ABSTRACT

Title of dissertation: EXPLORING WHAT STABILIZES TEACHERS' ATTENTION AND RESPONSIVENESS TO THE SUBSTANCE OF STUDENTS' SCIENTIFIC THINKING IN THE CLASSROOM

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Teachers' attention and responsiveness to the substance of students' disciplinary thinking is critical for promoting students' disciplinary engagement and learning, yet such attention is rare and fleeting in American classrooms. In this dissertation, I aim to learn more from teachers who *do* attend and respond to students' scientific ideas while teaching. I explore the classroom practices of three focal teachers in a professional development program who consistently place students' ideas at the core of their instruction with an eye toward the following research question: What might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking during sustained classroom episodes? Examining three episodes from each teacher, I identify aspects within these episodes that are salient to the teachers and plausibly interrelated with their attention and responsiveness to student thinking.

My primary data chapters include analyses of specific pairs of episodes that speak to my broader research question as well as other relevant topics in the literature on attending and responding to student thinking. The first data chapter makes the case that professional development efforts aimed at supporting responsiveness to student thinking primarily help teachers within planned discussions or progressions, but struggle to help teachers adapt their ongoing instruction in response to unexpected directions from students. I examine two episodes in which the discussions that emerged were not preplanned but rather emergent from students' contributions, with an eye toward what initiated and sustained teachers' responsiveness. The second data chapter contributes to discussions on what constitutes favorable change in attending and responding to the substance of student thinking, emphasizing the importance of disciplinary-specific considerations. Finally, I draw on the entire data set in noting specific commonalities within and across teachers, suggesting two complementary professional development approaches: 1) remaining open to and aware of what hooks and sustains individual teachers and their classroom practice, and 2) emphasizing aspects that cut across teachers, which might serve as meaningful foci for professional development efforts aimed at promoting an instructional focus on students' ideas.

EXPLORING WHAT STABILIZES TEACHERS' ATTENTION AND RESPONSIVENESS TO THE SUBSTANCE OF STUDENTS' SCIENTIFIC THINKING IN THE CLASSROOM

by

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Dedication

I dedicate this dissertation to Ms. L, Ms. R, and Mr. S, three of the most inspirational educators with whom I have ever worked. I only hope my portrayal does your teaching justice.

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Graduate school is a long journey, exciting and arduous in turn, and I owe a great deal to mentors and colleagues who have put up with me along the way. First, to my co-advisors, Andy Elby and David Hammer – I could not ask for a better pair of mentors. Your comments never fail to help me see my work in a new light, and often push me beyond where I thought I could go. Thank you. I also thank the rest of my dissertation committee – Ayush Gupta, Ann Edwards, and Todd Cooke – for your thoughtful feedback and time.

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[1] Special thanks to folks with * for reading and commenting on pieces of dissertation-related writing along the way.

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Chapter 1: Overview

Over the course of graduate school, I have had the privilege of visiting classrooms where exchanges like the following took place. In this particular exchange, a fifth-grade teacher, Ms. L[2], and her students were in the middle of a unit on magnetism. The class was discussing why it might be more difficult for a magnetic influence to act through a solid as opposed to a liquid or a gas. One student, Andrea, made an analogy to a shopping bag:

> Andrea: When your hands are full of, um, shopping bags, and you only have like a little bit of space, like one pinky to hold one more bag, you can't hold, like, this entire shopping bag with one pinky. So that's like the magnets, they don't have – the pinky, it's like the pinky because it's going through the solid, so it only has a little bit of strength left going through it –
>
> Ms. L: So it's like it's using up its strength to get through the solid, and once it gets through, it's only got so much left?
>
> Andrea: It only has a little bit left. So if you use your pinky to pick it up, it won't really work out.
>
> Ms. L: So, I think you're kind of going back to our deal with the wood, where the magnet could hold the paper clip, but couldn't hold the nail. Is that kind of where you're going?
>
> Andrea: But the paper clip is like a tiny, empty bag.
>
> Ms. L: It's like a tiny – like trying to pick up a tiny, empty bag, like maybe a little, um, lunch bag or something, but the nail was like a full grocery bag, so the magnet could, still had the strength to pick up the paper clip, but not pick up the nail –
>
> Andrea: Mm-hmm.

Here, Andrea provided an analogy between hands holding shopping bags and the magnets the class was discussing – a hand holding many shopping bags does not necessarily have room or strength to support another shopping bag, just like a magnet going through a solid cannot support extra weight on the other side of the solid. Ms. L restated Andrea's main idea that the magnet only has a little strength left on the other side of the solid. Andrea agreed and equated the situation to a pinky finger trying to hold an entire shopping bag. Ms. L then probed Andrea to see if Andrea's idea was tied to a previous observation the class had made that the magnet was able to support a paper clip through a solid, but not a nail. Andrea quickly compared the paper clip to a tiny, empty

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[2] All teachers' and students' names are pseudonyms.

bag (presumably that the pinky finger *could* hold), and Ms. L repeated Andrea's comparison and extended the analogy by comparing the nail to a full grocery bag.

This exchange is an exemplar of what it means for a teacher to attend and respond to the substance of students' scientific thinking in the classroom. Attending and responding to student thinking has been described as trying to get a sense of the student's perspective (Levin, Hammer, & Coffey, 2009), or seeking to "give a child reason" (Duckworth, 2006, p. 86) when the child's meaning may not be immediately obvious. It involves taking seriously the ideas that students put forth in conversations about scientific phenomena, regardless of how "scientific" such ideas may initially seem, and looking for the seeds of science within (Hammer & van Zee, 2006). In alignment with these descriptions, Ms. L's interactions with Andrea reflect that Ms. L was listening closely to and striving to make sense of what Andrea was saying, checking her interpretations with Andrea ("Is that kind of where you're going?") and recognizing and building on the analogy Andrea provided to connect Andrea's idea to the experiment the class had conducted.

Within science and mathematics education, a clear consensus is emerging that a cornerstone of effective instruction involves this kind of attention and responsiveness on the part of the teacher (NCTM, 2000; NRC, 2007). Numerous institutions around the country are beginning to study and talk about attending and responding to student thinking as an essential component of "ambitious" teaching (e.g., Lampert et al., 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). Such attention and responsiveness is a critical aspect of formative assessment in the classroom (e.g., Black & Wiliam, 1998; Coffey, Hammer, Levin, & Grant, 2011) and has been linked with students' enhanced conceptual understanding (e.g., Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Pierson, 2008) and rich opportunities for students to engage in disciplinary practices, such as explanation-building and argumentation in science (e.g., Berland & Reiser, 2009; Duschl & Gitomer, 1997). Furthermore, as students see their own ideas respected and valued in the classroom, they are more likely to see themselves as capable of and interested in engaging in the discipline (e.g., Cornelius & Herrenkohl, 2004; Engle & Conant, 2002).

As a teacher, this last point really resonated with me. Before starting my doctoral program in science education, I was a teacher candidate in a masters certification program with a strong emphasis on attending and responding to the substance of students' scientific thinking. I remember struggling to do so in the science classes I was student teaching due to a number of other considerations in play (aligning my instruction with my mentor teacher's instruction, staying on pace with the curriculum, etc.). Yet one experience still stands out to me as the first time I saw the power of opening up space for and respecting student thinking. In one of the earliest biology classes I taught, we were talking about respiration and how we generally take in oxygen and release carbon dioxide. A student who was taking biology for the third time, never having passed the class (largely due to a lack of work completion), raised an excellent question: "Wait, if you're blowing mostly CO_2, then how come CPR works?" His question excited me as he was pointing out a discrepancy he noted between our discussion of respiration and the process of CPR, and to that point, it was a seeming discrepancy I had never personally attended to. I was also excited by who was asking the question – a student who was still failing the class and rarely contributed. Moreover, the other students who provided ideas

in the short discussion that followed also tended not to participate and were not doing well grade-wise in the class. This experience demonstrated to me how willing students were to grapple with scientific questions that they wondered about, and that challenged them.

The short-lived nature of the discussion also aligns with findings that attention to student thinking is rare in American classrooms (NRC, 2007), and when it is present, tends to be "brief and fickle" (Lau, 2010, pp. 290-291) or "episodic and fleeting, only occasionally sustained for any meaningful length of time" (Levin, 2008, p. 104). These findings reflect the nature of the classroom as an complex environment in which multiple elements vie for the teacher's attention at any given time (Ball, 1993; Hammer, 1997; Hawkins, 1973; Lampert, 1985). Additionally, in the United States, the increased prominence of accountability measures and standardized testing has created an educational environment in which teachers are expected to march through the required curricular indicators, leaving less space for them to adapt their instruction to students in a responsive manner (e.g., Levin, 2008; Valli, Croninger, Chambliss, Graeber, & Buese, 2008). It is difficult for teachers, embedded in such an environment, to deviate and devote time to students' often unconventional ideas.

Yet there are teachers like Ms. L, subject to such considerations and constraints, who regularly engage students in extended discussions about their own scientific ideas. As I worked with Ms. L and other teachers on a professional development project, I found myself in awe of the discussions they orchestrated in their classrooms and wondering how and why they focused their instruction on students' ideas to the extent that I saw. This dissertation stems from and begins to address this larger wondering by exploring extended episodes in which three focal teachers attended and responded to the substance of their students' scientific ideas in a relatively stable manner.

In what follows, I provide an orientation to the structure of my dissertation.

Structure of the Dissertation

Chapter 2 begins with a literature-based argument for the importance of teachers attending and responding to the substance of students' scientific thinking for student learning and engagement. I then situate my work among approaches and findings from previous studies on teachers' attention and responsiveness to student thinking. As I described above, my dissertation work explores the classroom practices of three focal teachers who consistently place students' ideas at the core of their instruction with an eye toward the following research question: What might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking during sustained classroom episodes?

In Chapter 3, I set the groundwork for my analyses by describing the collective case study design I used in my dissertation, how I selected relevant cases or episodes for analysis, and my analytical approach to unpacking such episodes, as well as the limitations of my approach. All individual episode analyses are grouped by focal teacher and can be found in Appendices D-F. Each episode analysis follows the same general structure. I first situate the episode in the flow of classroom activity. This is followed by a full coded transcript of the episode and a description of how the episode meets the selection criteria for inclusion in my dissertation. Then I present evidence for several aspects that might be involved in stabilizing the teacher's attention and responsiveness to

students' scientific ideas in the episode. Each appendix also includes a section in which I synthesize across the episodes for a given teacher.

Chapters 4 and 5 include analyses of specific pairs of episodes that speak to my broader research question as well as other relevant topics in the literature on attending and responding to student thinking. In Chapter 4, I make the case that professional development efforts aimed at supporting teachers' attention and responsiveness to student thinking primarily help teachers within planned discussions or activities, but struggle to help teachers adapt their ongoing instruction in response to unexpected directions. I examine two episodes in which the discussions that emerged were not preplanned but rather emergent from students' contributions, with an eye toward what might be in play for teachers during such episodes and how a greater understanding of their decision-points can inform our professional development efforts. In Chapter 5, I join the conversation about what constitutes favorable change in attending and responding to the substance of student thinking. I analyze two episodes from one teacher in which he taught the "same" lesson in consecutive years, yet demonstrated a favorable shift in the aspects of scientific explanation that he foregrounded with respect to students' ideas from the first year to the second year. To better understand his attention and the shift within, I explore the variety of influences contributing to his foregrounding in each case.

Finally, in Chapter 6, I summarize my major findings. In exploring my research question, I found that different types of aspects were plausibly involved in stabilizing teachers' attention and responsiveness to student thinking in the selected episodes. I describe the major types permeating my analyses and their implications for modeling teacher behavior and working with teachers. I also identify specific commonalities within and across teachers, suggesting two complementary professional development approaches: 1) remaining open to and aware of what hooks and sustains individual teachers and their classroom practice, and 2) emphasizing elements that cut across teachers, which might serve as meaningful foci for professional development efforts. I conclude with questions that arose for me during the course of this work, reflecting future areas of study.

Chapter 2: Situating the Study in Literature on Attending and Responding to the Substance of Students' Disciplinary Thinking

This chapter highlights the importance of teachers attending and responding to student thinking and situates my study in the literature on such attention. I first review ways in which attention and responsiveness to student thinking is consequential for student learning of and engagement in disciplinary[3] concepts and practices. I then turn to approaches and findings from previous studies on teachers' attention and responsiveness to student thinking and describe how my work fits in and contributes to our evolving understanding of what supports teachers in focusing on students' ideas. At the end of this chapter, I articulate the research question and subquestions guiding my dissertation, transitioning into discussion of my methodological approach in Chapter 3.

The Importance of Attending and Responding to Student Thinking

I first review ways in which teachers attending and responding to the substance of students' disciplinary thinking is important for students' disciplinary learning and engagement. To preview my argument, I will provide evidence that when students' ideas are made central to classroom activity, students demonstrate enhanced conceptual understanding as teachers formatively assess students' understandings and provide feedback or promote reflection as a means of further learning (e.g., Black & Wiliam, 1998; Coffey, Hammer, Levin, & Grant, 2011; Pierson, 2008). Additionally, teachers' attention and responsiveness to students' scientific ideas creates rich opportunities for students to engage in scientific explanation-building, argumentation, and assessment and come to understand more about the nature and creation of scientific knowledge (e.g., Driver, Newton, & Osborne, 2000; Duschl & Gitomer, 1997; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000). Finally, as students see their own ideas respected and valued in the science classroom, they are more likely to see themselves as capable of and interested in doing science (e.g., Cornelius & Herrenkohl, 2004; Engle & Conant, 2002).

Students Demonstrate Enhanced Conceptual Understanding

Several studies have indicated that when teachers attend and respond to the substance of students' disciplinary thinking, students' conceptual understanding increases (Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Hiebert & Wearne, 1993; Saxe, Gearhart, & Seltzer, 1999; Stipek et al., 1998). For instance, Carpenter et al. conducted a multifaceted study of the Cognitively Guided Instruction (CGI) professional development project. The aim of the project was for teachers to understand the research base on how students develop their understandings of addition and subtraction and to use this information in instruction. They found that CGI teachers spent more time in class on problem solving, posing problems and listening to students' various solutions, than their non-CGI peers. In turn, first- and second-grade students in CGI teachers' classes

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[3] A point of clarification – I use the term "disciplinary" when the studies I refer to are from more than one discipline (typically mathematics and science). "Scientific" is reserved for science-specific discussion.

demonstrated higher recall of number facts and were better able to tackle complex problems than students who were not in CGI teachers' classes. Saxe, Gearhart, and Seltzer conducted a similar study on correlations between teachers' reform-oriented classroom practices (including what they called "Integrated Assessment," centered on eliciting and building upon students' thinking) and upper elementary students' performance on computation and problem solving with fractions. Alignment of practices with reform principles was generally positively correlated with problem solving performance, especially at higher levels of alignment.

There are several possible mechanisms by which teachers focusing on students' ideas contributes to enhanced student understanding. First, when teachers listen to and strive to understand student thinking, they are able to engage in formative assessment (Bell & Cowie, 2001; Black & Wiliam, 1998; Coffey, Hammer, Levin, & Grant, 2011; Levin, Hammer, & Coffey, 2009; Otero, 1996; Sadler, 1989). Formative assessment generally occurs during and informs instruction, as teachers get a sense of where students are and provide students with relevant feedback on their performance and/or adapt their own instruction to better address students' needs. Black and Wiliam documented that such practices of formative assessment led to significant learning gains for students and low achievers in particular, as long as feedback and instructional responses were specific to students' ideas rather than superficially concerned with correctness. The importance of specificity is echoed in Otero's critique of the "get it or don't" conception of formative assessment and Coffey et al.'s critique of the tacit focus on canonical correctness in much of the formative assessment literature. Thus, these studies collectively indicate that one way in which student understanding improves is through teachers tailoring their feedback and instruction in real-time to address students' specific ideas.

Another way that teachers focusing on student thinking likely enhances students' conceptual understanding stems from the egocentric or psychological function of language (Vygotsky, 1986). Vygotsky conducted a series of experiments in which he posed activities to young children and found that when an activity was challenging in some way, children's egocentric speech – essentially talking out loud to oneself – doubled. This led Vygotsky to consider such egocentric speech as "an instrument of thought in the proper sense – in seeking and planning the solution of a problem" (p. 31). In other words, opportunities for students to *articulate* their thinking might also serve as opportunities for students to further *develop* their thinking. Pierson's (2008) dissertation work supports the utility of students reflecting on their own ideas in this way. In her dissertation, Pierson examined the relationship between teachers' follow-up moves in response to student thinking and student achievement on a test about rate and proportionality. One of Pierson's primary measures was the level of responsiveness a teacher demonstrated with respect to students' ideas, ranging from low to high. Moreover, within high, Pierson distinguished responses that focused on the correctness of students' answers (high I) from responses that focused on the students' reasoning or sense-making regardless of correctness (high II). She found that high II responsiveness related most strongly to enhanced student achievement:

> With a correlation of .855 ($p<.01$), the measure of responsiveness with the strongest relationship to student learning is the proportion of high II follow-up moves… While responsive to students' ideas, high I moves may not encourage

> students to make sense of the content for themselves (because the teachers' reasoning is on display) or to verbalize their thinking so it becomes an object of reflection (Pierson, pp. 105-106).

In this case, what seemed most powerful for student learning was the continuing opportunity to make sense of, verbalize, and reflect on their own ideas. With high II responsiveness, the teacher did not necessarily provide explicit feedback on the students' ideas but rather almost served as a mirror, reflecting students' ideas back to them for further consideration. Thus, there is evidence that teachers' attention and responsiveness to the substance of students' disciplinary thinking can enhance students' conceptual understanding, either through direct feedback and/or instructional adaptations on the part of the teacher or further opportunities for students to interact with and develop their own ideas.

Students Engage in Authentic Scientific Practices

Yet the science classroom is about far more than student comprehension of scientific material. It is a place in which students may also begin to engage in the *practices* of science, such as the distributed reasoning and argumentation that underlies many scientific advancements (Dunbar, 1999; Ford & Forman, 2006). In fact, recent work on formative assessment (Coffey et al., 2011) has argued that such assessment in science classrooms should reflect practices of assessment in science more broadly, engaging students in assessing the merit of each others' ideas based on alignment with available evidence, explanatory and predictive power, etc. These kinds of experiences better support students in understanding how scientific knowledge is created and engage them in the doing of science, not just learning about previously agreed-upon scientific concepts.

As teachers enter into conversation with students about students' scientific ideas, rich opportunities often emerge for students to engage in scientific explanation-building, argumentation, and assessment (Berland & Reiser, 2009; Duschl & Gitomer, 1997; Sandoval, 2003). Although the cited studies each provided different scaffolds for supporting student participation in such practices, they cohered on the notion of discussion centered on students' ideas as a context in which students authentically create, defend, and evaluate scientific explanations. For instance, imagine a situation in which a teacher asks a student questions about his idea, or other students provide counterexamples to what he said – the student may begin to notice and flesh out missing links in his explanation. He may seek additional evidence for his idea to convince his peers of its veracity – indeed, Berland and Reiser suggested that the presence of an audience to convince was critical for student engagement in persuasion. Peers may contribute to his developing explanation, and continuing discussion of his and other students' ideas may shed light on the kinds of criteria scientists use to evaluate explanations, such as consistency with other bits of knowledge, explication of mechanism, etc. (e.g., Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Russ, Coffey, Hammer, & Hutchison, 2009). Sustained attention and responsiveness to the substance of students' scientific ideas is central to all of the above.

Furthermore, through engaging in scientific explanation-building, argumentation, and assessment, students are exposed to the epistemological commitments and nature of

science as a social enterprise (Berland & Reiser, 2009; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Driver, Newton, & Osborne, 2000). Driver, Newton, and Osborne highlighted this connection between classroom practice and epistemological understanding as a critical consideration in science education:

> The main point we wish to make is that, if we intend to show the socially constructed nature of scientific knowledge, we must give a much higher priority than is currently the case to discursive practices in general and to argument in particular (p. 297).

Through discussions centered on their own ideas, students gain firsthand experience in how scientific explanations are created through individual and collective sense-making about phenomena (Hutchison & Hammer, 2010). This kind of experience counteracts what Lemke (1990) described as the "mystique of science," the idea that "science stands somehow outside of the world of human experience, rather than being a specialized part of it" (p. 134).

Students See Themselves as Capable of and Interested in Doing Science

Finally, as students create and evaluate scientific explanations and see their own ideas being taken seriously in the science classroom, they are more likely to see themselves as capable of and interested in engaging in science. For instance, the ways in which the teachers in Cornelius and Herrenkohl's (2004) and Engle and Conant's (2002) studies positioned students as agentive in scientific discussions afforded students' passion and persistence in pursuing their own ideas and reconciliations with each others' ideas. Cornelius and Herrenkohl described this as a renegotiation of power between the students and the subject matter and documented how two focal students relied on their own ideas and research in the context of a sinking and floating unit, putting their knowledge on par with other (often more "authoritative") sources of knowledge. Other case studies also demonstrate how teachers positioning students as knowledgeable contributors impact student learning (Empson, 2003) and persistence (Richards, Conlin, Gupta, & Elby, 2013 and continuing work). Such experiences are particularly meaningful for students from non-dominant backgrounds, whose ideas are more often marginalized in traditional classroom discourse (e.g., Bang & Medin, 2010; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001).

To summarize, teachers' attention and responsiveness to student thinking enhances students' conceptual understanding, provides opportunities for students to engage in authentic scientific practices, and supports students' sense of capability and interest in science. Given the merit of teachers attending and responding to students' ideas in the classroom[4], I next turn to approaches researchers have taken in studying this attention.

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[4] Note that student thinking is not the *only* important consideration in science classrooms. There are numerous foci that may rightfully capture teachers' attention, and there may be times when it is inappropriate or counterproductive to focus primarily on students' ideas.

Situating My Work Among Descriptions and Studies of Teacher Attention and Responsiveness to Student Thinking

In this section, I situate my work among ways of thinking about and studying teachers' attention and responsiveness to the substance of students' disciplinary thinking. I first discuss my sense of what it means to attend and respond to student thinking and how it relates to other descriptions of responsive teaching, predominantly from work in mathematics education (e.g., Lampert et al., 2013, Sherin et al., 2011). I also illustrate that most of the research on teacher attention and responsiveness to student thinking has been conducted on teachers' discussions about and reflections on artifacts of classroom practice (e.g., Kazemi & Franke, 2004; van Es & Sherin, 2008), but connections between such discussions and reflections and teachers' in-the-moment classroom practice are underdetermined. In my dissertation, I strive to understand more about what supports teachers in focusing on students' ideas *while teaching*, contributing to an emerging body of such work (e.g., Lau, 2010; Levin, 2008).

Descriptions of Responsive Teaching

Recall my brief depiction of attending and responding to the substance of students' disciplinary thinking from Chapter 1. There are two main characteristics of such teaching to which I want to draw attention:

1. Attentive and responsive teaching starts with the students' ideas, seeking to understand how the students are making meaning in the moment. Underlying this is an assumption that students *are* making meaning or sense for themselves, and that the teacher's job is, first and foremost, to understand how they are doing so. Truly understanding students' ideas requires unpacking the details of their ideas, going beyond more superficial characteristics such as how an idea relates to the canonically correct response or whether a student is using appropriate vocabulary.

