teachers' framing of teaching in terms of attending to student thinking. Individuals have different lived experiences, both within formal educational systems and in other systems that make up their worlds. No two teachers have the same formative experiences, and they likely identify (or are identified by others) in diverse ways in various systems. Thus, a deeper understanding of variation in teachers' tendencies to attend to the substance of student thinking may come from a deeper understanding of the ways teachers identify themselves, or are identified by others, within these diverse systems. This would require a closer look into the personal history of participation in school and other systems that contributes to each teacher's framing of teaching and what it means to teach.

The concept of identity can serve as a useful analytic tool for exploring how individuals' personal history of participation both inside and outside the institutional system may influence their ease in framing teaching in terms of attending to student thinking. Focusing on identity and its role in an individual's framing extends my systems framework in important ways. It narrows the focus onto the person, while maintaining a social perspective. It also expands the focus beyond particular systems, such as those within the public schools, and calls attention to the broader social and cultural systems with which the individual identifies (Wenger 1998). A consideration of identity is important to understand how participation in systems shape personal worlds, and vice-versa, and how individuals participate in practices of various systems (Sfard & Pruzak,

2004). I take identity to be the “the way a person understands and views himself, and is often viewed by others, at least in certain situations” (Holland et al., 1998). To give a sense of how I understand identity, and to describe how might use it to make sense of how and why some teachers have more difficulty than others in framing teaching in terms of attention to student thinking, I will use examples from my case study of Ms. Hawkins’ teaching.

Individuals’ identities can be found in the stories that they tell about themselves and the stories that others tell about them (Sfard & Pruzak, 2004). My observations and interviews with Ms. Hawkins are suggestive of how these stories position a teacher with respect to the framing of the institutional system, and thus are suggestive of how teachers’ identities might discourage or support their appropriation of a framing of teaching in terms of attending to the substance of student thinking. This data suggests that Ms. Hawkins identified strongly with her role of leading her students to learn all of the content covered by the curriculum and to perform well on the HSA. When asked in interviews about why she became a teacher, and her sense of her roles and responsibilities, she told stories of herself as a leader, and she identified her leadership role in terms of meeting the expectations of the school and the district, helping the biology team, and helping students to attain achievement goals.

Ms. Hawkins also told stories of herself by the ways in which she participated within the institutional system. She was an active and dependable participant in the strong local professional community at Springfield, and she became the team leader in the second year of this study. She was a reliable participant in the school community, serving on committees, co-teaching inclusion classes with special educators, and

faithfully enacting school and district policy, including a new grading policy and a literacy initiative. Furthermore, Ms. Hawkins organized her lessons in order to move through the curriculum in an efficient manner, while making certain that her students were exposed to the content and vocabulary that they would see on the tests. In a recent informal conversation Ms. Hawkins and I had, she expressed exasperation with the continuous barrage of paperwork that teachers today must respond to. She said that she was beginning to “not respond to everything as I have in the past.” She said that she thought she had earned some latitude because she “always did that stuff.”

This conversation is interesting both in the story it tells about Ms. Hawkins’ dutiful participation in the institutional system, and in the story it may tell about her growing disenchantment with that identity. This highlights the aspect of identity that it is summarized by Holland et al’s emphasis of the context-sensitive construction of identity as “the way a person understands and views himself, and is often viewed by others, *at least in certain situations.*” That is, rather than characterizing identity in unitary terms, it opens the possibility that identities can change over time, or even that different identities might be activated in different situations, depending on how the person frames the situation.

Another important aspect of my understanding of identity, emphasized by “the way a person understands and views himself, *and is often viewed by others*, at least in certain situations” is that individuals’ identities are not only reflections of their own “sense of themselves” but are largely formed by the way they are identified by others. Not only do individuals tell stories of themselves, but others tell stories about them. For example, as I discussed in Chapter 5, other members of the biology team talked about

Ms. Hawkins as “our pacemaker” and expected that she took responsibility for helping the biology team as a whole to structure their time and the implementation of certain curricular activities in the interest of covering all of the material that would appear on the standardized tests. In this way, Ms. Hawkins’ stories of herself were reinforced by the way she was positioned by others in the local community. Others’ identification of Ms. Hawkins could feed back into her own sense of her self to amplify her identification as a person who helps everyone to move toward coverage of the curricular objectives. This positioning by others also constrains the kinds of behaviors that are expected for Ms. Hawkins. Ms. Hawkins’ identity in this context, formed by the complementary positioning of her by herself and others, may help shape how she frames her teaching and the foci of her attention. For example, it would be out of character, and inconsistent with the identity that she and others have constructed for her if Ms. Hawkins were to routinely attend to the substance of student ideas without regard to the distance of those ideas from canonically correct knowledge.

I have used this example to show how I might use identity to understand the variation in teachers’ ease in framing teaching in terms of attending to student thinking. A full analysis of the ways in which teachers’ in this study identified with various systems and the ways in which these identifications contributed to their framing of teaching is beyond the scope of this dissertation and is an important area for future research. Such research might entail looking more closely at particular teachers who have either great difficulties or great ease in adopting a framing of teaching in terms of attention to student thinking, and asking questions about formative experiences, in educational systems and elsewhere that contribute to the difficulty or ease.

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