2. Attentive and responsive teaching also strives to connect students' ideas to central ideas and processes in a given discipline – again, drawing on an assumption that there are productive connections to be made. In science, Hammer and van Zee (2006) described this as looking for and supporting its "beginnings in students" (p. 21), such as their providing mechanistic explanations for scientific phenomena, or recognizing and striving to remediate inconsistencies. In this way, attentive and responsive teaching is accountable to critical aspects of the discipline with which students should grapple while grounding their grappling in their own ideas and maintaining their intellectual agency in the classroom.

In what follows, I consider how these characteristics relate to other common descriptions of responsive teaching.

Nonetheless, knowledge of students' ideas is useful with respect to a wide range of classroom activities and goals.

Ambitious Teaching and High-Leverage Practices

A relatively recent but impactful initiative taking place across multiple disciplines involves identifying fundamental aspects of ambitious teaching and striving to articulate and decompose them into constituent practices and principles (Grossman, Hammerness, & McDonald, 2009; Lampert et al., 2013; TeachingWorks, 2013; Windschitl, Thompson, Braaten, & Stroupe, 2012). Ambitious teaching takes as central the need for teachers to "elicit, observe, and interpret student reasoning, language, and arguments and to adjust their instruction accordingly to promote learning" (Lampert et al., p. 227), indicating that such instruction is largely conceptualized as being responsive to students' ideas. Researchers engaged in this work typically focus on what they call "high-leverage practices," which are practices that are thought to be a) high frequency in teaching and applicable across settings, b) important for student learning, and c) learnable by novice teachers (Grossman et al.). These practices range in grain size, from relatively complex enterprises like "leading a whole-class discussion" (TeachingWorks) to simpler components like "orienting students to one another" (Lampert et al., p. 228) within a whole-class discussion. Given this range of grain sizes, it is difficult to tell whether such practices encompass or are encompassed by my sense of attentive and responsive teaching. Rather than attempting to articulate what encompasses what, I focus primarily on matters of *substantive* alignment between identified high-leverage practices and what I mean by attending and responding to student thinking.

The most closely related practice refers to individual students' thinking. The TeachingWorks (2013) website describes the high-leverage practice of "eliciting and interpreting individual students' thinking" as "draw[ing] out a student's thinking through carefully-chosen questions and tasks and consider[ing] and check[ing] alternative interpretations of the student's ideas and methods." A critical source of alignment here is that the teacher's responses continue to draw out and clarify the student's ideas, pressing for detail rather than taking an initial interpretation of what the student said at face value.

Other identified high-leverage practices may or may not be aligned with my sense of attentive and responsive teaching – it depends on how they are instantiated in specific classroom examples. Let me provide a few examples to illustrate what I mean. Take the practice of "orienting students to one another" (Lampert et al., 2013, p. 228) within a whole-class discussion. One could imagine this playing out as a teacher listens carefully to the substance of students' ideas and orients students to each other for the purpose of putting their ideas in conversation with each other. One could also imagine this playing out as a "move" that a teacher regularly makes during discussion, with little connection to the *substance* that is being discussed. In the first case, the practice of orienting students to one another would align with my sense of what it means to attend and respond to students' ideas; in the second case, it would not.

Or consider the ambitious practice of "eliciting students' ideas, using them to adapt instruction" (Windschitl et al., 2012, p. 899). In the most sophisticated version of this practice, teachers listen for "partial understandings as well as alternative conceptions" and use these and "students' language… to shape the direction of classroom conversations" (Windschitl et al., p. 899). This practice inherently involves attending to students' ideas and responding to them in some way, but whether or not it aligns with my sense of attentive and responsive teaching depends on the depth to which students' ideas

are pursued and the extent to which teachers' responses require *students* to do the ensuing intellectual work. For instance, one could imagine this playing out as a teacher listening closely to and recapping a range of ideas from students, then asking students to work with those specific ideas in some way – which ideas go together? Which contradict? How could we decide among competing ideas? Which explanation is most convincing to you, and why? Alternately, one could imagine a teacher quickly getting out a range of ideas from students and juxtaposing them in such a way that students are sequentially led to the correct answer. In both examples, the teacher is orchestrating the discussion (Stein, Engle, Smith, & Hughes, 2008) around students' ideas, but the aims and natures of the discussions differ. This may reflect a broader distinction between my sense of attentive and responsive teaching and the focus on high-leverage practices – although such moves and practices may provide evidence of attentive and responsive teaching, it is not the moves and practices *themselves* that are responsive. Rather, it is how such moves and practices are instantiated, situated, and taken up in the flow of classroom activity.

Teacher Noticing

Another subset of literature focused on responsive teaching is work on teacher noticing in mathematics (e.g., Sherin et al., 2011). This body of work focuses on the range of things teachers might notice in the classroom, but largely seeks to increasingly draw teachers' attention to the substance of students' ideas (e.g., Sherin & Han, 2004, van Es & Sherin, 2008). A particular point of debate among researchers who study teacher noticing is what it *means* to notice. In the introduction to the book *Mathematics Teacher Noticing*, Sherin, Jacobs, and Philipp (2011) described various conceptualizations of noticing:

> Although some authors… define noticing solely as that to which teachers attend, most authors consider noticing to involve two main processes (*attending* to particular events in an instructional setting and *making sense* of those events)… some conceptualize making sense only as *interpreting*… whereas others conceptualize making sense as both *interpreting* and *deciding how to respond* (p. 9).

In other words, there are numerous processes that may be included in researchers' senses of what it means to study teacher noticing – some focus primarily on what teachers attend to in the milieu of classroom activity, some include how teachers interpret what they attend to, and others include how teachers respond or plan to respond based on what they notice.

In my study of attentive and responsive teaching, I do not distinguish among these aspects; rather, all three are wrapped up in a more holistic picture of the teacher's focus. As I describe in more detail below, much of the research on teachers' attention to student thinking (including teacher noticing studies) has taken place in professional development or teacher education settings removed from the classroom (e.g., Kazemi & Franke, 2004; van Es & Sherin, 2008). When teachers reflect on examples of student thinking in these settings and articulate what they notice, it is easier to parse what teachers attend to (students' ideas or other considerations), how they do so, and how they might respond as separate dimensions. In contrast, in interaction with students in the classroom, these

dimensions highly entangled – in fact, the teacher's responses to students' ideas *are* the evidence for what the teacher is attending to and how. As my dissertation examines teachers' attention and responsiveness to student thinking as it is enacted in the classroom, distinctions among attending, interpreting, and responding are less meaningful than the holistic sense of what the teacher is doing. I next turn to why I chose to situate my study of teachers' attention and responsiveness to the substance of students' scientific thinking in the classroom setting.

Studying Attention and Responsiveness Via Artifacts of Classroom Practice

As highlighted above, most research on teachers' attention to the substance of student thinking has taken place in settings removed from the classroom as teachers grapple with the student thinking evident in artifacts of practice (e.g., Jacobs, Lamb, Philipp, & Schappelle, 2011; Kazemi & Franke, 2004; Levin & Richards, 2011; Sherin & Han, 2004; Star & Strickland, 2008; van Es & Sherin, 2008). For instance, Sherin and Han studied what mathematics teachers attended to in video clubs, in which researchers and teachers met to watch and discuss video from the teachers' own classrooms. Sherin specifically "wanted to explore whether teachers' attention might be drawn… to student thinking" and focused "teachers' attention on issues related to student conceptions – asking, for example, about the meaning of a student's statement or idea" (Sherin & Han, p. 167). Continuing video club work (e.g., van Es & Sherin) has maintained this focus on what teachers notice in videos of classrooms. In addition to video, researchers have explored how teachers interact with the student thinking evident in student work (e.g., Kazemi & Franke) and have started to consider how artifact medium (video vs. written work) and artifact familiarity (whether artifacts are from the teachers' own classrooms or not) impact teachers' practices of attending (Goldsmith & Seago, 2011).

Issues with Artifacts of Classroom Practice as Proxies

There is a critical assumption underlying the use of artifacts of practice, however, which is that these artifacts serve as proxies of classroom practice. There is a sense that helping teachers attend to student thinking evident in such artifacts will enhance their abilities to do so in the classroom, where such attention and responsiveness matters for student learning and engagement. Yet this assumption is understudied, and there are numerous reasons to question the relation between interacting with artifacts in settings removed from the classroom and interacting with students in the classroom. For instance, as van Es and Sherin (2010) noted, "watching and reflecting on video requires different practices than those teachers typically engage in teaching" (p. 157). Part of this difference lives in the time available for reflection – in remote settings, teachers have more time to reflect on students' meaning than they do while teaching, where they are expected to provide immediate responses. Part of this difference also lives in the number of competing attentional foci present – in remote settings, teachers are expected and often directed to focus on the substance of students' disciplinary ideas. Yet the classroom is an incredibly complex environment (Ball, 1993; Hammer, 1997; Hawkins, 1973; Lampert, 1985) in which teachers are subject to a myriad of competing factors and pressures that may make focusing on student thinking more of a challenge.

Some recent work (Sherin & van Es, 2009; van Es & Sherin, 2010) has started to examine the connection between what teachers do in video clubs and what they do in their own classrooms. By conducting classroom observations over the duration of teachers' involvement in video clubs, Sherin and van Es saw that teachers increasingly (albeit variably) took up students' mathematical ideas as objects of inquiry in the classroom (for instance, asking a student to explain his thinking and draw a picture on the board) as well as in the video club. This provides some preliminary evidence of an interplay between analyzing artifacts of classroom practice and changing classroom practice, but more work is needed to understand the ways in which these activities may be connected.

Studies Situated in the Classroom

The competing factors and pressures present in the classroom environment, as well as the variability in classroom practice seen in Sherin and van Es's (2009) study, highlight the importance of studying teachers' attention and responsiveness to student thinking in the classroom setting. We need to better understand the circumstances under which teachers focus on student thinking while teaching if we want to support them in doing so. Several case studies of teachers' attention and responsiveness to student thinking in the classroom have provided insights into what may stabilize or destabilize such attention (e.g., Fennema, Franke, Carpenter, & Carey, 1993; Franke, Carpenter, Fennema, Ansell, & Behrend, 1998; Lau, 2010; Levin, 2008). I review findings from these studies and what my dissertation work contributes in the next section.

Understanding What Stabilizes (and Destabilizes) A Focus on Student Thinking

Case studies of teachers from the CGI project highlight the power of teachers seeing what students are capable of when they are provided space and support to follow their own thinking in the classroom (Fennema, Franke, Carpenter, & Carey, 1993; Fennema et al., 1996; Franke, Carpenter, Fennema, Ansell, & Behrend, 1998). For instance, a first-grade teacher in the project reflected on how well her students rose to the challenges she posed:

> But what really, really convinced me was working that first year with my kids in first grade, and the more problems I asked the better they got. The more I challenged them, the better they got… It was the students who convinced me that CGI works, and they went far beyond what I ever expected they could do (Fennema et al., 1993, p. 579).

Fennema et al. (1996) conceptualized this sort of statement as a feedback loop situated primarily in teachers' classroom practices:

> As the teachers saw that their students were capable of inventing strategies and doing more than they had anticipated, they increasingly made problem solving a greater part of their instruction; the children increasingly solved harder problems and reported their thinking; the teachers listened and understood children's thinking better; and so it continued (p. 431).

This feedback loop suggests that recognizing students' capabilities would likely sustain attention and responsiveness to students' ideas in local moments, as well as over the long-term as such experiences accumulate over time.

The three focal teachers in Franke et al.'s (1998) case studies described other potentially stabilizing aspects as well. For example, one teacher, Ms. Nathan, indicated that having access to specific problems from the CGI project to pose students helped her open up space and listen to students' ideas in her classroom. Another teacher, Ms. Andrew, found it fun and insightful to try to understand students' solutions to problems: "You know, I've learned a lot just from listening to some of these kids. I'm thinking, wow, I never figured it out that way. But you know, I even find myself using some of their ways" (Franke et al., p. 78). In Ms. Andrew's case, it is likely that the enjoyment she experienced while listening to and considering students' solutions supported her ongoing focus on student thinking.

Levin's (2008) and Lau's (2010) dissertation work focused more directly on factors and framings that afforded or constrained teachers' attention and responsiveness to student thinking. For instance, for Ms. Hawkins, a high school biology teacher in Levin's dissertation, her sense of accountability to various institutional pressures (such as high-stakes tests and her local team of biology teachers) drew her attention away from student thinking and toward correctness and vocabulary usage. In Lau's dissertation, she highlighted numerous ways teachers framed the classroom activity at hand and how those framings interrelated with attention. An emergent framing of "searching for mechanistic explanation" in one teacher's classroom corresponded to the teacher attending closely to students' ideas as she herself tried to understand the scientific phenomenon under discussion. In contrast, a framing of "reviewing a concept" in the same teacher's classroom corresponded to attention to terminology rather than ideas. These examples illustrate how a teacher's attention is subject to a host of other considerations at various grain sizes, from national education initiatives to more local communities and projects to particular interactions with students, and may shift on very short timescales – even during the course of a given conversation. Moreover, Lau echoed Levin's findings that "the frames that supported attention to the substance of student ideas were easily destabilized and rare whereas the frames that focused on correctness and the more surface features of what students produced were more established and common" (Lau, p. 291).

Affordances and Limitations of Contrasting Cases

In general, the studies above made use of contrasting cases in order to explore attention to student thinking in the classroom. For example, Franke et al. (1998) specifically chose three teachers with "different trajectories" (p. 70) in the CGI project and different levels of attending to student thinking. One teacher, Ms. Carroll, provided space for students' ideas to emerge in the classroom but did not carefully listen to them or use them in designing further instruction, whereas another teacher, Ms. Andrew, worked to unpack the details of students' ideas and integrated them into her next instructional moves. Levin (2008) explored a range of teacher attention to student thinking across novice and experienced teachers, highlighting findings from teachers who did and did not make students' ideas central to their instruction. Lau (2010) also identified contrasting

episodes in teachers' classroom practice, looking at the framings in play when teachers' attention was directed toward student ideas and away from student ideas.

Such a focus on contrasting cases is useful for identifying features that are different between the cases and which may account for some of the contrast seen. For instance, Levin (2008) highlighted how two novice teachers, Scott and Susan, had relative freedom in their internships and worked and planned together. This openness and collaboration supported their attempts to attend to student thinking in their classrooms. In contrast, another novice teacher, Emma, lacked such collaborative opportunities and struggled with classroom management, and her administration's continual focus on her management struggles made it difficult for her to prioritize listening to students' ideas while teaching. Through the comparison of such contrasting cases, we could see the impact of various institutional structures on teachers' attention to student thinking.

Yet with this approach, we understand little about the *best* examples of teachers attending and responding to the substance of student thinking in the classroom. Although Franke et al. (1998) identified Ms. Andrew as their most developed teacher, they acknowledged, "We do not know why Ms. Andrew reached a point where she engaged in practical inquiry focused on understanding the development of her students' thinking" (p. 79). Likewise, in Levin's (2008) dissertation, we see *that* a high school biology teacher, Ms. Brown, consistently engaged and listened to her students in discussion, but we have little sense of why she did so – particularly given that she was in the same standards-driven instructional environment as Ms. Hawkins.

We also understand little about the *dynamics* that played out in classroom episodes where these teachers attended and responded to students' ideas. For instance, consider the case of Ms. Andrew (Franke et al., 1998). Her reflection of how much she enjoyed seeing what her students could do with mathematics was self-reported during a formal interview; it was also a general sentiment on Ms. Andrew's part, not connected to specific examples or ideas. As such, there is no direct evidence of how Ms. Andrew's enjoyment impacted her classroom practice or her focus on students' ideas in situ. To truly unpack the role that enjoyment (or other potentially stabilizing aspects) played for Ms. Andrew, a closer look at how she engaged with students' ideas in the moment and later described specific interactions would be beneficial. Lau (2010) took this sort of approach in unpacking how teachers' framings of their classroom activity directed their attention either toward or away from student thinking, but her analysis was limited to the specific construct of framing and its role in shaping teacher attention.

Focusing on Classroom Episodes from Exemplars

What my dissertation contributes is in-depth analyses of the dynamics of classroom episodes from three focal teachers who regularly attend and respond to students' ideas in their classrooms. Although these teachers are exemplars in terms of their overall focus on student thinking, I do not attribute stabilities seen in their practice solely to *them* or to any particular construct; I attempt to remain open to a range of aspects that might influence their practice. As I describe in the next chapter, I selected several classroom episodes for each teacher in which the teacher's attention was relatively stably on students' ideas for an extended period of time. I then drew on numerous data sources, including video of the classroom episodes themselves and

teachers' reflections on the episodes in conversations, meetings, interviews, etc., to explore the following research question and subquestions:

> What might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking during sustained classroom episodes?
>
> a. What seems salient to teachers within the episodes?
> b. What are plausible mechanisms by which identified elements might stabilize a focus on student thinking?

I consider this work to be highly exploratory, suggesting likely aspects that *might* be in play in stabilizing teachers' attention and responsiveness to student thinking rather than causal claims about what *is* in play. I will discuss this caveat further in the following chapter.

Chapter 3: Methodological Approach

In this chapter, I set the groundwork for my analyses. First, I describe the collective case study design I used in my dissertation and introduce my three focal teachers and the professional development project in which they participate. Second, I explain the criteria by which I selected relevant cases for analysis. Third, I discuss my analytical approach to understanding what might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking during sustained classroom episodes. I also acknowledge limitations in my approach along the way.

General Study Design

In this study, I employed a collective case study design (Bogdan & Biklen, 2007; Merriam, 2009; Yin, 2006). Here, a case, or unit of analysis, is a classroom episode in which a teacher's attention and responsiveness to the substance of students' scientific thinking is stable or sustained. I identified nine cases in total, three cases from each of three focal teachers, and triangulated across multiple data sources to better understand the dynamics involved within and across cases. I describe how I selected focal teachers and classroom episodes in the sections that follow.

Project Context and Focal Teachers

Professional Development Project

The data for this study comes from a multifaceted professional development project situated in one of the largest majority-minority school systems in the United States. Our strand of the project works with fourth through eighth grade teachers to promote inquiry teaching and learning in their science classrooms, working under the hypothesis that engaging students in authentic scientific inquiry will help maintain their interest and persistence in science.

Each year, teachers in our strand engage in numerous professional development activities – all of which we videotape. They attend a two-week summer workshop in which they grapple with what it looks and feels like to construct deep explanations of scientific phenomena that are causal, clear, and coherent (what we call the "3 C's" of scientific inquiry[5]). They engage in their own minimally-guided inquiry, discuss classroom video of students engaging in scientific inquiry, and collaborate on other issues related to inquiry teaching and learning in the classroom (such as assessment, lesson planning, etc.). During the school year, teachers work one-on-one with members of our research team to facilitate scientific inquiry in their classrooms. These individual collaborations may involve co-planning, co-teaching, or observing and debriefing – whatever level of involvement the teacher desires. In addition, teachers attend bimonthly small group teacher meetings with other teachers and members of the research team to

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[5] These are not the only components of scientific reasoning, but they do capture some of the important elements in a language that makes sense for elementary school students.

discuss each other's classroom videos, engage in mini inquiries, and support each other in dealing with concerns and issues as they arise. Teachers voluntarily apply and may continue in the project for multiple years.

Focal Teachers

Given my focus on understanding what might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking in sustained classroom episodes, I selected teachers from our project who consistently facilitate rich scientific discussions in their classrooms (agreed upon by members of the research team). These teachers are not intended to be representative of teachers in the project or more broadly; rather, they serve as exemplars who interact regularly with students' scientific ideas and from whom I can learn more about what supports their attention and responsiveness. All three focal teachers were in the first cohort accepted into the project in 2009-2010, and all have remained active participants over the years. Moreover, I have interacted directly with these teachers in all project contexts, including classroom visits. (I consider the impact of my familiarity with the teachers in more detail later in this chapter.)

Ms. L

The first focal teacher, Ms. L, teaches fifth grade at an elementary school. Demographic data from 2009-2010[6] indicate that the student body at the school was approximately 75% African American, with 30% of students receiving free and reduced lunch. The school has an English for Speakers of Other Languages (ESOL) program.

Ms. L began teaching at the university level as a faculty research associate in animal science. After she had children, she started working part time and volunteering at her children's parent cooperative nursery school, eventually teaching the four-year-old class from 1991 until 1996. She got certified to teach elementary school in 1996 and has been with the school system since then. Ms. L described the project as giving her "permission to teach the way [she's] always wanted," stating:

> [It] has made me focus on just how rich and applicable background knowledge my kids have in science just from their day to day observations. And that with a little encouragement, the kids will work to unlock their own brains to answer all sorts of really challenging questions… it has resulted in some kids absolutely LOVING science. And for me it has been a relief to not always be regurgitating knowledge to the kids, and it has become a joy to go on these intellectual journeys with them, often into areas I don't know myself [E-mail, October 2011].

Ms. R

The second focal teacher, Ms. R, taught sixth grade at a Title I elementary school at the time of the study. Demographic data from 2009-2010 indicate that the student body

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[6] All statistics come from publicly available 2009-2010 demographic data, not directly cited to protect the anonymity of the schools.

at the school was approximately 50% Hispanic and 40% African American, with 50% of the students classified as limited English proficient (LEP).

Ms. R has been teaching since 2003. She originally wanted to be a high school math teacher, but she ended up volunteering in her high school track coach's elementary school classroom and enjoying it. Ms. R described her involvement with the project as the second revitalization her teaching career has undergone, with the first being National Board Certification. In particular, Ms. R said she appreciates the opportunities the project provides to collaborate with colleagues and to reflect on and refine her teaching in ways that support her main goals, such as students becoming critical thinkers:

> My goal is that, for my students to be critical thinkers, so – eventually, as a critical thinker, you have to learn to take in new information, whether you like it or not, and, just, you know, just take it in as new and see where it works. You've gotta like turn it around (pause) any way so you can take something from it [Meeting, November 2011].

Mr. S

The third focal teacher, Mr. S, taught seventh grade at a Title I middle school at the time of the study. Since Ms. R's elementary school fed into Mr. S's middle school, the two schools had similar populations – according to the 2009-2010 demographic data, the middle school was also predominantly Hispanic (65%) and African American (30%) with approximately 35% of the students classified as LEP.

Mr. S has a background in law and theology, and he got into teaching in 1998 in order to "affect the lives of children who may have been at risk for certain life altering experiences, such as unemployment and incarceration, due to race, ethnicity, social class, and a lack of quality education" [E-mail, October 2011]. He is particularly supportive of the project's commitment to enhancing opportunities for underrepresented groups in science, and something he noticed early on in the project was how students who have traditionally been marginalized in systems of schooling engage in inquiry discussions:

> What I've noticed is that (pause) with more discussion, I, I see kids who normally – sit back and don't engage are engaged, and… it affirms them in a way that is not necessarily quote-unquote related to a grade… we all have an equal chance to, to – you know, engage – in a way that's not related to… A's and B's or, um, to a certain extent – um (pause) just kind of what happens in school [Meeting, May 2010].

Having introduced the three focal teachers, I now turn to my criteria for selecting episodes from their classrooms in which they attended and responded to the substance of students' scientific thinking in a sustained manner.

Selection Criteria for Episodes

My selection criteria for cases or episodes involve several components and reflect my positionality as a member of the research team who is familiar with the teachers.

Here, I describe these criteria, provide a brief description of each selected episode, and acknowledge the limitations in my approach.

Primary Considerations Governing Episode Selection

My aim was to select a range of episodes for each teacher in which the teacher's attention and responsiveness was relatively stably on students' ideas. I started by identifying the earliest videotaped episode from each teacher's classroom that fit the following specifications.

First, the episode needed to be extended in duration and exhibit potential distractors from a focus on student thinking, such as classroom management issues. Although episode duration varied, most were on the order of approximately ten minutes and either encompassed the entirety of a discussion or reflected a natural breaking point in a discussion (if the discussion continued). The teacher's attention and responsiveness to student thinking was considered stable if it persisted over the course of the episode, particularly in the face of evident distractions.

Specifically, I retained an episode for consideration if the majority (over 50%) of the teacher's speech turns over the course of the episode demonstrated responsiveness to the substance of students' scientific thinking. This criterion reflects a relatively stable focus on students' ideas while recognizing that teachers cannot realistically focus all of their attention on any one thing in the classroom. Table 3-1 reflects types of potentially responsive utterances, drawn partly from recent work focused on attentive and responsive teaching (e.g., Brodie, 2011; Lau, 2010) and partly from my own reflections on such teaching (indicated by the designation "original category," discussed further in Appendix A). The examples provided are all from selected episodes.

Table 3-1

Descriptions and Examples of Potentially Responsive Utterances

Description	*Example from Selected Episode*
Acknowledging attempts to answer – acknowledging a student's attempts to answer a question, especially in the face of continued questioning (original category)	S1: Why did the meteor shower only hit the females and not the males? S2: It only hit, it hit both of them, but, um, some of them stayed, some of them were still there. … S3: How come they only killed all the females, not all the males? T: Okay, he just tried to answer that question.
Altering activity – changing the activity or broadening its scope in response to a student's idea (original category)	S1: I say maybe we put one part of the magnet in the water, and the other like maybe a little bit higher, so there's still a lot amount of space? … T: If you want to try it- and then try it the

	way S1's suggestion, with one underwater and one not.
Attempting to elicit when little evidenced – consistently attempting to elicit student thinking when little is in evidence (Levin, 2008)	T: Any arguments against that? S1: No. S2: No, sir. … T: Who thinks that this ((points to board)) is not a good idea?
Attempting to hear – consistently attempting to hear the entirety of a student's idea when it is difficult to do so (original category)	S1: Uh, walk past it kind of fast and then – test if it'll go- T: Hold hold hold, hold on. On the outside, everybody, including S2, we are in the listen-only mode. Okay? Um, and inside, we're one at a time. S3: I have a question. T: Uh, just hold on, just hold on. Uh, S1, what did you say now?
Clarifying scenario – clarifying the question or scenario under discussion in response to a student's question or comment (original category)	S1: So like, are you walking right by the trash can, or are you walking, stopping, and then- T: I'm walking right by the trash can.
Confirming – ensuring a student's idea was heard correctly (Brodie, 2011)	S1: Because if the wind is working in a different direction than you, you're running and () ((moves one hand forward and the other in the opposite direction on top)). T: So when you, when you're saying, when you're running fast, there's some pressure coming up against you, coming against you?
Countering – providing or asking for a contradiction/counterclaim to a student's idea (as long as the student's idea is still the primary focus) (Pierson, 2008)	S1: If you're running, you feel like the wind is pushing you back. … T: What are some arguments against this ((points to board)), this idea that there's air pushing back or there's something pushing back?
Eliciting – trying to get something specific from a student that relates to his idea (Brodie, 2011)	S1: Wouldn't it make it go down because it's heavier? T: … What force will cause it to go straight down? What force will cause it to go straight down?
Identifying differences – identifying differences between students' ideas (Lau, 2010)	S1: Maybe it's because of their fur color. … S2: But then the difference between a coyote and a wolf, um, they have different colors, but they're still in the same group.

	T: Yeah, so that would sort of – argue against that.
Identifying similarities – identifying similarities between students' ideas (original category)	S1: So you gotta do- have you noticed that when you try to do it at that time when it's there, it doesn't work out if you do it after? But then when you do it before, it gets to the little thingie () get it. So it's related to this. T: So yours is similar to what S2 said a little while ago about timing.
Inserting – adding something in response to a student's idea, building on a student's idea by providing examples or illustrations (Brodie, 2011; Lau, 2010; Pierson, 2008)	S1: Oh wait no, it's gonna fall (). T: It's gonna fall over here ((points to board)). So it's gonna go straight down on an angle ((writes on board)).
Maintaining – keeping a student's idea in the public realm by repeating it, asking the student to repeat it for emphasis, or other moves (Brodie, 2011; Pierson, 2008)	S1: I have a question. Doesn't it start as liquid because when the snow falls down, it's liquid- I mean, liquid, but then it starts to form into a solid. … T: So now, S1's brought in the idea that, you know, maybe there's just- did that snow that they're, didn't it start off as water up there?
1. Reflecting – throwing a student's idea out for the class to consider, a "reflective toss" (van Zee & Minstrell, 1997)	S1: Gender… if there's more girl foxes than boy foxes- T: Than boys? But – um, anybody have a response to that? About it maybe being gender that the foxes were dropped?
2. Revoicing – aligning a student's idea with specific academic content or tasks (O'Connor & Michaels, 1993)	S1: When you put a magnet and magnet together, there's sometimes a force in the middle of them, and it won't, it won't ((moves fists together and apart)), it won't stick. T: So S1's talking about sometimes when you put magnets together, they're- you feel them resisting. It's like they're pushing each other apart, aren't they?
Pressing – probing a student for more on his idea, asking a student to clarify or elaborate on his idea (Brodie, 2011; Lau, 2010; Levin, 2008; Pierson, 2008)	S1: The weight of the keys. T: ((faces board, writes)) The weight. What's, say a little bit more about the weight. What is it about the weight?
Returning to idea later – returning to a student's idea at a later time (Lau, 2010)	T: Now somebody said yesterday, after would be better. Why after? There are a couple- I remember S1 said after.

Note that interpretation of such utterances depended on how they were deployed and taken up in context. For instance, take the "attempting to hear" example above. "Drake, what did you say now?" could actually be evidence of a teacher's inattentiveness if Drake's idea was clearly decipherable in the classroom environment, but positioned as it was in the face of disruptions from other students, it illustrated the teacher's desire to hear Drake's idea even when it was difficult to do so. If I was unsure about the responsiveness of an utterance, I took a conservative approach and simply did not include it in my count.

Additionally, there needed to be evidence of the teacher reflecting on the episode proximal to the time the episode occurred. This is not a criterion for stability, but rather a way to maximize my understanding of what happened in the episode. For instance, teachers often talked with members of the research staff about their lessons, or reflected on video of their lessons at the bimonthly small group teacher meetings. These data sources were critical for understanding more about the context of a given episode and triangulating my interpretations of what occurred during the episode with the teacher's reflections at the time.

Again, the first episode for each teacher was the earliest videotaped classroom episode that fit the above specifications. All subsequent episodes were subject to the same specifications, but their selection was also influenced by my and other research team members' familiarity with each teacher's classroom practice. I wanted to make sure the episodes included representative aspects of what each teacher regularly did in the classroom. For instance, Ms. R often projected a blank Word document at the front of the classroom and took notes on what students said as they shared; I made sure this aspect of her practice was represented in at least one of the selected episodes from her classroom. In this way, the research team's knowledge of the teachers' instructional practices from working with them on the project informed my selection of the second and third episodes for each teacher. When possible, I also selected episodes that provided natural points of comparison with each other, such as Mr. S teaching different versions of the "same" lesson his first two years in the project.

Descriptions of Selected Episodes

Table 3-2 contains brief descriptions of all selected episodes analyzed in this dissertation. Full transcripts of the episodes and how they fit the selection criteria are provided in Appendix D for Ms. L, Appendix E for Ms. R, and Appendix F for Mr. S.

Table 3-2

Descriptions of All Selected Episodes

Teacher	*Date*	*Description*
Ms. L	April 2010	Fifth-graders discussing a student's question about whether magnets work underwater and how they might test this scenario
Ms. L	September 2010	Fifth-graders discussing why a fox is classified in a different genus than a coyote and a wolf
Ms. L	February 2011	Fifth-graders discussing whether snow is a solid or a liquid, in the context of a lesson on melting
Ms. R	April 2010	Sixth-graders discussing what counts as a crest in a wave
Ms. R	September 2010	Sixth-graders discussing what makes something sink or float
Ms. R	April 2011	Sixth-graders discussing their own intuitive definitions for energy
Mr. S	April 2010	Seventh-graders discussing where you would drop keys to get them to land in a certain location as you're walking
Mr. S	January 2011	Seventh-graders discussing how dinosaurs became extinct
Mr. S	March 2011	Seventh-graders discussing where you would drop keys to get them to land in a certain location as you're walking (again!)

Limitations of Selection Criteria

There are several limitations of my selection criteria that I acknowledge here. First, a video camera and a member of the research team were present for all episodes, which may have enhanced teachers' propensity to engage students in inquiry discussions. We do not believe our presence was the only factor influencing their attention and responsiveness to students' ideas, though, as all three focal teachers also provided detailed descriptions of students' ideas from classes in which we were not present, suggesting that their attention and responsiveness to students' ideas spanned beyond classes we attended. Second, my selection criteria do not select for *all* possible episodes in which teachers focused on students' ideas. Specifically, my use of teachers' utterances as evidence of their attention and responsiveness to students' scientific thinking means that the teachers were active discussion participants in all selected episodes. There were other classroom conversations in which more of the responsibility for discussion was on the students, and the teacher remained relatively silent during the discussion. Although the teacher's focus may have been on student thinking, it was difficult to tell in the moment, and these episodes would not be identified by my selection criteria.

Analytical Approach

For each case, I considered careful transcription to be my first analytical step (Bird, 2005). After transcribing the content of the interaction, I layered in interactional markers like emphases, gestures, pauses, etc., adapting transcriptional notations from Sacks, Schegloff, and Jefferson (1974) as shown in Appendix B. Note that I did not attempt to represent every interactional detail I saw; rather, I sought to represent the cues that helped me better understand what participants were saying and how they were orienting to each other and the situation more generally.

I then began to explore the episodes, with an eye toward grounding claims of what might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking within the specific episodes. There are numerous approaches one might take in doing so. For instance, one approach I explored was examining participants' turn-taking (Sacks, Schegloff, & Jefferson, 1974) during such discussions, specifically striving to identify patterns of interaction between teachers and students. Discussions typically began with the teacher asking a question to elicit ideas from students. As students offered ideas, the discussions often fell into a relatively stable back-and-forth between students offering ideas and the teacher asking questions or making statements related to the ideas, as illustrated in the following example from Ms. R's classroom:

> Raul: It sinks when it has more weight, and, like, it floats when it has less weight. *(student idea)*
>
> Ms. R: Okay, less weight floats, more weight sinks. Okay. La- *(related teacher statement)*
>
> Raul: Because like with Titanic, like, it was like, um, huge, and it weighed a lot. And then when it hit the iceberg, it filled with water. *(student idea)*
>
> Ms. R: Okay. And then what happened? *(related teacher question)*
>
> Raul: It went underwater. *(student idea)*
>
> Ray: It fell down. *(student idea)*
>
> Ms. R: Because what? *(related teacher question)*
>
> Ray: Water was- *(student idea)*
>
> Raul: Going in it. *(student idea)*
>
> Ms. R: Because the water got in it. *(related teacher statement)*
>
> Raul: And then, like, it caused more weight, and then it's underwater. *(student idea)*

Ms. R: So the water has weight itself, and then that made it go down? *(related teacher question)*

Raul: Yeah. *(student idea)*

Ms. R: And that's kind of like somebody just said with the water bottle over here, when you put the water in the water bottle, that's make it- *(related teacher statement)*

Thurman: It'll sink. *(student idea)*

This interactive pattern was prevalent in all selected episodes, and as such, I do not unpack it in each individual episode analysis, but rather note its role here more generally. The very structure of the interactive pattern may have stabilized teachers' focus on students' ideas – as teachers elicited and listened to students' ideas, students offered more ideas, teachers attended to these additional ideas, and so on.

Such an approach certainly provided meaningful insight into the structural nature and stability of the selected episodes, but it felt limited to me when I considered the myriad of factors known to influence teachers' attention – teachers' own manifold knowledge and orientations (e.g., Schoenfeld, 2011), goals for the lesson (e.g., Schifter, 2011), institutional mandates (e.g., Levin, 2008), etc. In the face of such complexity, I found the stability afforded by the interactive pattern to be important, but only part of the story. Moreover, a critical part of the story that I wanted to understand was what the *teachers* found meaningful in the episodes.

Thus, my analytical approach in this dissertation frames teacher attention and responsiveness to the substance of students' scientific thinking as emergent from a complex system of multiple interrelating influences, including but not limited to those above. Consonant with perspectives on dynamic systems (e.g., Thelen & Smith, 1994), I take a stability to be a self-assembly of various factors and their interactions, from which the state of interest (i.e., teacher attention and responsiveness to student thinking) emerges. To use Thelen and Smith's (1994) language, a stability is an area of "tight coordination" (p. 68); Hammer, Elby, Scherr, and Redish (2005) might describe it as a local coherence that often involves contextual influences. In other words, a stable state emerges from the activation and interrelation of multiple aspects or elements that coalesce into a coherence or intersecting coherences. This conceptualization draws my attention, first and foremost, to searching for aspects or elements that might contribute to or support the emergence and continuation of a stable state[7].

To do so, I sought to approach the episodes in a bottom-up manner, considering evidence from the episodes themselves first. Then, I iterated between the episodes and

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[7] I flesh out this conceptualization of stability in more detail in Appendix C, and consider what it might look like to model the dynamics and interrelations in an episode from a complex systems perspective. For the purposes of my dissertation, though, I focus primarily on identifying aspects that might be in play in selected episodes.

additional data sources (debrief conversations, recollections from teacher meetings, stimulated recall/reflection interviews, and feedback on preliminary analyses) to flesh out my understanding and gain more insight into teachers' perspectives on the episodes. In their discussion of complex systems in the learning sciences, Jacobson and Wilensky (2006) highlighted such bottom-up modeling as a way for researchers to "distill their qualitative intuitions about critical factors that might be most responsible for the behavior of a system of interest," which is "often quite valuable when confronting systems of multidimensional and multilevel complexity" (p. 28).

In what follows, I describe my subquestions about salience and mechanisms of stabilization in positing what might be part of the stabilities or local coherences, then turn to an example from the second episode from Mr. S's class to illustrate how I orient to these subquestions in the data.

Co-occurrence, Salience, and Mechanisms of Stabilization

In seeking to understand what might be part of the local coherence(s) involved in a given episode, I considered two primary types of evidence:

1. Elements that were co-occurrent with the teacher's attention and responsiveness to students' scientific thinking and salient to the teacher were candidates to be part of the local coherence(s).

2. If plausible mechanisms could be posited linking such elements and the teacher's focus on students' ideas, the likelihood that they were part of the local coherence(s) increased.

By co-occurrent, I mean that the element was present with the focus on students' ideas – similar to what Conlin, Gupta, and Hammer (2010) described as "clustering" or "hanging together" (p. 278), which they took as one kind of evidence of coherence. Moreover, if a co-occurrent element was also salient to the teacher in some way, I considered it more likely to be active in the dynamic, drawing on an intuitive sense that significant events tend to be more influential on behavior than insignificant events. Finally, if the element plausibly stabilized or was in a mutually reinforcing relationship with the focus on students' ideas, that served as the strongest evidence of its involvement in the local coherence(s).

Recent work looking at various kinds of stabilities has taken a similar approach (e.g., Azevedo, 2012; Conlin, Gupta, & Hammer, 2010; Frank & Scherr, 2012). For instance, in studying the sustained interests and practices of amateur astronomers, Azevedo acknowledged the critical role of individuals' preferences that intersected with but extended beyond participation in amateur astronomy. For example, one amateur astronomer, Mitchell, exhibited a preference for "technifying" (Azevedo, p. 25), calling attention to the various technologies he used in his practice. This preference, which extended beyond the practice of amateur astronomy, was nonetheless co-occurrent with Mitchell's amateur astronomy practice, salient enough for him to mention, and mutually reinforcing as he used technologies in the course of his practice. In other words, Mitchell's preference for "technifying" was often coupled with his amateur astronomy practice, along with other preferences and conditions.

Frank and Scherr (2012) also investigated a sustained phenomenon:

> Our guiding question is, "When a pattern of student reasoning is sustained in specific moments and settings, what mechanisms contribute to sustaining it?" We find that stabilities in student thinking can be attributed to real-time activities that sustain specific understandings (p. 020101-1).

In their paper, they focused on instances of a particular pattern of student reasoning that arose while a group worked on a task and analyzed what was going on in those instances that might have contributed to or sustained the reasoning. For example, they discussed how contextual cues from a worksheet and other materials in the setting may have tipped students into thinking a certain way, and how other ideas that students raised and the initial pattern of reasoning mutually reinforced each other. In each case, the elements they discussed co-occurred with the pattern of reasoning under investigation, were salient to the students, and plausibly sustained the students' line of reasoning.

I now turn to an example to illustrate how I identify these types of evidence in the selected episodes and other data sources.

An Illustrative Example

My sample analysis comes from the second selected episode from Mr. S's class, in which he and his seventh-grade students were discussing how dinosaurs became extinct. The following exchange occurred at the beginning of the episode and seemed salient to Mr. S, for reasons I explicate below:

> Evan: ((Mr. S writes while Evan talks)) Um, a meteor shower killed the dinosaurs, and um, they just became extinct because all the females died, and the males couldn't mate, and they just died.
>
> Mr. S: So you're saying that the meteor shower, um (pause) basically killed all of the females and left the males alive?
>
> Evan: Yeah.
>
> Mr. S: Okay, okay. And, and how, okay, um, before you- how did the, how did the meteor know that it was the female and not the male? How did it, how'd it differentiate?
>
> Student: There were-
>
> Mr. S: Uh uh uh uh, he's answering. What? (pause) What do you think? How did the meteor ((smiles)) decide that just the females, how did- why did the females die and not the males? That's the point I'm raising if you said a meteor shower [Episode, January 2011].

In this exchange, Evan suggested that a meteor shower killed all the female dinosaurs, and the males couldn't reproduce. Mr. S paused to consider his idea, then pressed him to articulate how the meteor differentiated between males and females.

What first caught my attention in this exchange was Mr. S's subtle affect toward Evan's idea – smiling as he questioned Evan, being a bit playful with his wording (how did the meteor "know," "differentiate," "decide," all of which gave the meteor an unusual level of agency). The coordination of such verbal and nonverbal communicative cues (Stivers & Sidnell, 2005) gave me the sense that Mr. S was amused and/or intrigued by Evan's idea in some way. Furthermore, Mr. S stayed with Evan's idea for an extended period of time, beyond the exchange noted above. Such evidence – displaying an affective response to something, spending an extended period of time attending to it, and/or repeatedly referring to it (not seen in this example, but evident in others) – suggests that it is salient to the teacher in the moment, even if the teacher is not consciously aware of it.

Other data sources, such as videotaped conversations during teacher meetings, provide additional information about what may have been salient to the teacher during the episode, but not visible to an observer. I used the same types of evidence to identify salience in these settings, with an additional consideration of whether the teacher spontaneously brought up something that happened on his or her own. For instance, Evan's idea seemed to be memorable to Mr. S, as he mentioned it when a similar idea came up in another class period and spontaneously brought it up during a teacher meeting shortly following the episode:

> Several groups in different classes mentioned that the, the female species of dinosaurs were, were eaten, were eaten somehow, consumed, or died off – for various reasons, and that the males had no, no, no, no male- no female, um, um, um, members of the species to, with which to have, uh, reproduce [Meeting, January 2011].

Additionally, when we watched video of the episode at a teacher meeting two months later, Mr. S again smiled and laughed while watching footage of the exchange. We paused the video, and Mr. S described what he was thinking:

> I was trying to understand from him, how did all the females- whatever did- whatever it was that was the killing off of the dinosaur, how was it that they, that the- what was it about the females that made them susceptible to this mass extinction? [Meeting, March 2011]

The repetition of Mr. S's affective response to Evan's idea provides further evidence of the salience of the exchange to Mr. S, as it invoked similar feelings two months after the fact as it did in the moment. Although claims of salience may come from evidence from the episode *and/or* reflections on the episode, and I iterate among various data sources to saturate my sense of what was salient to the teacher in the episode, the strongest evidence of salience comes from agreement between data sources as seen here.

Moreover, Mr. S's actions in the moment and description of what happened suggest that he was authentically curious about what Evan was thinking. In the moment,

he pressed Evan to explain how the females died and not the males; upon reflection, he still seemed to be wondering why the females were susceptible to mass extinction. Although Evan never really came up with a clear explanation, Mr. S wondered if it had something to do with the culture in which Evan was immersed:

> I wondered when he spoke, I wondered if, coming from a patriarchal society or culture, how much of his, his, his rationale is somewhat based on this idea that the female is the weaker vessel, and somehow she is more prone to die off because of this mass environmental change that took place [Meeting, March 2011].

Mr. S's continued intrigue with respect to Evan's idea suggests a mechanism of mutual reinforcement between Mr. S's attention and responsiveness to Evan's idea and his curiosity. As Mr. S attended to Evan's idea, he became curious about why Evan was thinking what he was thinking, which supported continued attention to Evan's idea, and so on. This indicates that Mr. S's curiosity with respect to Evan's idea was likely involved in the local coherence(s) supporting his attention and responsiveness to Evan's thinking at the very least; moreover, given that this was one of the earliest exchanges that took place during the episode, it is plausible that Mr. S's curiosity was piqued for what other students might offer as well.

This example also highlights an analytical subtlety – what is salient to the teacher might not always *be* the aspect that is plausibly part of the local coherence(s), but might *point to* the aspect. In this case, what was salient to Mr. S was Evan's idea, but the plausible aspect in play was Mr. S's curiosity with respect to Evan's idea. Regardless, for each identified salient element in a given episode, I attended to whether and how it interacted with the teacher's attention and responsiveness to students' scientific thinking. To remain a hypothesized part of the local coherence(s) supporting attention and responsiveness to student thinking, there had to be at least one way in which the element reinforced or stabilized the focus on students' ideas, and I acknowledged when there was evident variability in whether the element supported or detracted from this focus.

Triangulating with Interviews and Member Checks

Once I completed my preliminary analysis of an entire episode, I met with the teacher to watch video of the classroom episode together. I provided the teacher with a transcript that contained students' real names for reference. As we watched, I conducted a semi-structured stimulated recall/reflection interview (Lyle, 2003) in which I paused the video periodically, or if the teacher began talking, to discuss the following central question: "What should I understand, or what stands out to you, about what's going on?" Follow-up questions and clarifications were developed in real-time based on the teacher's responses. In this way, I remained open to new insights that I might gain during the interview. I also took the opportunity to ask specific questions related to my analysis in order to triangulate my interpretations with the teacher's perspective or to reconsider my interpretations in light of disconfirming evidence. After editing my analysis to

incorporate interview data, the teacher was given an opportunity to read and provide feedback on the written analysis[8].

I use the term stimulated recall/reflection interview rather than just stimulated recall interview to illustrate what kinds of insights I expected to gain by using this method. Lyle (2003) raised the concern that as the time between the event and the interview increases, the accuracy of the recall of what participants were thinking and feeling at the time decreases. For Lyle, considering the interview to be stimulating reflection rather than recall "obviates the potential lack of association between videoed episode and concurrent cognitions" (p. 863)[9].

Yet it is doubtful that participants' reflections were purely new constructions either. Work on "remembering" (Bartlett, 1932; Nemirovsky, 2011) provides a useful way of conceptualizing the connections between what went on at the time and what is remembered. For instance, Bartlett had participants read a particular story, *The War of the Ghosts*, twice and then asked them to retell the story at repeated intervals. He found that even the first retellings, a mere fifteen minutes after they had read the story, were rife with omissions, explanations that were not part of the story, etc. These and other related findings from Bartlett's work suggest that literal recall is rare at any timescale, not just after a significant time lapse. However, participants did repeatedly remember specific details from the story that were significant to them:

> For the particular form adopted is due directly to the functioning of individual special interests… or to some fact of personal experience, or to some pecularity of individual attitude which determines the salience or potency of the details in the whole material dealt with (Bartlett, p. 71).

These salient details or "dominant features were the first to appear" (Bartlett, p. 209) in retellings.

Bartlett (1932) also noted that the determination of salience or potency was often accompanied by an affective tone, which he cited as an important factor: "if the interesting material is pleasing, the change is in the direction of elaboration and development; if the affect is displeasing, distortions are most likely to occur" (p. 90). The role of affect is also important in Nemirovsky's (2011) recent work on episodic feelings and transfer. Nemirovsky described episodic feelings as "feelings embedded in the specific circumstances of a time/place lived by the participants" (p. 311), and he demonstrated through the case of Eleanor how episodic feelings might serve as a vehicle for transfer between one experience and another.

Thus, I did not expect that the semi-structured stimulated recall/reflection interviews would provide me with accurate depictions of what teachers were thinking or feeling during the selected episodes *or* brand new reflections upon watching the videos. Rather, I expected reconstructed accounts of what they "remembered," organized around

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[8] Only Ms. L did so by the time of submission.

[9] This is part of the reason I selected episodes for which I had evidence of teachers' reflections proximal to the time the episodes occurred.

the most salient, affectively-charged details – the exact details likely to be part of the local coherences I sought to unpack.

Looking Across Episodes

Part of my analysis also involved looking across cases, both within and across teachers. In doing so, I attended both to natural contrasts between episodes and commonalities across episodes. For instance, take two episodes in which the attention and responsiveness to student thinking in one episode was more stable than in the other, such as the second and third episodes from Ms. L's classroom, respectively. One distinction between the episodes was the extent to which Ms. L saw the discussion that ensued as aligned with her intended content objectives. The presence of perceived alignment in the second episode, and the absence of perceived alignment in the third episode, allowed me to make a stronger case that perceived alignment played an active role in stabilizing Ms. L's attention and responsiveness to students' ideas in the second episode. (See Chapter 4 for more detail on this example.) I also noted if a given element was part of multiple local coherences across episodes, suggesting that the element was more likely to be tightly coupled with attention and responsiveness to student thinking. I highlight such commonalities for individual teachers and across teachers in Chapter 6.

Limitations of Analytical Approach

There are several limitations of my analytical approach that I acknowledge here. First, my focus on salience and mechanisms of stabilization supports plausibility cases for the involvement of identified elements, but does not definitively prove their involvement. I may have identified elements that do not actively contribute to the stability – this is particularly likely in the case of elements that are more fleeting within an episode, even if they are salient when they are present[10]. Second, these analyses are by no means exhaustive in terms of what stabilizes teachers' attention and responsiveness to students' ideas in the episodes or more generally. Additionally, although I was open to anything that seemed salient (regardless of grain size, ontological character, etc.), my emphasis on teachers' reflections increased the likelihood that I would note explicit saliences more often than other sorts. By explicit saliences, I mean aspects that teachers were aware of and reflective about with respect to their likely impact on classroom practice. From a professional development standpoint, we can interact most readily with such saliences, so they are of critical importance to understand. Third, while my analytical approach identifies aspects that may support teachers' attention and

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[10] That said, I am undecided on what exactly it means to "actively contribute to the stability." If attention would still be focused on students' ideas without the influence of a given element, does that mean that the element is not actively contributing? Or might it be actively contributing, but the dynamic is otherwise stable enough that its absence wouldn't cause a shift? This is analogous to a question Ayush Gupta raised in conversation – does the fourth leg of a table (that would remain standing with only three legs) impact the stability of the table? Does the fourth leg carry some of the weight?

responsiveness to student thinking during the selected episodes, I do not seek to map out the specific coherences or interrelations among the aspects themselves as I noted previously. The aspects I identify are mutually consistent in each episode in that they do not clearly oppose each other, and it is plausible that some reinforce each other and further contribute to the stability of the dynamic of which they are part (which I note at times in my analyses). But close consideration of how the aspects interrelate, and the coherences that result, is beyond the scope of this largely exploratory work of unpacking what aspects might even be involved. (Again, see Appendix C for an initial attempt to model one episode in this manner.)

Onto the Analyses

Recall that all individual analyses are grouped by focal teacher and can be found in Appendices D-F; a synthesis across the episodes for each teacher is also included. The studies in Chapters 4 and 5 foreground the comparison of dynamic stabilities supporting teachers' attention and responsiveness to the substance of students' scientific thinking. In Chapter 4, I make the case that current professional development efforts support teachers in attending and responding to student thinking within planned discussions or activities, but struggle to help teachers adapt their ongoing instruction in response to students' ideas that could take the classroom activity in unexpected directions. I examine two episodes – Ms. L's fox episode from September 2010, and Ms. R's crest episode from April 2010 – in which teachers altered their plans on the spot in ways that were responsive to students' ideas, with an eye toward informing professional development efforts to encourage this type of responsiveness. In Chapter 5, I compare Mr. S's attention and responsiveness to student thinking during the two key drop episodes from April 2010 and March 2011. Not only did the local coherences differ, but the attention itself progressed as Mr. S oriented to different forms of scientific knowledge in relation to students' explanations in each case.

Chapter 4: Exploring When Teachers Alter Plans in Response to Students' Unexpected Ideas in the Science Classroom

Within science and mathematics education, a consensus is emerging that a cornerstone of effective instruction involves attending and responding to the substance of students' disciplinary thinking (NCTM, 2000; NRC, 2007). Providing space for students to reason and converse about phenomena is consistent with learning theories that hold that learners construct their own knowledge out of their experiences (Piaget, 1970) and that language is often a mediational tool for such construction (Vygotsky, 1986). Moreover, as students construct their own explanations for phenomena, teachers can listen to those explanations and adapt their instruction accordingly; in other words, teachers can engage in disciplinary formative assessment (Coffey, Hammer, Levin, & Grant, 2011), which has been linked to enhanced student learning (Black & Wiliam, 1998) and engages students in assessing their own ideas according to various disciplinary criteria. Empirical work has also demonstrated that putting students' ideas and reasoning front and center in the classroom correlates with enhanced student conceptual understanding (e.g., Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Pierson, 2008) and engagement in disciplinary practices, such as argumentation and explanation-building in science (Berland & Reiser, 2009; Duschl & Gitomer, 1997).

Thus, it is critical to understand what attending and responding to the substance of students' disciplinary thinking looks like in the classroom and how we can support teachers in doing so. Several firsthand teacher-researcher accounts (Ball, 1993; Hammer, 1997) provide examples of instruction in which student thinking was at the front and center – where the teacher consistently strove to get a sense of the student's perspective (Levin, Hammer, & Coffey, 2009) and "give a child reason" (Duckworth, 2006, p. 86) when the child's meaning was not immediately obvious. For instance, in Ball's third-grade mathematics classroom, her primary aim was to teach mathematics in a way that was "intellectually honest" (p. 374) to her students. This aim focused her on what she called the "twin perils of responsiveness and responsibility" (Ball, p. 374) – she desired to teach in a way that both respected her students as mathematical thinkers and drew them in to the discipline of mathematics, including currently-accepted ideas, aspects of mathematical reasoning, etc. The classroom examples provided were rife with opportunities for students to share their ideas about mathematics problems and evidence that Ball attended to their ideas closely, as she recapped specific students' ideas in detail and described how she made sense of what they said. In fact, the dilemmas Ball highlighted in the paper *arose from* attending carefully to students' ideas and deciding how to respond in a way that respected both students and mathematics. Hammer's (1997) description of his high school physics teaching experiences was similarly focused on the tension between honoring student discovery and making sure students learned intended physics content. Again, this tension typically arose as Hammer listened to his students' ideas about physical phenomena and had to decide how to respond when what students discovered did not line up with what was intended.

This pair of firsthand accounts highlights several important points with respect to attention and responsiveness to the substance of students' disciplinary thinking. First, it is clear from these accounts that such teaching, in which students' ideas are taken seriously, is neither easy nor unproblematic – both teacher-researchers regularly confronted

decision points about what to do with the ideas they heard. In general, the kind of attention Ball (1993) and Hammer (1997) exhibited with respect to students' ideas is rare in American classrooms (NRC, 2007) and tends to be "brief and fickle" (Lau, 2010, pp. 290-291) or "episodic and fleeting" (Levin, 2008, p. 104) as teachers' attention is drawn to other considerations. Despite the importance of focusing on student thinking, we have relatively few extended classroom examples to consider.

Second, in Ball's (1993) and Hammer's (1997) accounts, there are two senses of what it means to be *responsive* to the substance of student thinking. The first involves teachers listening and responding to students' ideas within planned discussions or progressions of activities. This kind of responsiveness is evident in Ball's recap of a problem she posed to her third-grade students. The class was learning about negative numbers by using the model of a building with floors above and below ground, and they hit a wall with how to think about 6 + (-6) on the building. One student, Mei, proposed that the solution would be nine, and Ball invited Mei to "come and show us how you did that" (p. 389). As Mei laid out her solution, Ball indicated where she was not following:

> Mei: So when we put two in each group in order to make one because it's below zero.
>
> T: I don't understand this part – put two in each group in order to make 1 (p. 390).

In this example, Ball responded to Mei in ways that kept Mei's idea in the spotlight and attempted to clarify confusing parts of Mei's admittedly unorthodox solution. Within the bounds of the question posed about 6 + (-6), Ball demonstrated attention and responsiveness to students' proposed solutions. Hammer's account contains similar examples, including the opening exchange in which high school students were working on an electrostatics activity. The students had just found that a charged aluminum plate induces a charge on an aluminum-foil-covered straw, but not on a plastic straw:

> Greg: Because this [indicates the plate] is aluminum, right? And this [the foil-covered straw] is the same thing, and we've already proved that this [the plate] is charged.
>
> Teacher: OK.
>
> Greg: And if it's the same material, and it's touching, that whole thing should be charged, too.
>
> Teacher: Do you think if this [the plate] were plastic, then this [the plastic straw] would be charged?
>
> Greg: If this [the plate] was proved charged, and it was plastic.
>
> Teacher: So your idea is that, once any given kind of material, like if it's plastic, everything that's plastic that's touching it will be charged.

This exchange also contains evidence of Hammer responding to Greg's idea within the scope of the activity – first seeking to clarify his understanding of the scope of Greg's idea by asking about what would happen if the plate were plastic, then recapping what he heard. These examples illustrate a kind of responsiveness to students' ideas that may occur within a teacher's intended activity.

The second kind of responsiveness involves teachers altering plans in response to directions or ideas from students. Hammer, Goldberg, and Fargason (2012) have described this as "responsiveness at a coarse grain-size" (p. 58), in which teachers "adapt and discover instructional objectives responsively to student thinking" (p. 55). For instance, when Ball's (1993) class was discussing even and odd numbers, a student, Sean, described six as both even and odd because it was made of three groups of two. After deliberating overnight, Ball chose to legitimize Sean's idea and created a new category called "Sean numbers," defined as having "an odd number of groups of two" (p. 387). As students continued exploring even and odd numbers, they explored Sean numbers as well. Hammer (1997) also reported altering his plans in response to a discovery a student, Camille, made in class: "In charging an electrophorus, she noticed that if she held it very close to the charged foam plate, when she touched the electrophorus with her finger the foam plate would lift off the table" (p. 508). Hammer noted this was one of the discoveries the worksheet he was using intended, but not until later. Instead, he responded by calling the discovery "the *Marino phenomenon*" (Hammer, p. 508, original emphasis), after Camille's last name, and devoting class time to discussing why it occurred.

Both kinds of responsiveness demonstrate to students that their ideas are meaningful and worth discussing in the classroom. The primary distinction between the two senses relates to whose ideas or questions set the overall direction of the conversation – the teacher's or the students'. If students' ideas are allowed to impact or even drive the direction of classroom activity at times, students may be more likely to see their ideas as consequential for their own and others' disciplinary learning and themselves as able creators of disciplinary knowledge (Cornelius & Herrenkohl, 2004; Engle & Conant, 2002).

In this chapter, I argue that we know less about how to support teachers in this second sense of responsiveness, despite its importance in promoting a classroom environment in which students' ideas have consequence. I first review literature on professional development efforts focused on teacher responsiveness, illustrating how such efforts better support the first sense of responsiveness as compared to the second. This motivates a closer look at classroom episodes in which teachers altered their plans in response to unexpected ideas from students, resulting in extended discussions where the teachers attended and responded to the substance of students ideas in a relatively stable manner. Unpacking these examples sheds light on what initiates and stabilizes teachers in shifting their intended activity, with implications for professional development efforts aimed at supporting this kind of responsiveness.

Characterizing Professional Development Efforts Focused on Teacher Responsiveness

In this section, I review professional development efforts aimed at enhancing teachers' attention and responsiveness to the substance of students' disciplinary thinking. I describe how efforts primarily support teachers in setting up generative spaces and

listening to the student thinking evident in those spaces, at times in an iterative manner (e.g., Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Kazemi & Franke, 2004). Fewer efforts support teachers in adapting their instruction in light of ideas or questions students raise in ways similar to Ball (1993) or Hammer (1997) above.

Numerous Efforts Support the First Sense of Responsiveness

In general, professional development efforts aimed at enhancing attention and responsiveness to student thinking in the classroom focus on supporting teachers in setting up generative spaces for student thinking to be on display and listening carefully to the student thinking evident in those spaces (e.g., Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Fennema et al., 1996; Franke, Carpenter, Fennema, Ansell, & Behrend, 1998; Jacobs, Franke, Carpenter, Levi, & Battey, 2007; Kazemi & Franke, 2004). For instance, the Cognitively Guided Instruction (CGI) project initially centered its efforts on providing teachers with detailed information on children's thinking in domains like addition and subtraction and related problem taxonomies, as well as space to design instruction based on this information (Carpenter et al., Fennema et al.). Although CGI did not prescribe specific instructional practices, "teachers were asked [during the summer workshop] to plan a unit to teach during the following year, as well as a year-long plan for instruction based on principles of CGI" (Carpenter et al., p. 506). Evidence from teachers' classroom practice indicated that some teachers drew on the presented problem taxonomies to generate a variety of problems for students to solve (Carpenter et al., Fennema et al.), or used problems directly from the workshop (Franke et al.).

Later instantiations of CGI-related professional development turned to a workgroup model, in which teachers posed preplanned problems to their students and reported back to the group on students' approaches (Jacobs et al., 2007; Kazemi & Franke, 2004). When teachers struggled with eliciting and responding to students' ideas about the problems, facilitators described questions or tools teachers might use in interaction with students' ideas. One example of such a tool was a set of number sentence index cards that teachers created (in conjunction with each other and facilitators) to challenge students' algebraic understandings: "The idea was that teachers could use their index cards in their classrooms by presenting an initial number sentence, listening to their students' thinking, shuffling through their cards to determine an appropriate follow-up number sequence, and repeating the process" (Jacobs et al., p. 271). Such supports were intended to help teachers respond to students' ideas with appropriate follow-up questions.

Other professional development efforts involve teachers in the study of classroom artifacts, either video or student work, "to encourage teachers to develop the dispositions to value and inquire into students' mathematical thinking as a regular part of their classroom practices" (Goldsmith & Seago, 2011, p. 185). A notable example of this approach is Sherin and van Es's work on video clubs (e.g., Sherin & van Es, 2009; van Es, 2011; van Es & Sherin, 2008, 2010). In the clubs, videos from participating teachers' classrooms were shown and discussed, with an eye toward helping "teachers learn to notice and interpret students' mathematical thinking" (van Es & Sherin, 2008, p. 248). To this end, facilitators asked questions that focused teachers' attention on the details of what students were saying in the videos and requested evidence for claims teachers made about student understanding. Although "there were no explicit conversations in the video

clubs concerning how to take the information discussed in any given meeting 'back to the classroom'" (Sherin & van Es, p. 32), teachers reported that they became more aware of students' ideas in their own classrooms. Classroom observations demonstrated that over the course of participating in the video clubs, some teachers pursued and attempted to make sense of students' ideas while teaching (Sherin & van Es; van Es & Sherin, 2010). Furthermore, some teachers' self-reports suggested that they began to alter their instruction in ways that were responsive to students' ideas; for example, "Drew further explained that he found himself adapting his teaching based on the information students provided about their mathematical understandings and any difficulties he observed" (van Es & Sherin, 2010, p. 168).

Yet what is underdetermined in such reports is the nature of the adaptations and how they interrelate with students' ideas. For instance, such adaptations may involve minor changes to questions the teacher was already planning to ask, as noted in Fennema et al.'s (1996) description of sophisticated CGI implementation: "Sometimes decisions were made during instruction. Sometimes a problem was modified because the teacher perceived it was too easy or too hard for many of her students" (p. 418). This kind of alteration is adaptive to student thinking, but in a way that maintains the teacher's intended direction. Even as CGI teachers decide what problems to pose to students based on how students grappled with previous problems, basing their ongoing instruction on students' ideas, the direction is still ultimately the teacher's.

The second kind of responsiveness evident in Ball (1993) and Hammer (1997), in contrast, takes more account of directions arising *from* students, following up on ideas or questions they pose. Note that this second sense of responsiveness often follows from the first – changing the intended activity to take students' ideas into account requires attending to their ideas in the first place, often in the context of a planned discussion[11]. I now turn to a professional development project explicitly attempting to promote *both* senses of responsiveness.

Fewer Efforts Support the Second Sense of Responsiveness

A noteworthy professional development effort that distinguishes and explicitly promotes both senses of responsiveness is the Learning Progressions (LP) project (see Hammer, Goldberg, & Fargason, 2012; Lineback, 2012; Maskiewicz & Winters, 2012). The focus of the project is studying teachers' and students' learning progressions with respect to scientific inquiry in the classroom. Workshop activities included engaging teachers in their own scientific inquiry and watching videos from classrooms with an eye toward unpacking the student thinking evident. While watching videos, facilitators hoped to encourage "teachers to recognize the potential merit of students' ideas and help them create lists of potential instructional 'next moves' grounded in those ideas" (Lineback, p. 32). In other words, facilitators promoted both senses of responsiveness – attending and

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[11] This posed an issue for a professional development project originally focused on teachers' modifications of curriculum (Lau, 2010; Levin, 2008). Project staff wanted to explore modifications that were responsive to student thinking, but the dearth of such modifications led to a change in the focus of the project – "helping teachers develop their skills for attending to and making sense of student ideas" (Lau, p. 72).

responding to what students offered, as well as letting students' ideas drive the direction of classroom activity moving forward.

This dual sense of responsiveness was also recognized and built into the curricular materials developed by the LP project. As Maskiewicz and Winters (2012) described:

> One 15- to 2-hour modular unit per grade level (Grades 3-6) was developed by our research group to provide teachers a generative context that would facilitate teacher responsiveness to students' scientific thinking… The modules consisted of an opening question and several possible follow-up questions that would allow space for students' ideas and reasoning to become explicit and be considered, investigated, and expanded upon by those in the classroom community (p. 435).

On one hand, the idea of designing a "generative context" with an "opening question" is similar to approaches taken in professional development projects described previously (e.g., CGI) – it sets up a space in which students may contribute ideas and teachers may attend and respond to those ideas. On the other hand, the LP modules also go beyond promoting this first sense of responsiveness by providing "possible follow-up questions" that reflect directions students might go while remaining open to unanticipated directions. Hammer, Goldberg, and Fargason (2012) described this as a "menu of possibilities, from which the teacher could choose depending on what has been taking place" (p. 69) and highlighted this sort of adaptability at the level of the activity as a critical feature of a responsive classroom: "Both the moment-by-moment and day-by-day decisions the teacher makes in a responsive classroom are determined by what she hears and how she interprets the ideas and reasoning of her students" (p. 69). Researchers continue to study how various teachers in the project implemented the modules in their classrooms and, to a lesser extent, what impacted their implementation.

I aim to complement these ongoing research efforts by unpacking extended classroom episodes in which teachers engaged in this second sense of responsiveness, focusing on what initiated and sustained teachers in shifting their intended activity in response to students' ideas. I next provide information about the context, selection, and analysis of the episodes before turning to the analyses themselves.

Theoretical and Methodological Underpinnings

Here, I situate the extended classroom episodes in the context of the broader professional development project and dissertation of which they are part. I briefly describe how I selected the range of episodes I analyzed for my dissertation work, then identify several episodes that exemplified the second sense of responsiveness. Finally, I discuss the approach I took toward understanding what initiated and sustained teachers' responsiveness in those episodes.

Context of Professional Development Project and Focal Teachers' Schools

The data for this study come from a professional development project aimed at helping fourth through eighth grade teachers promote inquiry teaching and learning in their science classrooms. Teachers voluntarily apply and may continue in the project for multiple years. As part of the project, teachers attend a two-week summer workshop in

which they engage in their own minimally-guided inquiry, watch classroom video of students discussing scientific phenomena, and collaborate on other issues related to inquiry teaching and learning in the classroom (i.e., assessment, lesson planning, etc.). During the school year, teachers work one-on-one with members of our research team to facilitate scientific inquiry in their classrooms and attend bimonthly small group meetings with other teachers and members of the research team. Many of our early project activities centered on coming up with generative inquiry questions to pose to students and discussing how students responded, but over time, we sought to support teachers in both senses of responsiveness. We increasingly focused on brainstorming and evaluating possibilities for where teachers might go next, given the ideas on the table. We also explored ways of building lessons out of students' ideas or questions. The point here is not to claim that our focus on the second sense of responsiveness had an impact on teachers' classroom practice, but rather to acknowledge that this sense was something we were aware of and interested in promoting.

Context of My Dissertation Work

My dissertation draws on project data to explore what might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking in sustained classroom episodes. Although attention to student thinking is generally rare (NRC, 2007) and fleeting (Lau, 2010; Levin, 2008), there are teachers who devote a substantial amount of class time to understanding and exploring students' ideas. My aim was to get a sense of how and why they do so by focusing on the classroom practice of such teachers across a range of extended examples.

To that end, I focused on the teaching of three focal teachers in their fourth year of participation in the project. Our research team identified these teachers as participants who consistently facilitate rich student discussion around scientific phenomena in their classrooms, many of which we have videotaped. Thus, these teachers were not intended to be representative of teachers in the project or more broadly; rather, they served as exemplars from whom I felt I could learn more about attention and responsiveness to student thinking in the classroom. More about the teachers' positions and school contexts can be found in Table 4-1.

Table 4-1

Focal Teachers' Positions and School Contexts

Teacher[12]	Position	Demographic Data from 2009-2010[13]
Ms. L	Started teaching in 1996, fifth grade at an elementary	Student body approximately 75% African American, with 30% receiving free and reduced lunch. School has English for Speakers of Other Languages

[12] All teachers' and students' names are pseudonyms. Real names are provided for members of the research team.
[13] All statistics come from publicly available 2009-2010 demographic data, not directly cited to protect the anonymity of the schools.

	school	(ESOL) program.
Ms. R	Started teaching in 2003, sixth grade at an elementary school	Student body approximately 50% Hispanic and 40% African American, with 50% classified as limited English proficient (LEP). School categorized as Title I.
Mr. S	Started teaching in 1998, seventh grade at a middle school	Student body approximately 65% Hispanic and 30% African American, with 35% classified as LEP. School categorized as Title I.

I selected three classroom episodes for each teacher from their first two years of participation in the project in which the teacher's focus was relatively stably on students' ideas. Given that teacher attention and responsiveness is enmeshed in a complex dynamic involving teachers' own manifold knowledge and orientations (e.g., Schoenfeld, 2011), interactions with students (e.g., Maskiewicz & Winters, 2012), institutional mandates (e.g., Levin, 2008), and other factors, and may vary over short timescales (see Lau, 2010), any relative stability in focus is something to be explained. My criteria for episode selection are more fully described in Chapter 3, but I briefly outline them here. An episode needed to be extended in duration (on the order of ten minutes or so) and exhibit potential distractors from a focus on student thinking, such as classroom management issues. If in that context, the majority (over 50%) of the teacher's speech turns over the course of the episode demonstrated responsiveness to the substance of students' scientific thinking, the episode was retained for consideration. Table 4-2 reflects types of potentially responsive utterances, drawn partly from recent work focused on attentive and responsive teaching (e.g., Brodie, 2011; Lau, 2010) and partly from my own reflections on such teaching (indicated by the designation "original category"[14]). The examples provided are all from selected episodes. Note that interpretation of such utterances depended on how they were deployed and taken up in context. If I was unsure about the responsiveness of an utterance, I took a conservative approach and simply did not include it in my count.

Table 4-2

Descriptions and Examples of Potentially Responsive Utterances

Description	*Example from Selected Episode*
Acknowledging attempts to answer – acknowledging a student's attempts to answer a question, especially in the face of continued questioning (original category)	S1: Why did the meteor shower only hit the females and not the males? S2: It only hit, it hit both of them, but, um, some of them stayed, some of them were still there. … S3: How come they only killed all the females, not all the males?

[14] See Appendix A for descriptions of these original categories.

	T: Okay, he just tried to answer that question.
Altering activity – changing the activity or broadening its scope in response to a student's idea (original category)	S1: I say maybe we put one part of the magnet in the water, and the other like maybe a little bit higher, so there's still a lot amount of space? … T: If you want to try it- and then try it the way S1's suggestion, with one underwater and one not.
Attempting to elicit when little evidenced – consistently attempting to elicit student thinking when little is in evidence (Levin, 2008)	T: Any arguments against that? S1: No. S2: No, sir. … T: Who thinks that this ((points to board)) is not a good idea?
Attempting to hear – consistently attempting to hear the entirety of a student's idea when it is difficult to do so (original category)	S1: Uh, walk past it kind of fast and then – test if it'll go- T: Hold hold hold, hold on. On the outside, everybody, including S2, we are in the listen-only mode. Okay? Um, and inside, we're one at a time. S3: I have a question. T: Uh, just hold on, just hold on. Uh, S1, what did you say now?
Clarifying scenario – clarifying the question or scenario under discussion in response to a student's question or comment (original category)	S1: So like, are you walking right by the trash can, or are you walking, stopping, and then- T: I'm walking right by the trash can.
Confirming – ensuring a student's idea was heard correctly (Brodie, 2011)	S1: Because if the wind is working in a different direction than you, you're running and () ((moves one hand forward and the other in the opposite direction on top)). T: So when you, when you're saying, when you're running fast, there's some pressure coming up against you, coming against you?
Countering – providing or asking for a contradiction/counterclaim to a student's idea (as long as the student's idea is still the primary focus) (Pierson, 2008)	S1: If you're running, you feel like the wind is pushing you back. … T: What are some arguments against this ((points to board)), this idea that there's air pushing back or there's something pushing back?
Eliciting – trying to get something specific from a student that relates to his idea	S1: Wouldn't it make it go down because it's heavier?

(Brodie, 2011)	T: … What force will cause it to go straight down? What force will cause it to go straight down?
Identifying differences – identifying differences between students' ideas (Lau, 2010)	S1: Maybe it's because of their fur color. … S2: But then the difference between a coyote and a wolf, um, they have different colors, but they're still in the same group. T: Yeah, so that would sort of – argue against that.
Identifying similarities – identifying similarities between students' ideas (original category)	S1: So you gotta do- have you noticed that when you try to do it at that time when it's there, it doesn't work out if you do it after? But then when you do it before, it gets to the little thingie () get it. So it's related to this. T: So yours is similar to what S2 said a little while ago about timing.
Inserting – adding something in response to a student's idea, building on a student's idea by providing examples or illustrations (Brodie, 2011; Lau, 2010; Pierson, 2008)	S1: Oh wait no, it's gonna fall (). T: It's gonna fall over here ((points to board)). So it's gonna go straight down on an angle ((writes on board)).
Maintaining – keeping a student's idea in the public realm by repeating it, asking the student to repeat it for emphasis, or other moves (Brodie, 2011; Pierson, 2008)	S1: I have a question. Doesn't it start as liquid because when the snow falls down, it's liquid- I mean, liquid, but then it starts to form into a solid. … T: So now, S1's brought in the idea that, you know, maybe there's just- did that snow that they're, didn't it start off as water up there?
1. Reflecting – throwing a student's idea out for the class to consider, a "reflective toss" (van Zee & Minstrell, 1997)	S1: Gender… if there's more girl foxes than boy foxes- T: Than boys? But – um, anybody have a response to that? About it maybe being gender that the foxes were dropped?
2. Revoicing – aligning a student's idea with specific academic content or tasks (O'Connor & Michaels, 1993)	S1: When you put a magnet and magnet together, there's sometimes a force in the middle of them, and it won't, it won't ((moves fists together and apart)), it won't stick. T: So S1's talking about sometimes when you put magnets together, they're- you feel them resisting. It's like they're pushing each other apart, aren't they?
Pressing – probing a student for more on	S1: The weight of the keys.

his idea, asking a student to clarify or elaborate on his idea (Brodie, 2011; Lau, 2010; Levin, 2008; Pierson, 2008)	T: ((faces board, writes)) The weight. What's, say a little bit more about the weight. What is it about the weight?
Returning to idea later – returning to a student's idea at a later time (Lau, 2010)	T: Now somebody said yesterday, after would be better. Why after? There are a couple- I remember S1 said after.

Other criteria included retaining the earliest videotaped episode from each teacher's classroom, selecting other episodes that either exemplified characteristic aspects of teachers' classroom practice or formed natural contrasts with each other, and ensuring I had reflections from the teacher proximal to the episode to facilitate my understanding of what happened. Table 4-3 contains brief descriptions of all selected episodes in my dissertation[15].

Table 4-3

Descriptions of All Selected Episodes

Teacher	*Date*	*Description*
Ms. L	April 2010	Fifth-graders discussing a student's question about whether magnets work underwater and how they might test this scenario
Ms. L	**September 2010**	**Fifth-graders discussing why a fox is classified in a different genus than a coyote and a wolf**
Ms. L	*February 2011*	*Fifth-graders discussing whether snow is a solid or a liquid, in the context of a lesson on melting*
Ms. R	**April 2010**	**Sixth-graders discussing what counts as a crest in a wave**
Ms. R	September 2010	Sixth-graders discussing what makes something sink or float
Ms. R	April 2011	Sixth-graders discussing their own intuitive definitions for energy
Mr. S	April 2010	Seventh-graders discussing where you would drop keys to get them to land in a certain location as you're walking
Mr. S	January 2011	Seventh-graders discussing how dinosaurs became extinct
Mr. S	March 2011	Seventh-graders discussing where you would drop keys to get them to land in a certain location as you're walking (again!)

Note. Bolded episodes will be analyzed in depth in this chapter. The italicized

[15] For full transcripts of all selected episodes and explanations of how they fit my selection criteria, see Appendices D-F. Analyses are also included.

episode will be used for contrast.

Episodes Exhibiting the Second Sense of Responsiveness

Two of the nine episodes (in bold in Table 4-3) exemplified the second sense of responsiveness in that the discussions that occurred were not preplanned – they emerged from students' contributions[16]. In both cases, the teacher had been planning to review material, and discrepancies or questions from students emerged and were taken up. In contrast, in the February 2011 episode from Ms. L's classroom (in italics in Table 4-3), Ms. L demonstrated and described tension in taking up a debate that emerged among students. This episode provides an interesting point of contrast with the September 2010 episode from Ms. L's classroom.

Analytical Approach

My analytical approach to unpacking what might have initiated and stabilized teachers' attention and responsiveness to the substance of student thinking in extended classroom episodes draws on notions from dynamic systems (Thelen & Smith, 1994), interaction analysis (Jordan & Henderson, 2005; Stivers & Sidnell, 2005), and work on learners' framings of their activity in physics classes (Frank & Scherr, 2012; Hammer, Elby, Scherr, & Redish, 2005). Consonant with perspectives on dynamic systems, I take a relative stability to be a self-assembly of various factors and their interactions, from which the state of interest (i.e., teacher attention and responsiveness to student thinking) emerges. To use Thelen and Smith's (1994) language, a relative stability is an area of "tight coordination" (p. 68); Hammer et al. (2005) might describe it as a local coherence that often involves contextual influences. In other words, a stable state emerges from the activation and interrelation of multiple aspects or elements that coalesce into a coherence or intersecting coherences. This conceptualization of stability draws my attention, first and foremost, to searching for aspects or elements that might contribute to or support the emergence and continuation of a stable state.

To do so, in each episode I attended to what was co-occurrent with the teacher's attention and responsiveness to student thinking and salient in some way to the teacher. Co-occurrence means that a given element was present with the focus on students' ideas – similar to Conlin, Gupta, and Hammer's (2010) notion of "clustering" or "hanging together" (p. 278), which they took as one kind of evidence of coherence. Moreover, if a co-occurrent element was also salient to the teacher in some way, I considered it more likely to be active in the dynamic, drawing on an intuitive sense that significant events tend to be more influential than insignificant events. Finally, if the element plausibly stabilized or was in a mutually reinforcing relationship with the focus on students' ideas, that served as the strongest evidence of its involvement in the local coherence(s). This

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[16] To be clear, the second sense of responsiveness can include instances that are less drastic in nature, such as following students' reasoning in a discussion when it turns from the initial purpose or question the teacher set out. In this beginning, exploratory work, I chose to focus on more clearcut instances – discussions that *came into existence* due to what students offered.

approach is similar to how Frank and Scherr (2012) studied a sustained pattern of student reasoning – they identified co-occurring elements (contextual cues on a worksheet, other ideas students raised) that students attended to and that plausibly contributed to the reasoning.

In terms of my analytical process, I began by considering evidence from the episode itself first. Specifically, I drew on tools from interaction analysis (Jordan & Henderson, 2005; Stivers & Sidnell, 2005), including both verbal and nonverbal communicative cues, to identify what seemed salient to the teacher in the episode. I considered something to be salient to the teacher if the teacher spent an extended period of time attending to it, repeatedly referred to it throughout the episode, and/or displayed an affective response to it (i.e., heightened pitch, raised eyebrows, etc.). Coordinating these multiple types of evidence strengthened my claims of salience, as the "communicative work that is performed by one modality may be… extended [or modified] by the work of another modality" (Stivers & Sidnell, p. 6). Such evidence from the classroom allowed me to identify what was salient to the teacher in the moment, even if the teacher was not consciously aware of it.

Then, I layered on additional data sources to gain more insight into the teacher's perspective on the episode. These data sources included recordings and field notes of debrief conversations with teachers shortly after the episodes, recollections shared at teacher meetings, semi-structured stimulated recall/reflection interviews (Lyle, 2003) in which we watched and discussed video of the episodes together, and teachers' written feedback on my preliminary analyses. Such data sources provided additional information about what may have been salient to the teacher during the episode, but not visible to an observer. I used the same types of evidence to identify salience in these settings, and I iterated between analyzing the episode itself and these settings to saturate my sense of what was salient to the teacher in the episode. To be clear, claims of salience were grounded in evidence from the episode *and/or* reflections on the episode, with the strongest evidence coming from agreement between the two.

I also considered whether and how these salient elements interacted with the teacher's attention and responsiveness to students' scientific thinking. To remain a hypothesized part of the local coherence(s) supporting attention and responsiveness to student thinking, there had to be at least one way in which the element reinforced or stabilized the focus on students' ideas. I acknowledged when there was evident variability in whether the element supported or detracted from this focus.

Analyses

I now turn to Ms. L's September 2010 episode and Ms. R's April 2010 episode – the two episodes in my dissertation data corpus in which the discussion emerged in the moment from student contributions. I first explore what might have initiated and stabilized Ms. L's responsiveness to students' ideas in the September 2010 episode, contrasting this with the February 2011 episode in which Ms. L experienced tension between maintaining the direction she wanted to pursue with students and being responsive to a direction that emerged from their ideas. I then explore what might have initiated and stabilized Ms. R's responsiveness to students' ideas in the April 2010 episode before synthesizing across the episodes.

Unpacking Ms. L's Discussion of Why the Foxes Got Dropped

The September 2010 episode took place at the beginning of Ms. L's second year in the project. The class was in the midst of a unit on classification. Ms. L was reviewing the idea that as we move from kingdom down to species, the groups of organisms get smaller, but what we know about the organisms gets larger. She used the following diagram from the textbook (see Figure 4-1) to illustrate this point, moving sequentially from the top of the diagram toward the bottom:

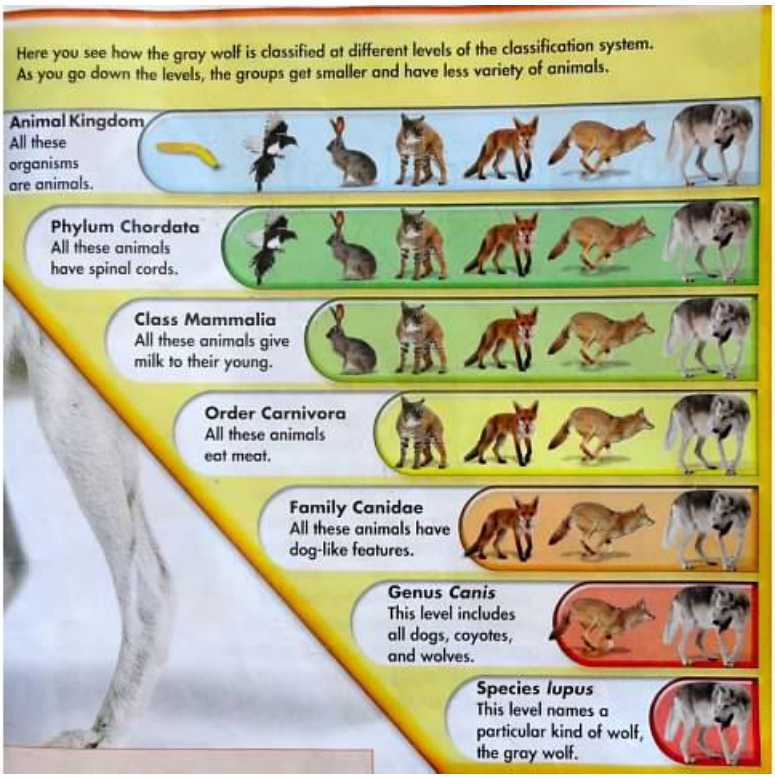

Figure 4-1. Textbook classification diagram in question during September 2010 Ms. L episode.

At each level, the textbook explained why given organisms were still included in the group; for instance, all of the animals in "Order Carnivora" eat meat. However, at "Genus *Canis*," the textbook simply listed the organisms included. Discussion ensued when a student, Albert, asked why the fox was no longer included at this level. The full transcript of the discussion can be found in Appendix D – here, I summarize the discussion in narrative form.

After Albert asked why the fox was no longer included, Ms. L indicated that would be an interesting thing to think about. Students offered that the fox must not be as closely related and looked more cat-like than the other organisms (the coyote and the wolf). Ms. L wondered what trait separated the fox from the other organisms and started to write this on her "questions for later" board – a place where she recorded questions students raised to return to later. However, she quickly changed course and asked students to consider in real time why the fox was dropped. Students offered a variety of

ideas, including restatements that the fox was dropped and traits that distinguished the fox from the other organisms (fur color, size, habitat, behavior, etc.). After this extended discussion, Ms. L turned the question into a bonus homework question that students could research on their own and returned to her planned lesson about invertebrates, in which students determined the characteristics of worms and arthropods using their textbooks for reference.

Upon reflection at a teacher meeting shortly after the episode, Ms. L identified that she had not noticed this lack of explanation in the textbook until Albert's question:

> Ms. L: I didn't even notice this ((points at book))… it was one of the kids who brought this up, and then I went like, yeah, wait a minute, I get this ((points at class level)), and I get this ((points at order level)), and I get this ((points at family level)), but I don't get that ((points at genus level)). I don't know what's going on at that step [Meeting, October 2010].

Thus, the discussion that ensued was unplanned and emerged from Albert bringing his observation to public awareness during class. Below, I list several salient aspects of the discussion that likely initiated and stabilized Ms. L's responsiveness in this setting, providing evidence of these aspects and how they interrelated with Ms. L's attention and responsiveness to students' ideas:

- Alignment between the question and desired content understandings
- Interest in figuring out the answer
- Sense that students were into the discussion

Alignment Between the Question and Desired Content Understandings

A brief point to note is the alignment between the emergent question at hand – why foxes got separated from coyotes and wolves – and the more general focus of the classification unit. During the unit, Ms. L repeatedly tried to convey that classification occurs for a reason, and how and why organisms are classified depends on their traits. In an interview, she identified the fox discussion as "so relevant to what we were doing" [Interview, October 2012] with the larger topic of classification. This connection can be seen in the classroom episode as well when Ms. L reminded students, "We've been doing traits, and we know that when we classify, it's gotta be for a reason, right?" [Episode, September 2010]. It is likely that as students started proposing traits that might be distinct between the fox and the other organisms, Ms. L noted that they were reasoning about classification, which further promoted her attention to their ideas, and so on.

Furthermore, she worried about what might have happened if she did not pursue Albert's question:

> Ms. L: And I just thought we would, it would, you know, that would be like, well, just accept my word for it, guys, there's some reason- when the whole point is we were trying to figure out the reasons [Interview, October 2012].

By not following up on the question, Ms. L thought students would have to rely on her authority rather than make sense of the situation for themselves – and as she said, "the

whole point" of the unit was for students to see the logic in classification. This also played out in the episode when Ms. L pushed students to think beyond what the textbook said. For instance, a student, Luciano, simply read what the book stated about the genus level and how foxes were not part. Ms. L acknowledged what he said but also clarified that "what we're trying to figure out is what trait they were using" [Episode, September 2010]. Later, another student, Randy, stated that the genus level has coyotes and wolves, and Ms. L again acknowledged this but tried to get students to think about the *reason* the fox is no longer included. During the interview, Ms. L articulated what concerned her about this approach on the part of the students:

> Ms. L: They're just stuck on, it's almost like how they regard authority. It was like they're gone because the chart says they're gone.
>
> Jen: Gotcha.
>
> Ms. L: Yeah, that's alm- that's how I felt they were doing it. They, they still, a lot of them still weren't really thinking. They were like, well, they're gone because that's what the book says [Interview, October 2012].

Ms. L interpreted responses like Luciano's and Randy's as literal appeals to the authority of the textbook. While she acknowledged those responses, she responded by pressing students to think about *why* the fox would have been dropped at the genus level. In other words, responses that did *not* address why may have also stabilized Ms. L's attention and responsiveness to student thinking during the episode; these were often moments in which she pushed and listened for more from her students.

In contrast, in Ms. L's February 2011 episode, she perceived a tension between her desired content objective and a debate that emerged among students. Just before this episode, Ms. L had students share observations they had made about the remnants of a recent snowfall, intending to connect their observations to melting. Specifically, Ms. L wanted students to see snow as a solid that could melt:

> Ms. L: So what do we mean by melt then, specifically? In, in science, melting – if everybody's agreeing if I put the snow in my hand, and let it sit there, and it turns into a liquid, we- would we all agree that's what we call melting?
>
> Students: Yes.
>
> Ms. L: So in scientific terms, what has happened to the snow that was in my hand? It's gone from a what to a what?
>
> Students: Solid to a liquid [Episode, February 2011].

Yet students expressed varying opinions on whether snow really *was* a solid, which Ms. L initially attempted to minimize in order to communicate her point about melting, but later took up as a question to pursue. In an interview, Ms. L positioned these as two different directions, stating, "I think I was struggling with myself in the moment trying to

think of which way we should go with this conversation" [Interview, October 2012] and indicating that she felt pulled between "the content that I was trying to cover, and… [what] could have been a totally good question on its own. Like, you know, are ice and snow both solids?" [Interview, October 2012]. This example further demonstrates the relevance of alignment between emergent directions from students and what Ms. L hopes for them to understand – Ms. L quickly altered her plan to allow space for discussion of students' ideas in the September 2010 episode when she perceived the two as aligned, but did not do so as quickly in the February 2011 episode when she perceived the two as in tension with each other. Note also the difference in the nature of the "content" Ms. L promoted in each case – the September 2010 episode centered on the purpose and process of classification, whereas the February 2011 episode centered on the scientific definition of melting. The content itself was much more expansive in the September 2010 episode, including conceptual knowledge about classification as well as more epistemological considerations of how and why scientists choose to classify organisms in the ways they do. In the February 2011 episode, the relevant content was primarily conceptual knowledge about melting.

Interest in Figuring Out the Answer

One of the most salient aspects throughout this discussion was Ms. L's own interest in figuring out the answer to the question. Looking more closely at Ms. L's participation during the episode, there is evidence that she did not know the answer to Albert's question. Her immediate response was "I'm not exactly sure why the foxes get dropped out at this point" [Episode, September 2010], and she reiterated not being sure about why the foxes got dropped seven other times during the discussion. She referenced a "mystery trait" [Episode, September 2010] that must be in play.

What is particularly noteworthy is that this confusion seemed motivating for Ms. L rather than stifling. Immediately after saying she did not know why the foxes got dropped, she acknowledged, "That would be an interesting thing to think about" [Episode, September 2010]. Ms. L repeated that the question was interesting three other times early in the conversation, with her raised pitch at one point – "So that, th::at's an int::eresting question…" [Episode, September 2010] – suggesting that she was enthused by the question and the possibility of pursuing it with her students. During an interview, she excitedly recalled her confusion:

> Ms. L: I had NO idea! It was fun::ny, I just hadn't even ever really tho::ught about it. I'm not sure I ever really no::ticed it – that closely. And, but we were trying to work our way down ((mimics moving through diagram)) through o::ne, and it was like ((sits back with furrowed brow and pursed lips)) – why is this- I, I had NO idea. It was so cool! [Interview, October 2012]

In this statement, Ms. L indicated twice that she "had NO idea" why the foxes got dropped and appeared puzzled as she described working her way through the diagram. Furthermore, the emphatic way in which she described this experience and her tagging of it as "so cool" indicated that not only was she okay with not knowing something, but she was actually enthused by the idea of exploring the topic. As she wrote in her feedback on

my initial analysis of this episode, "I LOVE authentically trying to figure stuff out with the kids" [Feedback, January 2013].

Indeed, Ms. L's participation in the discussion suggested that she was actively processing students' ideas and often referencing her own thinking in conjunction. For instance, when a student, Shavonne, suggested that coyotes and wolves look more like regular dogs, Ms. L agreed but indicated she wasn't sure what she was attending to that made her think that: "Yeah… in appearance they do look more like a regular dog, don't they. Um, I'm not sure I can pinpoint exactly what it is that makes them look more doggy" [Episode, September 2010]. Similarly, when a student, Latrisha, offered that fur color might be relevant and another student marshaled a counterargument against this idea, Ms. L indicated that the idea of fur color sparked her thinking about a different fur characteristic: "When Latrisha said fur, there – there might be something about a – fox's fur that is a little bit different. Something popped in my- see if you guys think of it" [Episode, September 2010]. Ms. L brought up the silkiness of the fox's fur later in the discussion. Thus, in striving to figure out why the foxes got dropped, Ms. L iteratively attended and responded to students' ideas as possibilities to consider and sparks for her own thinking on the matter. Her rhetoric in describing the discussion at a teacher meeting shortly thereafter reiterated that she and the students were in it together:

> Ms. L: We were looking at this chart, and it was neat because this was like taking the grey wolf and working your way down. And so, like, it made sense here, we dropped out, you know, these are animals, vertebrates, and every time the kids, we could understand the characteristic that was being used… and then all of a sudden, here they just drop it, and their explanation is just that this group just includes the-
>
> Ayush: Huh.
>
> Ms. L: And they don't really give a-
>
> Jen: Say why.
>
> Ms. L: They don't say why, and so the one kid said so, so why do they do it there? And then we were all I don't know why, I don't know why the fox goes one way and the others, so it was pretty cool [Meeting, October 2010].

In this description, Ms. L included herself with the kids, stating that at first "we could understand the characteristic that was being used," but when the fox got dropped, "we were all I don't know why." Her repeated use of "we" indicates that she and the kids were striving to figure it out together.

This feature of the September 2010 episode, again, contrasted with the February 2011 episode. While reading my initial analyses of episodes from her classroom, Ms. L recognized certain parallels and distinctions between the two:

> Ms. L: I realized [the February 2011 episode] was similar to the fox in that I wasn't sure of how to distinguish the states of ice and snow from one another, so

> it was definitely an authentic question for me, and one that I had not anticipated, like the fox. But in this episode, I didn't jump on it the way I did with the fox, but did acknowledge it. Trying to think WHY… in my heart it might have had to do with my level of interest and comfort with the topic. Life sciences are much dearer to me than chemistry, so I'm wondering if this affected how I reacted, subconsciously? [Feedback, January 2013]

Although this account was retrospective and almost certainly influenced by reading my analyses, Ms. L acknowledged the role that her own interest in a topic might play in her pursuit of continued discussion and posited it as a difference between the episodes. In conjunction with the evidence above of her demonstrated interest in the fox question in real time and upon reflection, it is likely that her "level of interest and comfort with the topic" did play a role in how readily she responded by delaying her intended activity in favor of addressing Albert's question[17].

Sense That Students Were Into the Discussion

Yet Ms. L's decision to address Albert's question was not absolute from the beginning of the episode. An interesting shift occurred between Ms. L adding the question to the list of questions for later and resuming the conversation in real time. Upon watching this section of video more closely, I noticed that students still had their hands up as Ms. L wrote the question on the "questions for later" board. Additionally, students continued discussing the question, including a student, Daria, who talked directly to Ms. L as she wrote on the board. Thus, Ms. L's decision to continue the conversation was probably influenced by students continuing to talk about the question.

In an interview, Ms. L corroborated this interpretation:

> Jen: It seemed, you know, for a minute that it was going up on the questions for later, maybe to be-
>
> Ms. L: Yeah, and then we, it was just too clear that everybody was really into it… I think we were just trying to get through all this stuff today, that day, and it just was too cool to pass on… I had no idea, and they seemed to be coming up with these great ideas, and they really seemed to be very interested in it [Interview, October 2012].

Here, Ms. L explicitly tied her decision to continue discussing the question to student interest in the topic. Additionally, her attention to students' ideas may have supported their continuing interest, as they saw that she was interested in what they were saying.

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[17] An open question at this point is what Ms. L meant by "comfort with the topic," as her not knowing the answer to Albert's question did not stifle her sense-making pursuit with students. The distinction she made between "life sciences" and "chemistry" suggests that how she categorizes a given question, disciplinarily, might influence whether she feels comfortable delving into inquiry on that question. More data would be needed to confirm or disconfirm this hypothesis.

Ms. L also reiterated that she did not know the answer to the question, so students' "great ideas" may have helped her make sense of the situation herself. Regardless, students being motivated to discuss a topic came up in relation to every selected episode from Ms. L, including the February 2011 episode, indicating that her responsiveness may be closely tied to such evident interest from students.

Interactions Among Identified Aspects

The identified aspects in this case – alignment between the question and desired content understandings, Ms. L's interest in figuring out the answer, and a sense that students were into the discussion – are mutually consistent and likely mutually reinforcing, further stabilizing the dynamic. For instance, as Ms. L expressed interest in the question Albert asked, students' interest might have been piqued, supporting their offering of ideas. As Ms. L saw students offer ideas that were in line with what she wanted them to understand conceptually and epistemologically about classification and that furthered her own thinking on the question, and as she noted their level of interest, her level of interest might have continued to increase – begetting even more student interest and ideas. In other words, in addition to interactions between the identified aspects and Ms. L's attention and responsiveness to student thinking, there are likely amplifying interactions among the identified aspects themselves that enhance the stability of Ms. L's attention. Although this discussion is largely theoretical, it is a plausible way of understanding the stability of Ms. L's attention and responsiveness to students' ideas in this episode.

Unpacking Ms. R's Discussion of What Counts as a Crest

The April 2010 episode took place during Ms. R's first year in the project. The class was learning about types and properties of waves and briefly reviewed the differences between transverse and longitudinal waves before moving onto the day's activity. Ms. R laid a jumprope on the floor in the center of the classroom and had a student, Keven, hold one end still while another student, Horacio, shook the other end of the rope to create a wave. When the student shook the rope at a steady rate of once per second for ten seconds, students agreed that the resulting wave had one crest. Then the student shook the rope faster, at a steady rate of twice per second for ten seconds. Figure 4-2 depicts the wave that resulted.

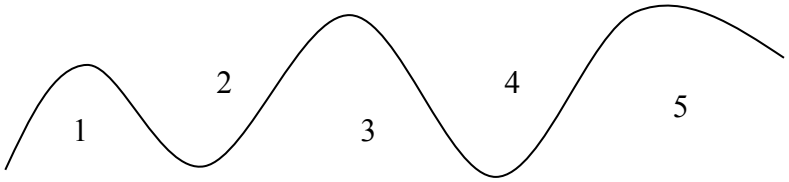

Figure 4-2. Schematic of jumprope on floor of Ms. R's classroom during April 2010 episode, with crests and troughs numbered for reference purposes.

During an interview, Ms. R noted that "the rope thing is in the textbook" and indicated that the purpose "was really just to count wavelengths, but it turned into something else

from here" [Interview, December 2012]. One wavelength is the distance from crest to crest (or trough to trough), so Ms. R asked students how many crests there were in the wave in Figure 4-2. Discussion ensued when students provided numerous unexpected answers to Ms. R's question. The full transcript of the discussion can be found in Appendix E – here, I summarize the discussion in narrative form.

Students initially called out different numbers of crests, and Ms. R had several students come up to the jumprope and point to what they were counting. Students pointed out numerous combinations, with some identifying all crests and troughs as crests and others only identifying particular crests (e.g., #3 and #5). Ms. R stated that "we gotta settle this" [Episode, April 2010] and asked for explanations for what students were counting. As discussion continued, the role of perspective came up, as students sitting on one side of the rope saw something different than students sitting on the other side of the rope. Although Ms. R at times pressed toward a more canonical understanding of crests and troughs, her main focus remained on students' ideas about crests and why they had counted what they had. After this initial discussion, Ms. R provided students with time to write their thoughts in their journals, then share with partners and eventually with the whole class. The matter remained unresolved at the end of class.

Upon reflection during an interview, Ms. R indicated that she was surprised by the number of different options students raised for how many crests there were: "I didn't expect the students to think that many, like the range of how they, like the number of crests they had ((laughs)), I didn't think it was going to be THAT many" [Interview, December 2012]. The discussion emerged from this surprising level of disagreement about what counts as a crest. Below, I list several salient aspects of the discussion that likely initiated and stabilized Ms. R's responsiveness in this setting, providing evidence of these aspects and how they interrelated with Ms. R's attention and responsiveness to students' ideas:

- Interest in understanding what students were thinking
- Need for agreement on what counts as a crest to count wavelengths
- Opportunity for students to reconcile their own debate
- Desire to move beyond appeals to authority

Interest in Understanding What Students Were Thinking

Ms. R's surprise with respect to the variety of options students put forth and desire to understand where they were coming from supported her responsiveness to students' ideas in both senses – shifting her plan to focus on their ideas, and attending closely to their ideas in the moment. After students pointed out numerous combinations on the jumprope, there was a five-second pause as Ms. R stepped back from the class and put her hand over her mouth. In an interview, Ms. R reflected on this pause as a time in which she was thinking about what to do next: "That's why when I did like this ((puts hand over mouth)), I was thinking ((both laugh)). I was like, oh" [Interview, December 2012]. During the episode, she followed this pause with the following statement: "We gotta settle this. Why you all- whoever said four, why you think it's four?" [Episode, April 2010]. Her response in the moment was to shift from the intended activity of

counting wavelengths to seeking further explanation from students about how they were identifying crests.

What is underdetermined at this point is exactly *why* Ms. R wanted to understand more about what students were thinking. At times, understanding students' ideas seemed to serve an instrumental purpose for Ms. R – she needed to understand how students were thinking about crests in order to decide what to do next, instructionally. For instance, consider how Ms. R described her pursuit of students' ideas during this episode in an interview:

> Ms. R: Imagine if you didn't ask, and then they would have just kept it in their brains. You wouldn't know, you wouldn't know wh::y they thought what they thought… having that opportunity to have all those numbers come out at least makes me think okay, now what do I need to do, so they can – say, this is al::ways what it is [Interview, December 2012].

Here, Ms. R referred to the importance of knowing "wh::y [students] thought what they thought," but primarily for the purpose of figuring out what she needed to do as the teacher to help them solidify their understanding of crests. Consonant with this purpose, Ms. R strategically used students' ideas in the episode to push the class' thinking forward. When a student, Rosie, indicated that the number of crests depended on which side of the jumprope you were on, Ms. R recapped her idea for the class and asked other students to weigh in:

> Ms. R: I think I understand what you're saying. She's saying because she's on this side of the rope, right, it looks like there's three [crests]. But on this side of the rope, it would look like it's two [crests], that same part that she's looking at. Does that make sense? What do you all think about that? [Episode, April 2010]

Later, Ms. R wrote the following question on the chalkboard: "Does it matter which side of the rope that you are on, when you counted your crests and your troughs?" [Episode, April 2010]. In an interview, Ms. R indicated that she decided in the moment "this is gonna be the application question" [Interview, December 2012] – the question she would pose to help students further explore and clarify their own thoughts.

Yet there was also an element of interest in simply understanding students' ideas on their own terms, not necessarily for a particular instructional purpose. For instance, after watching video of the episode in a teacher meeting, Ms. R reflected on her surprise at how a student, Carmen, only counted #3 and #5 as crests:

> Ms. R: I didn't expect like one student Carmen, when she said, you know, she didn't count the one little crest because she said it was smaller than the oth::er one, I didn't expect that. I had to try to fi- figure out what they saw- what did they think qualified as a crest? [Meeting, April 2010]

In part, Ms. R's general sense of needing to figure out what students thought "qualified as a crest" likely related to figuring out how to deal with their ideas instructionally, as indicated above. But her detailed recap of ideas like Carmen's, which she did not use for

any particular instructional purpose during the episode, indicated that Ms. R may have been intrigued by some of the ideas that came up, especially ones that she did not anticipate. Additionally, note how Ms. R responded to other teachers highlighting students' confusion during the episode: "I was com- sur::prised that they, like you all said, were con::fused about what to count, so I had to – just go and investigate what you're talking about, and that's how it basically went down. It was fun" [Meeting, April 2010]. Ms. R agreed with and explained her actions in light of her colleagues' focus on students' confusion, yet quietly added "It was fun," suggesting that her investigations were not just about remediating students' ideas – she also seemed to enjoy hearing what they had to say.

Thus, Ms. R's interest in understanding what students were thinking likely reinforced and was reinforced by her attention and responsiveness to their ideas. She needed to understand what they were thinking in order to decide where to go instructionally, so she listened closely to their ideas and used some of their ideas to push the conversation forward. And as she attended to students' ideas, some of their unexpected lines of reasoning seemed to intrigue her, plausibly supporting her interest in unpacking their ideas.

Need for Agreement on What Counts as a Crest to Count Wavelengths

In terms of instructional flow, the discrepancy about what counted as a crest needed to be resolved in order to move forward with the planned lesson on counting wavelengths. Ms. R noted this in an interview: "When I recognized that the students- because you're supposed to go crest to crest, and trough to trough. You can do either one. But when we couldn't say what's a crest, then we can't say the wavelength" [Interview, December 2012]. Ms. R's attention to students' ideas alerted her to the fact that there was disagreement, and the need to resolve this disagreement generally maintained her focus on students' ideas. At times this need for reconciliation prompted Ms. R to move the conversation in the direction of distinguishing crests from troughs, but ultimately she was willing to take the time for discussion on the matter because "what's the purpose of moving on to count it if they don't believe what they're seeing?" [Interview, December 2012].

Opportunity for Students to Reconcile Their Own Debate

In fact, Ms. R's desire for students to "believe what they're seeing" [Interview, December 2012] suggests that Ms. R not only wanted students to agree on *what* counts as a crest, but to understand and agree on *why* a given crest counts. This was particularly evident in the amount of prompting and time Ms. R gave students to reconcile the matter for themselves, both as a group and individually. The clearest evidence from the episode came from Ms. R's meta-comments about who was responsible for the reconciliation and how much time she allowed for discussion. For instance, Ms. R's proclamation of "We gotta settle this" [Episode, April 2010] tacitly communicated that she expected students to participate in doing so. Moreover, her next statement – "Why you all- whoever said four, why you think it's four?" [Episode, April 2010] – suggested that settling the matter involved students sharing and considering others' ideas. This focus was also reflected when Ms. R asked students to weigh in on Rosie's idea about the number of crests

depending on which side of the jumprope you were on ("What do you all think about that?" [Episode, April 2010]) and indicated that it was up to students to figure out what to do next ("How do you solve that problem?" [Episode, April 2010]). In the context of Ms. R giving students the entire class period to work toward reconciliation, these statements suggest that she actually wanted students to take the lead in settling the matter, and her attention and responsiveness to their ideas supported them in doing so.

During an interview, Ms. R acknowledged that she was trying to get students to listen to others' ideas and clarify their own thinking. She wanted students to hear "other people's ideas and way of thinking" [Interview, December 2012], yet she also wanted to help students "tease out and make like a, a clear answer or clear rule for their reasoning" [Interview, December 2012]. Ms. R had students journal individually at the end of the episode because she was concerned that some students had not yet figured out what they thought:

> Ms. R: Some students are still trying to rationalize this in their mind. So without the distractions of other people, or trying to make sense of other people's rules without getting my own rule, I was like okay, write it down, what you think [Interview, December 2012].

Although I did not explicitly pursue the reasoning behind this emphasis, some of Ms. R's language provided hints. For instance, her statement in the previous section about whether students "believe what they're seeing" and her sense that without discussion, students "probably would have just memorized whatever you said, but not understood" [Interview, December 2012] suggest that for Ms. R, students truly *understand* content when they have made sense of it for themselves. Simply telling them what to count as a crest would not have resulted in deep understanding; grappling with their own and others' ideas (and Ms. R doing the same) was more beneficial in this regard.

Desire to Move Beyond Appeals to Authority

Closely tied to the section above, Ms. R seemed particularly sensitive to what could be considered students' appeals to authority. For example, consider the following exchange:

> Rosie: Isn't the crest like the highest point, the highest point of the wave?
>
> Ms. R: Is the crest the highest point of the wave?
>
> Student: Yes.
>
> Ms. R: Okay. So what are you saying by that? What are you saying, what do you mean by that? I mean, why did you ask that? [Episode, April 2010]

During an interview, Ms. R stated that "in the book it said, the crest is the highest point… I'm like, what's that mean?" [Interview, December 2012]. Recognizing the language from the book in Rosie's statement, Ms. R might have taken extra care to press Rosie for *her* thinking and how that piece of information was relevant, asking three clarifying

questions in close succession. Ms. R also noticed another student taking her book out while we were watching the video together, which was salient enough for her to spontaneously point out to me.

In addition to the book, Ms. R also recognized that students might treat other students as authorities. In an interview, Ms. R described how some students do not want to go against "the smart kid, or the cool kid" [Interview, December 2012]. Toward the end of the episode, this kind of awareness and sensitivity may have actually drawn her attention *back* to students' ideas. Ms. R was pressing a student, Rolland, to distinguish between crests and troughs when another student, Marcelo, spoke up:

> Marcelo: Look, does this count? ((points at #1))
>
> Rolland: Yes.
>
> Ms. R: Does it count for you?
>
> Rolland: Yes.
>
> Marcelo: No.
>
> Ms. R: This is what I want you to write in your journal right now. Write the question, does it matter which side of the rope you are on? And then tell me your response and why [Episode, April 2010].

My interpretation of the exchange above in part hinges on the particular students involved. During an interview, Ms. R indicated that she felt Marcelo was confused at this point in the conversation, and she identified Rolland as a student who liked and portrayed himself as knowing a lot about science. In this context, Ms. R may have interpreted Marcelo asking Rolland whether #1 counted as an appeal to Rolland's authority. Ms. R's attention quickly turned away from crests and troughs and to Marcelo's thinking, asking if it counted *for him*. In her next statement, she transitioned students to independent journal-writing.

In short, although Ms. R wanted students to consider each other's ideas, she wanted them to do so as part of their own sense-making. Her concern with appeals to authority cohered with and was perhaps a special case of the previous section on students reconciling the matter for themselves. However, her seeming sensitivity to possible appeals to authority, as evidenced by her rapid-fire questioning of Rosie, spontaneous mention of another student looking at the book, and attention to what Marcelo thought, suggests that this might serve as a particular trigger for Ms. R. In fact, this trigger occurred as Ms. R listened to students' ideas in every selected episode, and typically resulted in Ms. R pressing students to articulate *their* thinking (as seen with Rosie and Marcelo here).

Interactions Among Identified Aspects

As in the case of the September 2010 episode from Ms. L's classroom, the identified aspects in this episode likely interacted with each other as well as with Ms. R's

attention and responsiveness to student thinking. For instance, as noted above, Ms. R's concern with students' appeals to authority was likely a special case of her broader desire for students to make sense of the situation themselves and seemed to refocus her on this desire in the moment. Additionally, as Ms. R sought to understand students' ideas, students were more able to understand and consider each other's ideas, possibly contributing to Ms. R's goal of students reconciling their debate. In turn, as Ms. R prompted students to consider each other's ideas, more ideas came out that Ms. R may have found intriguing or useful. The only aspects that were not mutually consistent at times were the need for students to agree on what counts as a crest and the desire for students to figure it out on their own. Sometimes the former aspect resulted in Ms. R moving the conversation in a particular direction, at the expense of students driving the reconciliation. However, these aspects often worked together as Ms. R felt that students reconciling the matter for themselves was the best way to promote their agreement and understanding of what counts as a crest and why. These plausible interactions among identified aspects may have enhanced the overall stability of Ms. R's attention and responsiveness to students' ideas during the episode.

Commonalities Between the Episodes

Although the two episodes analyzed above were distinct in origination and substance, there are several commonalities worth noting in what was salient to the teachers and interrelated with their responsiveness to student thinking. Specifically, both teachers were intrigued by aspects of the emergent discussions and indicated that such discussions served as opportunities to promote deeper content understandings among students and support students in seeing their own ideas as worthwhile. These commonalities were not necessarily at the same grain size or playing the same role in both episodes, but they were likely part of the dynamics of each.

Intrigue With Respect to Aspects of the Emergent Discussions

In both episodes, the teachers seemed intrigued by the discussions that ensued their classrooms, but their intrigue was different in nature. More generally, by intrigue, I mean in-the-moment interest in or captivation by what is happening – a sense that may accompany a given experience or drive it in a particular direction. In what follows, I suggest that intrigue played a more active role for Ms. L, but that intrigue was in play in the dynamics of the episodes for both teachers.

Ms. L was primarily intrigued by the question Albert raised about why the foxes got dropped from the classification scheme. As seen above, she repeatedly indicated that she did not know the answer but found the question interesting, suggesting that she was curious about the *scientific topic* under consideration. Consonant with her curiosity about the topic, she often oriented to students' ideas as possibilities to consider and build on herself. In other words, Ms. L and the students were inquiring together, to an extent – Ms. L described this as "figur[ing] stuff out with the kids" [Feedback, January 2013] and cited the "fox thing" as an example: "If it's something I really don't understand, then I really am like yeah, let's try to figure this out!" [Interview, December 2012]. Ms. L's curiosity about the fox question likely played an active role in the class' impromptu pursuit.

Ms. R, on the other hand, was primarily intrigued by her students' unexpected ideas. After students provided numerous responses to how many crests there were on the jumprope, Ms. R sought further explanation from them, indicating that she "had to try to figure out what they – what did they think qualified as a crest?" [Meeting, April 2010]. Although Ms. R needed to figure out what students thought in part for instrumental reasons, to decide on her instructional course of action, her interest was not *just* instrumental. She indicated that investigating what students thought was "fun" [Meeting, April 2010] and recapped specific ideas that caught her attention – specifically those she did not anticipate ahead of time. Ms. R's intrigue during the episode, then, was oriented toward *students' ideas about the scientific topic* rather than the scientific topic itself[18], and was less obviously active as compared to Ms. L's curiosity, but still part of the dynamics.

Promoting Deeper Content Understandings Among Students

Another commonality across both episodes was that the teachers saw the discussions as ways to enhance students' understanding of the scientific content they were studying at the time. According to Ms. L's written feedback, exploring why the foxes got dropped "totally reinforced the basic concept we were working on (basically couldn't have come up with a better one myself)" [Feedback, January 2013]. Yet as I noted above, what Ms. L meant by "concept" was more expansive than traditional notions of what classification is and different ways in which scientists classify organisms. Ms. L wanted students to understand that classification has "gotta be for a reason" [Episode, September 2010], that there is logic behind how and why scientists choose to classify organisms in the ways they do. In this context, "content" included both conceptual knowledge and a more epistemological sense of scientists' purpose and process with respect to classification.

For Ms. R, students' disagreement over what counts as a crest and why provided an opportunity to solidify their understanding of crests. Although the jumprope activity was supposed to be quick, Ms. R acknowledged that "it turned into something else, which I was willing to take the time for because what's the purpose of moving on to count it if they don't believe what they're seeing" [Interview, December 2012]. She did not tell students what to count, believing that "they probably would have just memorized whatever you said, but not understood" [Interview, December 2012]. Rather, she elicited a variety of ideas and left it up to students to reconcile what counted as a crest, believing that their negotiated definition would ultimately result in a deeper understanding of crests.

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[18] These foci on the part of the teachers parallel what most captured their attention during the summer workshops – Ms. L became notably engaged in making sense of scientific phenomena for herself (see Gupta, Elby, & Conlin, under review), whereas Ms. R tended to focus on making sense of students' ideas. Deeper consideration of these parallels is beyond the scope of this chapter, but worth noting.

Supporting Students in Seeing Their Own Ideas as Worthwhile

Finally, both teachers also took advantage of opportunities to demonstrate to students that their ideas are worthwhile in the science classroom. This manifested in several ways. For Ms. L, she described how students are "astonished when you take their questions seriously" [Interview, October 2012], and that she hopes to never "make the kids feel like, well, that question's not worth us talking about" [Interview, October 2012]. Her pursuit of Albert's question, in part, seems tied to this aim of students feeling valued and agentive in asking their own questions in the classroom; to do otherwise would be, as Ms. L stated, "against the spirit of inquiry" [Interview, October 2012]. Respecting and pursuing students' questions is closely related to the second sense of responsiveness.

Additionally, both teachers pressed students to focus on and value their own ideas during the episodes. For instance, in describing why she pursued Albert's question, Ms. L indicated that she did not want students to "accept [her] word" [Interview, October 2012] that there's some reason for why the foxes got dropped. She also did not want students to take the book's authority for granted; rather, she asked students to think for themselves about what trait might have distinguished foxes from the other organisms. Ms. R also demonstrated resistance to perceived instances of students appealing to the book or each other for answers, and she explicitly made students responsible for settling the matter of how many crests there were for themselves. In sum, an important aim for both teachers seems to be to help students see their own ideas as useful in discussing and making sense of scientific phenomena.

Revisiting Ball (1993) and Hammer (1997)

Looking back at Ball's (1993) and Hammer's (1997) examples of the second kind of responsiveness with these commonalities in mind, I see clear evidence of promoting content understandings and supporting students in valuing their own ideas, as well as the possibility of intrigue with respect to the discussions that ensue. I address each point in turn.

Both authors noted the relevance of the discussions for the disciplinary content they were addressing at the time. In Ball's (1993) discussion of Sean numbers, the class had been in the midst of "working with patterns of odd and even numbers" (p. 385) when Sean noticed "that some even numbers have an *odd* number of groups of two" (p. 386). Ball recognized this as in line with the class' work on patterns (although unconventional) and as a way to "enhance what kids are thinking about 'definition' and its role, nature, and purpose in mathematical activity and discourse, which, after all, has been a major point this week. What should a definition do? Why is it needed?" (p. 387). Similar to Ms. L, Ball's sense of "content" was expansive and included epistemological considerations of purpose. Hammer also connected the discovered Marino phenomenon to the physics content being studied at the time:

> This was one of the discoveries that the worksheets intended… but it was not until later in the worksheets that the students were intended to explain why this happens. Planning for class the next day, I decided to focus on this as a topic of conversation. I thought it could serve in several ways: It was another opportunity to show the students that their discoveries mattered, it was an example of a

> phenomenological contribution to scientific progress, and it was a phenomenon that could point us toward the notions of induced polarization and charging by induction (p. 508).

Ball (1993) and Hammer (1997) also both described wanting to support students in seeing their ideas as meaningful and consequential. In the quote from Hammer above, he emphasized showing "students that their discoveries mattered" in addition to supporting students' understanding of induced polarization and charging by induction, as well as how scientific progress occurs more generally. Ball made a similar point with respect to her pursuit of Sean numbers: "… it seemed defensible to give the class firsthand experience in seeing themselves capable of plausible mathematical creations" (p. 387).

Finally, Hammer's (1997) broader framing of his teaching emphasized the role of "teacher exploration – of the students' understanding and reasoning, of the subject matter, of what constitutes progress toward expertise, and of how to facilitate that progress" (p. 516). It seems reasonable that such exploration might be accompanied or driven by a sense of intrigue or curiosity on the part of the teacher, but there was not enough data in either paper to tell whether Ball (1993) or Hammer were personally intrigued by what happened in their classrooms, nor did they explicitly describe these sorts of experiences for themselves. In part, this might be due to teachers' (understandable) tendencies to describe or explain their instruction in light of its impact on students and their goals for students, rather than their own experiences. Even if intrigue or curiosity are part of the dynamics stabilizing a teacher's focus on students' ideas, they might not be as apparent as other aspects.

Conclusion and Implications

To recap, classroom examples of instruction in which student thinking was at the front and center (Ball, 1993; Hammer, 1997) demonstrate two senses of what it means to be responsive to student thinking. The first involves teachers listening and responding to students' ideas within planned discussions or progressions of activities. The second involves teachers altering plans in response to directions or ideas from students, often incorporating yet extending beyond the first kind of responsiveness in allowing the ideas they hear from students to influence the class' direction. Professional development efforts focused on teacher responsiveness better support the first sense of responsiveness as compared to the second, despite the second's importance in promoting a classroom environment in which students' ideas have consequence. With an eye toward informing such professional development efforts, I analyzed two classroom examples in which teachers altered their plans in response to unexpected ideas from students to understand what initiated and stabilized teachers in shifting their intended activity and attending and responding to students' ideas in the discussions that ensued.

Looking across these classroom examples and the teacher-researcher accounts cited above (Ball, 1993; Hammer, 1997), I noted several commonalities with respect to what likely motivated and stabilized teachers' responsive shifts. For instance, in all cases, teachers saw opportunities in what students offered to promote deeper content understandings among students and to support students' senses that their ideas are worthwhile. It is important to note that these teachers' notions of "content" were

relatively expansive and included students gaining an epistemological understanding of the purpose and process of core disciplinary activities, such as classifying in science or creating definitions in math. Such expansive notions of disciplinary content create more space for responsiveness and more potential connections between students' ideas and the discipline than a narrow focus on specific conceptual content. Additionally, teachers' own intrigue with respect to aspects of the emergent discussions may have contributed to their ongoing responsiveness, including Ms. L's shift in intended activity and Ms. L's and Ms. R's close interactions with students' ideas. I draw on these findings – specifically promoting 1) expansive notions of disciplinary content and 2) teachers' in-the-moment intrigue – in considering implications for professional development aimed at supporting the second sense of responsiveness[19].

Implications for Professional Development

Fostering an expansive sense of disciplinary content and supporting teachers' in-the-moment intrigue about scientific topics and students' scientific ideas might be particularly meaningful in professional development aimed at supporting the second sense of responsiveness. For instance, after spending time unpacking students' ideas evident in classroom video or student work, facilitators could ask teachers, "What opportunities do you see to promote students' deeper content understandings?" to support teachers in extrapolating their understanding of students' ideas into responsive instructional trajectories[20]. Explicit conversation around the affordances and constraints of proposed trajectories – including whose direction they emphasize (the teacher's or the students') and what sorts of disciplinary content understandings they promote – could help teachers conceptualize and explore more of the responsive instructional space and see various ways in which students' ideas connect to the discipline.

Additionally, as professional developers, we could frame part of our work as supporting teachers' in-the-moment intrigue about scientific phenomena and students' scientific ideas, remaining alert and open to examples or topics that spark their curiosity and flexibly pursuing those[21]. In her collection, *The Having of Wonderful Ideas*, Duckworth (2006) described how she found herself "captivated by [the] world of fascinating phenomena, by its accessibility and its complexity" (p. xiv), and how it was through the exploration of scientific topics that she "got hooked and [has] been an educator ever since, trying to develop learning experiences of that sort for every child and every teacher" (p. 125). In her work with teachers, she strove to engage their interest and curiosity about phenomena (what she called the "secondary subject," p. 175) as well as

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[19] To be clear, I recognize that these teachers are not representative of teachers more broadly, but the habits of mind identified are likely to be widely accessible. Further research will be needed to see whether and how they are meaningful.

[20] One risk is that teachers may end up focusing on content in seemingly unresponsive ways, posing options that are dissociated from students' ideas. Asking how such options connect to students' current understandings may refocus the conversation and/or draw out tacit connections that teachers were making (Hammer, 2000).

[21] This would also demonstrate what the second sense of responsiveness looks like in action.

children's ideas about phenomena. These interests often dovetailed with each other and supported teachers' in-depth pursuit of students' ideas while teaching. Thus, in professional development, capitalizing on moments when teachers demonstrate interest in exploring particular scientific phenomena and students' ideas about such phenomena may go a long way toward promoting a curious, responsive attitude and enhanced flexibility in the classroom.

Implications for Continuing Research

Research efforts should continue to explore more examples of the second sense of responsiveness in the classroom, contributing to our collective understanding of what initiates and sustains such responsiveness. Additionally, it would be illuminating to study how teachers in professional development settings respond in the posited discussions about disciplinary content understandings. What kinds of instructional next steps do they put forth? How are those next steps related to students' ideas? Do the kinds of next steps teachers put forth change over time in some way, and if so, how can we understand those changes? And critically, are there signals that engaging in such discussions in professional development settings impacts teachers' responsiveness in the classroom in any way? These are but a few of the questions that could guide further pursuit of professional development and research aimed at supporting teachers in *both* senses of responsiveness to student thinking in the classroom.

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Chapter 5: Characterizing a New Dimension of Change in Attending and Responding to the Substance of Students' Scientific Thinking

To preview the focus of this chapter, I will share two exchanges from Mr. S's[22] seventh-grade science classes. In consecutive years, Mr. S posed the same basic question to groups of students: If you're walking with keys, and you want to drop the keys into a container, sitting on the floor, should you release the keys before the container, over the container, or after the container? Table 5-1 contains snippets of students arguing that the speed of the walker would endow the keys with continuing forward motion, meaning you would release the keys before the container. In these snippets, consider how Mr. S interacted with students' ideas:

Table 5-1

Illustrative Snippets from Mr. S's Science Classes

April 2010	*March 2011*
Diane: I feel like I would go before. Mr. S: Be::fore. Why before? You're for the first option. Diane: Yeah. Mr. S: Why before, Diane? Diane: Because I thi:::nk that – well, let me try to give you an example, li:::::ke ((loudspeaker interruption)) I think, like, when you're racing? Like, you're in a racecar? And then, you know, let's say you have to () on fire or something? So when you're trying to land on the grass – because you're not going to get there right when you're at the grass or else you're gonna- because the car's fast, and you're going fast too. You gonna, like, get on the mud or something, so you're going to have to go	Chavez: If you do it before, it'll go directly in? But if you do it like, like- Mr. S: Why do we have to do it before again? Chavez: Because it'll go, like, IN, like the keys will go in the trash can or the thing will go in the trash can. Mr. S: What will cause it to go in the trash can if we drop it before as opposed to over, because ear::lier you said over? Chavez: Like, like, like, like, like the speed of the keys also I guess coming off. Mr. S: The speed of the- so the keys have speed? Chavez: Because you're walking, no

[22] All teachers' and students' names are pseudonyms. Real names are provided for members of the research team.

before, so you know, you could, you know what I mean[23]? Mr. S: So what do you mean is that there's some kind of forward motion? Diane: Yeah. Mr. S: ((faces board, writes)) Okay. So you're saying some kind of forward motion based on what? Diane: On the speed of the person who (). Mr. S: So based on sp::eed, right?	because like you're walking? (pause) And like, and like since you're walking fast, like, I guess the keys will also go fast too? Mr. S: The keys will go fast too?... Chavez: (pause) Yeah. Mr. S: Why will the keys go fast too? Chavez: I don't know! Mr. S: I re::leased the keys, wouldn't the keys just be there?

In both exchanges in Table 5-1, Mr. S focused on unpacking the students' ideas about the scenario. When the students indicated they would drop the keys before the container, Mr. S asked them to explain why. He recapped the sense he made of what they said, giving the students space to confirm or disconfirm his interpretations. He asked follow-up questions to elicit more information from the students. In these ways, Mr. S clearly attended and responded to student thinking in both exchanges – and as we will see, in longer segments of discussion featuring a range of ideas both years. Yet, as I will argue below, the March 2011 exchange also represents a favorable shift in attending and responding to the substance of students' scientific thinking over the April 2010 exchange. This chapter focuses on how we might characterize that shift and why it is favorable.

When teachers attend and respond to students' ideas and seek to draw out or connect them with important aspects of the discipline, students demonstrate enhanced conceptual understanding (e.g., Carpenter, Fennema, Peterson, Chiang, & Loef, 1989; Pierson, 2008) and experience rich opportunities to engage in disciplinary practices, such as explanation-building and argumentation in science (e.g., Berland & Reiser, 2009; Duschl & Gitomer, 1997). Ball (1993) has described this sort of teaching as involving "twin imperatives of responsiveness and responsibility" (p. 374) – focusing on and grounding instruction in students' ideas, while helping them learn important disciplinary ideas and practices. In science, Hammer and van Zee (2006) highlight the importance of teachers focusing on various beginnings of science in what students are saying and doing. Take the following example they discussed: A student says it gets hotter in the summer because the earth is closer to the sun. Although this idea is incorrect and widely considered to be a common student misconception about the seasons, Hammer and van Zee emphasized the scientific features of the explanation – its mechanistic nature (involving "physical cause and effect" (p. 19)), tangibility, and consistency with other

[23] My sense of Diane's example is that if you want to jump out of a racecar that's on fire and land on a particular grassy spot, you need to jump before you reach the spot because you're going fast and will continue to move forward.

information the student knew. These are a few examples of scientific aspects teachers could note and promote in students' reasoning; Hammer and van Zee described numerous others (e.g., anticipation of counterarguments, clarity of expression, etc.).

Characterizations of favorable change in attending and responding to the substance of students' disciplinary thinking, however, primarily emphasize how closely teachers focus on students' meanings with little attention to how teachers hook those meanings up with disciplinary ideas and practices. Researchers tend to focus on the specificity with which teachers attend to students' ideas (e.g., Jacobs, Lamb, Philipp, & Schappelle, 2011; van Es, 2011), the stance teachers take toward students' ideas (e.g., Crespo, 2000; Goldsmith & Seago, 2011), and/or the types of follow-up moves teachers make in response to students' ideas (e.g., Brodie, 2011; Pierson, 2008). These foci foreground teachers' treatment of students' ideas but do not clearly address disciplinary-specific considerations.

In this chapter, my primary aim is to bring disciplinary-specific considerations into the discussion of change in attending and responding to the substance of students' disciplinary thinking. Drawing on the two instantiations of the key drop conversation in Mr. S's classroom, I argue that part of what constitutes the favorable shift in Mr. S's attention and responsiveness to student thinking from April 2010 to March 2011 is the aspects of scientific reasoning and explanation Mr. S foregrounds with respect to students' ideas in each case. A secondary aim of this chapter is to distinguish between what I call *episodic* shifts and *stable* shifts in attending and responding to student thinking, and how we might assess each. By *episodic* shifts, I mean that one episode is better than or demonstrates a favorable change over another – for instance, March 2011 in Mr. S's classroom represents an *episodic shift* from April 2010. Assessing episodic shifts requires a close look at the characteristics of two or more specific instantiations. However, this evidence alone would not be enough to say that Mr. S has made a *stable shift* in his attention and responsiveness to student thinking more generally – that his teaching shows persistent and pervasive change over time. Stable shifts are far more difficult to demonstrate empirically, but I highlight additional evidence that is suggestive of this sort of shift for Mr. S.

Characterizations of Favorable Change in Attending and Responding to Student Thinking

I begin by reviewing ways in which shifts are described and assessed by researchers studying attention and responsiveness to the substance of students' disciplinary thinking. First, I highlight the dimensions along which researchers describe favorable change in attending and responding to student thinking, demonstrating that these dimensions are largely free of disciplinary-specific considerations. Second, I review how researchers measure changes or shifts in teachers' attention and responsiveness over time, raising questions about these approaches for assessing teachers' classroom practice.

Identified Dimensions of Favorable Change

Several dimensions along which researchers define favorable change in attending and responding to student thinking are the 1) specificity of the teacher's focus (e.g., Jacobs, Lamb, Philipp, & Schappelle, 2011; van Es, 2011), 2) stance the teacher takes toward the ideas he hears (e.g., Crespo, 2000; Goldsmith & Seago, 2011), and 3) types of

follow-up moves the teacher makes in response to students' ideas (e.g., Brodie, 2011; Pierson, 2008). I briefly review each of these dimensions below.

Specificity of Focus

One way researchers characterize shifts in attending and responding to student thinking is in the specificity with which teachers attend to students' ideas. The primary distinction here is whether teachers' descriptions of students' reasoning are a) general and draw on more superficial aspects of the ideas or b) specific and draw on details and nuances within the ideas, with the latter representing favorable change from the former (e.g., Crespo, 2000; Fennema et al., 1996; Franke, Carpenter, Fennema, Ansell, & Behrend, 1998; Jacobs, Lamb, Philipp, & Schappelle, 2011; Kazemi & Franke, 2004; Levin & Richards, 2011, van es, 2011). For instance, in a teacher work group in which teachers were expected to share how their students approached a particular mathematics problem, Kazemi and Franke noted that early on, teachers focused on whether students' strategies were correct or not and "were unsure as to *how* the students had completed the problem" (p. 216, emphasis added), indicating that they paid little attention to the specifics of students' solutions. Similarly, Crespo noted that the preservice teachers in her study initially made claims about student understanding that were not grounded in much evidence, but later attended to the details of what students said and did. As she described, later "comments revealed greater attention towards the meaning of student's mathematical thinking rather than surface features" (Crespo, p. 170), with attention to detail and meaning representing a positive shift from attention to surface features. van Es's (2011) "framework for learning to notice student thinking" (p. 138) includes a distinction between generality and specificity in the descriptions of different levels; part of what distinguishes Level 1 (baseline) from Levels 3 (focused) and 4 (extended) is that teachers in Level 1 "form general impressions of what occurred" (p. 139) and "provide little or no evidence to support analysis" (p. 139), whereas teachers in Level 3 or 4 "refer to specific events and interactions as evidence" (p. 139).

Stance Toward Ideas

Another way in which researchers characterize shifts in attending and responding to the substance of student thinking is in the stance teachers take toward that substance (e.g., Crespo, 2000; Empson & Jacobs, 2008; Goldsmith & Seago, 2011; Levin & Richards, 2011; van Es, 2011). For instance, Goldsmith and Seago (2011) described how early mathematics teacher work groups "primarily took a normalizing view of students' solutions: They interpreted the work in terms of a standard correct answer, expressed in formal algebraic notation" (p. 177). Later, teachers looked "for the logic in students' solutions" (Goldsmith & Seago, p. 179), demonstrating a shift from a more evaluative stance centered on the correctness of students' ideas to a more interpretive stance centered on making sense of students' ideas. Revisiting van Es's (2011) framework, stance is also integrated into the different levels. For example, in Level 2 (mixed), teachers "provide primarily evaluative with some interpretive comments" (van Es, p. 139), whereas Levels 3 (focused) and 4 (extended) shifted to entirely interpretive comments. Similarly, Empson and Jacobs (2008) define a progression in listening expertise that moves from "directive listening" (p. 268), in which the teacher focuses on

alignment between a student's idea and an expected response, to "observational listening" (p. 268), where the teacher passively listens to students' ideas, to "responsive listening" (p. 269), in which the teacher actively probes students' ideas and seeks to understand and build on the details. In each of these examples, the shift is in how teachers view and thus work with students' ideas and involves a change from seeking to evaluate students' ideas to seeking to understand them in more depth.

Types of Follow-Up Moves

Finally, in the classroom, researchers focus on the extent to which teachers' follow-up moves are responsive to the student thinking that came prior (e.g., Brodie, 2011; Franke et al., 2009; Pierson, 2008). Moves like clarifying a student's idea or giving a related example fall under what Pierson called high II responsiveness, in which the focus is "on how students are making sense of the content regardless of the correctness of their responses" (p. 75). In Brodie's terms, such a focus on substance would be reflected by confirming what a student has offered, maintaining a focus on the idea, and pressing for more information; Franke et al.'s evidence for this focus would be a probing sequence of specific questions. Alternatively, Pierson described high I responsiveness as more corrective in nature, evidenced by moves like providing targeted feedback about a student's misunderstanding. For Brodie, a corrective focus would be reflected by eliciting particular information from students and inserting ideas into the conversation. Franke et al. indicated that such a focus may be largely dissociated from students' ideas:

> Here the teacher assumed much of the mathematical work while supporting students when moving them through correct and complete explanations. Unlike probing questions, leading questions did not always relate to students' mathematical thinking but instead corresponded to strategies the teacher thought would enable students to solve the problem (p. 390).

By looking at the kinds of follow-up moves teachers make, researchers are able to characterize teachers' activity as more or less responsive to the substance of student thinking.

Summary

Generally, the shifts described above can be seen as movement from a) evaluating students' ideas, in which the focus is primarily on the surface features of those ideas to determine alignment with expected responses and follow-up moves serve to push students in particular directions, to b) interpreting students' meaning, in which the focus is on the details of students' ideas and follow-up moves serve to elicit more information from students. Note that these descriptions of change reflect important dimensions of how teachers interact with students' ideas, but they do not reflect how teachers interact with specific disciplinary aspects of those ideas (other than movement away from a pure focus on correctness).

Evidence of Changes or Shifts

In terms of measuring changes or shifts in teachers' attention and responsiveness, researchers primarily examine patterns in teachers' discourse over time, either in reference to artifacts of student reasoning examined in professional development or teacher education settings (e.g., Crespo, 2000; van Es & Sherin, 2008) or during instruction in the classroom (e.g., Brodie, 2011; Fennema et al., 1996). Generally, researchers use the dimensions of favorable change noted above to compare teachers' discourse around student thinking at different time points. For instance, Brodie observed mathematics teachers' classroom practice for one week, classifying and counting the types of follow-up moves teachers used in interaction with students' ideas during whole-class discussions. After teachers had an opportunity to jointly plan lessons aimed at engaging learners' mathematical thinking, Brodie observed their practice for another week. Her sense that teachers' classroom practice shifted was grounded in comparisons of the proportions of types of follow-up moves between the two weeks, with greater proportions of reform-type follow-up moves seen in the second week. van Es and Sherin examined teachers' discourse in response to video clips of classroom teaching across ten meetings over the course of a year. Drawing on the dimensions of specificity and stance noted above, as well as others, the researchers broke each meeting into segments and coded for each teacher's primary focus along each dimension in a given segment. By combining the segments and comparing the percentages of foci across meetings, van Es and Sherin noted that "teachers' analyses of video shifted in terms of who and what they found noteworthy, how they analyzed these interactions, and their level of specificity" (p. 253).

Yet there is variability within these patterns. When van Es and Sherin (2008) examined individual teachers' trajectories over the course of the year, they found that some teachers took a "cyclical path" (p. 258) where they cycled among different ways of discussing video over time, at times focusing on specific students' mathematical ideas and at times adopting a much broader perspective on what they were seeing. Moreover, van Es and Sherin's analytical approach purposely masked variation at finer grain sizes:

> Because of the dynamic nature of the conversations in the video club meetings, individual teachers may have participated in different ways within a given segment. In order to characterize how the individual teachers analyzed video in this context, however, each teacher received one code per dimension for each segment based on his or her primary focus (p. 251).

By coding teachers according to their primary focus, within-segment variation is lost. Thus, it is likely that teachers exhibited more variation in their attention than was noted.

Given the variability evident in settings in which the focus is specifically on drawing attention to student thinking, such as van Es and Sherin's (2008) video clubs, variability in the classroom is even more likely as there are more foci competing for attention (e.g., Hammer, 1997; Lampert, 1985). Lau's (2010) dissertation work demonstrated that teachers' attention may vacillate within the course of a given conversation with students, at times focused on the meaning of their ideas and at times focused on other considerations. Such variability raises difficult questions about

assessing the stability or sustainability of shifts in teachers' attention and responsiveness to the substance of students' disciplinary thinking.

Examining the Nature and Stability of Mr. S's Shift(s)

In what follows, I return to the two key drop conversations in Mr. S's classroom to examine the nature of the shift(s) evident in Mr. S's attention and responsiveness to student thinking between April 2010 and March 2011. In Part 1, I provide evidence that Mr. S foregrounded different aspects of scientific reasoning and explanation with respect to students' ideas in each case. In the first episode, Mr. S foregrounded students identifying *causal factors* responsible for the motion they predicted. In the second episode, Mr. S foregrounded students articulating *causal stories* for the motion they predicted, fleshing out how and why the object would move the way it did. This episodic shift in attention from causal factors to causal stories represents a favorable change in the sophistication of explanation Mr. S attended to and pressed students for in the context of the key drop question. In Part 2, I explore the variety of influences contributing to Mr. S's foregrounding in each case and consider their ramifications for assessing the stability of his shift in practice.

Methods and Methodology

Context of the Professional Development Project

The data for this study come from a professional development project aimed at helping fourth through eighth grade teachers promote inquiry teaching and learning in their science classrooms. Teachers voluntarily apply and may continue in the project for multiple years. As part of the project, teachers attend a two-week summer workshop in which they engage in their own minimally-guided inquiry, watch classroom video of students discussing scientific phenomena, and collaborate on other issues related to inquiry teaching and learning in the classroom (i.e., assessment, lesson planning, etc.). During the school year, teachers work one-on-one with members of our research team to facilitate scientific inquiry in their classrooms and attend bimonthly small group meetings with other teachers and members of the research team.

Data: Context and Selection

Our research team identified Mr. S – currently in his fourth year of participation in the project – as someone who came to consistently facilitate rich scientific discussions in his classroom, many of which we have videotaped. The two selected episodes in this paper come from Mr. S's seventh-grade classes at a Title I middle school in which 65% of the students identify as Hispanic, 30% as African American, and about 35% are classified as having limited English proficiency[24].

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[24] These statistics come from publicly available 2009-2010 demographic data, not directly cited to protect the anonymity of the school.

Specific features of this pair of episodes made them an ideal naturalistic setting for thinking about different scientific aspects teachers may attend to in students' ideas. In many respects, the episodes are similar – they feature the same teacher teaching the "same" lesson in consecutive years (April 2010 and March 2011). In both episodes, Mr. S posed the same basic question: If you're walking with keys, and you want to drop the keys into a container sitting on the floor, should you release the keys before the container, over the container, or after the container? Students posed sensible reasons for each option, and Mr. S entertained a range of possible answers. Yet what Mr. S foregrounded in students' explanations in each episode differed. Our research team had previously noted that Mr. S's own explanations of scientific phenomena during the summer workshops varied in nature, at times identifying the causal factors responsible for the phenomena and at other times fleshing out more mechanistic explanations for how phenomena occurred. I was aware of these different explanatory approaches and noted that they seemed evident in his facilitation of this pair of episodes.

Data Analysis: Part 1

My first analytical step was to fully transcribe the two videotaped episodes[25], each approximately fifteen minutes in length. I then compared Mr. S's attention and responsiveness to students' ideas in the two episodes in the following manner. I focused on exchanges in which common ideas came up in both episodes or in which Mr. S followed up with students extensively, because these sorts of exchanges were likely to provide useful points of comparison. I drew on three kinds of evidence to unpack what Mr. S was foregrounding during these exchanges:

- How Mr. S revoiced students' ideas (O'Connor & Michaels, 1993) – emphases in his summaries suggested what he primarily attended to (e.g., "Maybe GRA::vity. GRA::vity" [Episode, April 2010] vs. "Gravity's pulling it <u>down</u>" [Episode, March 2011])
- How and when Mr. S pressed on students' ideas (Brodie, 2011) – questions Mr. S asked students indicated what he wanted them to flesh out (e.g., "So you're saying some kind of forward motion based on what?" [Episode, April 2010] vs. "Why will the keys go fast too?" [Episode, March 2011])
- When Mr. S made verbal and nonverbal bids to close the conversation (Schegloff & Sacks, 1999; Stivers & Sidnell, 2005) – accepting students' ideas as sufficiently articulated demonstrated what he found satisfactory (e.g., moving to another idea after a student identified wind as influential vs. after a student explained *why* wind was influential)

I interwove these strands of evidence in a given exchange as a way of understanding what Mr. S was foregrounding in students' explanations.

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[25] For transcriptional notations, see Appendix B. For full episode transcripts, see Episodes 1 and 3 in Appendix F.

Data Analysis: Part 2

I also explored influences on Mr. S's attention and responsiveness in each episode. To do so, I examined a range of other data sources from the professional development project, including videotaped small group teacher meetings, debrief conversations after classroom observations, workshop sessions, etc. I watched all video in which Mr. S reflected on his interactions with students during the aforementioned classroom episodes and noted points he raised that may have influenced the nature of his attention, such as how the discussion fit into his plan for the day. I also searched our data stores for examples of Mr. S posing his own explanations for scientific phenomena and describing what he looked for in others' explanations to get a sense of where his thinking was on the matter at various points in the project. Finally, I conducted semi-structured stimulated recall/reflection interviews (Lyle, 2003) in September and October of 2012 in which Mr. S and I watched the two videotaped episodes together and I asked him to describe what was going on, particularly during the exchanges I focused on in my analysis.

Part 1: Characterizing the Episodic Shift

Mr. S Foregrounded Causal Factors in the First Episode

In the first key drop episode in April of 2010, Mr. S primarily attended and responded to a particular form of scientific knowledge in students' ideas – their identification of the causal factors or force-like entities responsible for the motion they predicted. In general, if the factor causing the motion was not apparent in a student's explanation, he pressed the student to articulate it; if the factor was apparent, he accepted the student's response. Here, I provide two in-depth examples to illustrate Mr. S's focus on causal factors and cite supporting evidence from other exchanges throughout the episode.

The first exchange I turn to occurred well into the discussion and was one of the longest continuous exchanges Mr. S had with an individual student during the episode. In the exchange, the student, Suri, provided his sense of when it would be best to drop the keys, if you're running fast:

1. Mr. S: Okay, Suri, you want to respond to that or add something to the discussion?

2. Suri: Yeah, I'm like, if you're running, you feel like the wind is pushing you back.

3. Mr. S: So <u>you're</u> saying as you're going <u>fast</u>, faster, you're also feeling some <u>press</u>::ure, some <u>air</u>, pushing back against you.

4. Suri: So my drop, um, is from above or after.

5. Mr. S: Above or after because of what?

6. Suri: Because if the wind is working in a different direction than you, you're running and () ((moves one hand forward and the other in the opposite direction on top)).

7. Mr. S: So when you, when you're saying, when you're running fast, there's some pressure coming up against you, coming a::gainst you?

8. Suri: Mm-hmm.

9. Mr. S: What is that? (pause) What do you think that is? (pause) So you're saying there's a press::ure, there's something push::ing back against you. ((faces board, writes)) There's a push back. And, so that push back, when you release the keys, what is it going to do to the keys?

10. Suri: They're gonna drop backward.

11. Mr. S: They're going to drop back. Okay, okay. Um, now, what are some- [Episode, April 2010]

Throughout the exchange, Mr. S attended and responded to Suri's idea – he maintained his focus on Suri's idea and pressed Suri to say more. However, there are nuances in the ways Mr. S interacted with Suri that highlight Mr. S's emphasis on causal factors. For instance, after Suri provided his initial explanation and indicated that he would drop the keys above or after, Mr. S asked Suri, "Above or after because of what?" [line 5]. The fact that Mr. S had already revoiced Suri's explanation in line 3 and the wording of the question in line 5 suggest that Mr. S may have been looking for Suri to further specify the particular factor he thought was in play. Instead, Suri reiterated his story of the wind "working in a different direction than you" [line 6], and Mr. S again acknowledged Suri's story but pressed for the responsible factor: "What is that?... What do you think that is?" [line 9]. Note here that Mr. S attended to the causal story Suri provided about the wind working in a different direction and pushing back against you – this aspect was not completely absent. Yet what Mr. S pressed for was Suri's identification of the causal factor involved.

At several other times throughout the episode, Mr. S also pressed for or attempted to elicit specific factors or forces underlying the motion students described. For example, early in the discussion, one student, Jack, talked about the keys falling straight down because of their weight. Mr. S responded in part by asking, "What force will cause it to go straight down?" [Episode, April 2010] and excitedly accepted the response of gravity. In an interview, Mr. S reflected on the different factors under discussion:

12. Mr. S: So that, that, that was part of what I was trying to get to, is that you have an internal, uh, possible factor that would, that would explain the drop, but is there anything external in the environment that would explain it? If so, what, what would that be?

13. Jen: Okay. So like, the weight would be the internal factor, and the gravity would be the external factor.

14. Mr. S: Right [Interview, September 2012].

Another example occurred when a student, Katherine, talked about the keys going backward if you're going fast. In response, Mr. S asked, "If I'm going fast, why would that cause the keys to go backwards? What, what force, what would cause the keys to go back?" [Episode, April 2010] His reframing of the question from *why* the keys would go backward to *what force* would cause the keys to go backward, and his subsequent summary that Katherine "said something about the wind" [Episode, April 2010], reflected his emphasis on causal factors.

Further evidence of Mr. S foregrounding causal factors in students' ideas comes from a close look at another exchange around an idea that came up in both key drop episodes – that the speed of the runner would make the keys move forward. (These are the snippets highlighted at the beginning in Table 5-1.) In the first key drop episode, a student, Diane, related this scenario to what would happen if you were to jump out of a racecar:

15. Diane: No, no, I'm not for that one, I feel like I would go before.

16. Mr. S: Be::<u>fore</u>. Why before? <u>You're</u> for the <u>first</u> option.

17. Diane: Yeah.

18. Mr. S: Why before, Diane?

19. Diane: Because I thi:::nk that – well, let me try to give you an example, li:::::ke ((loudspeaker interruption)) I think, like, when you're racing? Like, you're in a racecar? And then, you know, let's say you have to () on fire or something? So when you're trying to land on the grass – because you're not going to get there right when you're at the grass or else you're gonna- because the car's fast, and you're going fast too. You gonna, like, get on the mud or something, so you're going to have to go before, so you know, you could, you know what I mean?

20. Mr. S: So what do you mean is that there's some kind of forward motion?

21. Diane: Yeah.

22. Mr. S: ((faces board, writes)) Okay. So you're saying some kind of forward motion based on what?

23. Diane: On the speed of the person who ().

24. Mr. S: So based on <u>sp</u>::eed, right? [Episode, April 2010]

Again, Mr. S attended and responded to what Diane was saying, but what I find notable is *how* he did so. His response did not acknowledge Diane's specific example, but rather clarified the kind of motion she implied (line 20) and pressed Diane to identify the causal factor responsible for the motion (line 22). Mr. S then acknowledged Diane's identification of "sp::eed" as the relevant causal factor (line 24) and moved on to another student.

In summary, Mr. S's attention and responsiveness to students' ideas in the first key drop episode was centered on identifying the causal factors or forces responsible for the motion students described. In contrast, Mr. S foregrounded a different form of scientific knowledge in students' ideas in the second key drop episode – their articulation of fleshed-out causal stories.

Mr. S Foregrounded Causal Stories in the Second Episode

When Mr. S explored the same question with another group of students in March of 2011 during his second year in the project, he attended and responded to a different form of scientific knowledge in students' ideas – their articulation of causal stories of what they thought would happen. This foregrounding involved his continued pursuit of different stories and more detail from students. I again provide two examples that are illustrative of Mr. S's emphasis on causal stories during the second key drop episode and cite supporting evidence.

As the discussion started, many students thought you should drop the keys over the container in order to get them in. Yet they offered multiple kinds of explanations, including restatements of their conclusions and problematic alternatives (e.g., "Because if we drop it before or after the container, it won't get in the container" [Episode, March 2011]) and appeals to the skill of the person dropping the keys (e.g., "Some people have bad aim, so they can't even aim towards the trash can" [Episode, March 2011]). Among these explanations was the following causal story from a student, Cooper:

25. Mr. S: Um, Cooper?

26. Cooper: Um, above?

27. Mr. S: Above.

28. Cooper: Because like the gravity, like, when you put it up, it goes down.

29. Drake: = It's heavy…

30. Mr. S: Coop::er said that because it's hea::vy, what happens, Cooper, I have to, I have to drop it-

31. Cooper: No, gravity puts, like, pulls it down.

32. Mr. S: So, because gravity's pulling it down [Episode, March 2011].

Here, Cooper offered both a causal factor and how it works – gravity pulls things down (lines 28 and 31). Even though Mr. S momentarily conflated Cooper's idea about gravity with Drake's idea about heaviness, note the kind of follow-up question Mr. S asked – "what happens?" (line 30). Mr. S was not satisfied with the identification of the relevant causal factor; rather, he asked Cooper for more of a narrative.

As students continued to offer different kinds of explanations, Mr. S returned to Cooper's causal story as the kind of explanation he was after:

33. Mr. S: So now let's, we want to get back to – why, why above? Cooper, you had some explanation why, what's the reason for it?

34. Cooper: Because the gravity, like, because of its weight, the gravity will push it down, it'll like fall directly in [Episode, March 2011].

Mr. S also recapped Cooper's response for a third time as he asked students for other reasons why you should drop the keys over the container: "Are there any other reasons why I should drop it above the container, other than Cooper said, the gravity's gonna pull it down. Why else might I drop it above the container?" [Episode, March 2011] This repeated referencing of Cooper's idea suggests that it was the kind of explanation Mr. S desired.

In an interview, Mr. S acknowledged that he was attempting to elicit causal stories from students during the second key drop episode:

35. Mr. S: I was basically trying to get them to, to, to, to weigh in all the potential factors and also to, um, to come up with some kind of causal story as to how and where the, the item should be dropped. What are those factors, and uh, trying to get them to think more deeply about the movement of the, of the keys as related to the container.

36. Jen: Okay, so like the factors are part of an explanation-

37. Mr. S: Right.

38. Jen: And the causal story is relating the factors to –

39. Mr. S: The causal story, the causal story would, would utilize those various factors in its explanation as to how, how the keys would fall [Interview, October 2012].

Here, Mr. S indicated that causal stories incorporated the causal factors he focused on during the first key drop episode, but the factors were parts of broader explanations about "how the keys would fall" [line 39]. In other words, identification of the relevant causal factors was not the endpoint, but rather part of the process of telling deeper causal stories about the movement of the keys.

This push beyond causal factors became most apparent in an exchange between Mr. S and a student, Chavez, about the speed of the runner making the keys move forward:

40. Chavez: If you do it before, it'll go directly in? But if you do it like, like-

41. Mr. S: Why do we have to do it before again?

42. Chavez: Because it'll go, like, IN, like the keys will go in the trash can or the thing will go in the trash can.

43. Mr. S: What will cause it to go in the trash can if we drop it before as opposed to over, because ear::lier you said over?

44. Chavez: Like, like, like, like, like the speed of the keys also I guess coming off.

45. Mr. S: The speed of the- so the keys have speed?

46. Chavez: Because you're walking, no, because like you're walking? (pause) And like, and like since you're walking fast, like, I guess the keys will also go fast too?

47. Mr. S: The keys will go fast too?...

48. Chavez: (pause) Yeah.

49. Mr. S: Why will the keys go fast too?

50. Chavez: I don't know!

51. Mr. S: I re::leased the keys, wouldn't the keys just be there? [Episode, March 2011]

Recall how the exchange between Mr. S and Diane went the previous year when the idea of speed came up – Mr. S simply acknowledged Diane's idea of speed and moved on to another student. Here, there are notable differences in Mr. S's response, despite the parallels between Diane's idea that "the car's fast, and you're going fast too" [Episode, April 2010] and Chavez's idea that "since you're walking fast… the keys will also go fast too" [Episode, March 2011]. First, Mr. S did not simply accept the idea of speed – he initially started to repeat it (line 45) and then reflected the idea back to Chavez with a questioning intonation (lines 45, 47). Second, Mr. S pushed Chavez to fill out an additional part of the story by asking, "Why will the keys go fast too?" [line 49]. This question, followed by Mr. S's counterpoint that the keys might "just be there" once they're released (line 51), indicates that Mr. S was interested in more than the identification of speed as the relevant causal factor. He was also interested in Chavez fleshing out a causal story for how the keys would still have speed after they'd been released.

Thus, although Mr. S attended to both causal factors and causal stories to some extent in both episodes, we can see that he foregrounded one or the other in each case. I now turn to a discussion of why Mr. S's foregrounding of causal stories represents a favorable change over his foregrounding of causal factors.

Considerations of Explanatory Sophistication in Science

Work in science education (e.g., Chinn & Malhotra, 2002; Russ, Scherr, Hammer, & Mikeska, 2008; Sandoval, 2003; Windschitl, Thompson, Braaten, & Stroupe, 2012) emphasizes the importance of students constructing complete causal explanations or narratives for phenomena. For instance, Chinn and Malhotra drew on work from the psychology, sociology, philosophy, and history of science to argue that one aspect of what they call authentic inquiry is "the development of theoretical mechanisms with entities that are not directly observable" (p. 186). Sandoval's analysis of causal coherence in students' scientific explanations also focused on causal mechanisms, how students chain causes and effects to create coherent explanations of phenomena. In creating and developing causal stories of how or why something happened, students engage in a practice that is arguably at the core of what scientists strive to do.

When possible, fleshing out causal stories is a more sophisticated form of scientific explanation than simply identifying relevant causal entities or factors (Russ, Scherr, Hammer, & Mikeska, 2008; Windschitl, Thompson, Braaten, & Stroupe, 2012)[26]. For instance, Russ et al. developed a framework for analyzing students' mechanistic reasoning, adapted from philosophy of science studies on the work of scientists. In their framework, "identifying entities" or "objects that affect the outcome of the phenomenon" (Russ et al., p. 512) is one component of mechanistic reasoning – more sophisticated mechanistic reasoning involves identifying the activities various entities engage in and how they are organized relative to each other, as well as chaining forward and backward to create step-by-step stories of how various phenomena occur. In other words, identifying causal factors contributes to but is less sophisticated than telling causal stories, which requires consideration of how the factors behave and interact with each other over time.

Moreover, in the context of the key drop conversation, students demonstrated the ability to engage in causal story-type reasoning that could have been capitalized on both years. Take Diane's racecar example from the first key drop episode as a focal point. As we saw, when identifying relevant causal factors was foregrounded, the rich detail that Diane offered was summarized as having to do with speed and forward motion. Although

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[26] That said, there are certainly situations in which foregrounding the identification of relevant causal factors is appropriate, like when engaging in experimental design (e.g., Ford, 2005; Toth, Klahr, & Chen, 2000). The identification of relevant causal factors for a given phenomenon provides useful insights about the phenomenon and predictive power with respect to similar phenomena, and is a publishable finding in various scientific disciplines, such as ecology, epidemiology, etc. See publications like "Changes in sub-alpine tree distribution in western North America: a review of climatic and other causal factors," or "Risk factors for ectopic pregnancy: a comprehensive analysis based on a large case-control, population-based study in France."

this summary was coherent with Diane's idea, it quickly slotted her idea as a certain kind of thing rather than permitting further exploration and probing of her explanation. Yet imagine what this exchange might have looked like if it occurred in the second key drop episode, when constructing causal stories was foregrounded. Judging from the Chavez exchange, Diane might have been asked to explain why you would still be going fast once you jumped out of the car. Rather than assuming that the same mechanisms were in play in the key drop scenario and the racecar example, like in the first key drop episode, the relationship between the situations might have been called into question. In short, it is likely that various aspects of Diane's explanation would have received deeper attention and more air time in the context of the second episode as compared to the first.

Thus, the favorable change seen in Mr. S's attention and responsiveness to the substance of students' scientific thinking between the episodes can be characterized by the aspects of scientific explanation he recognized and sought to promote with respect to students' ideas. This shift in foregrounding also corresponds to another dimension of favorable change noted above – the specificity with which Mr. S attended to students' ideas. A causal stories foregrounding necessitates attention to the details of students' explanations, to how the posited entities and activities are connected, in a way that is not required by a causal factors foregrounding. However, with the other dimensions noted above – the general stance Mr. S took toward the ideas he heard, and the types of follow-up moves he deployed – it is more difficult to see differences between the episodes. In neither case did Mr. S direct the conversation toward the correct answer, nor did he listen passively – he seemed to be engaged in interpreting what students were saying in both episodes. Similarly, drawing on Brodie's (2011) scheme, the most frequent types of follow-up moves in both episodes were the reform-type moves of maintaining focus on students' idea and pressing for more information. What *was* distinct between the episodes was the kind of information Mr. S pressed *for* in each – again, related to which aspects of scientific reasoning he was foregrounding.

Part 2: Exploring Influences On and Considering the Stability Of the Shift

Given the shift in foregrounding between the key drop episodes, I sought to better understand the influences contributing to Mr. S's foregrounding in each case. Here, I highlight three sets of influences that differed between the episodes – 1) the nature of Mr. S's own explanations of scientific phenomena at the time, 2) how the discussion was situated with respect to other classroom activities, and 3) how the discussion was structured. I also explore what this additional information could tell us about the stability of the shift in Mr. S's practice.

Mr. S's Own Scientific Explanations

First, the kinds of explanations Mr. S put forth about scientific phenomena himself shifted slightly between the episodes. During the first summer workshop (before the first key drop episode), Mr. S and his colleagues grappled with the key drop question themselves, and the explanations Mr. S gave often centered on factors and how they interacted with each other. For instance, on the first day of the inquiry, Mr. S was discussing how water would fall from a crop plane on a windless day with a small group of teachers, and he offered that the momentum of the plane, temperature, and air pressure

would all matter in determining what would happen to the water, with little detail about how or why. A bit later, the same group was discussing a similar scenario in which there was now not only no wind, but no air, and Mr. S highlighted that "two of the main factors" [Workshop, July 2009] would be the altitude and speed of the plane. During a whole-group discussion several days later, Mr. S stated "I think there are many factors" and offered the following comparison:

> … if we increase the speed, or keep the speed constant at a certain level and increase the weight, at some point the impact of gravity on the weight of the object's going to be greater than the momentum causing the object to go forward [Workshop, July 2009].

Here, Mr. S identified two relevant factors with regard to the motion of the keys – speed and weight. He seemed to be specifically considering a situation in which speed was kept constant and weight was constantly increasing, and he thought there would be a point at which gravity (causing the object to move down) would overcome momentum (causing the object to go forward). It is likely that what Mr. S attended to within students' ideas during the first key drop episode was influenced by his sense of what constituted a satisfactory scientific explanation at the time – namely a factors-based explanation, the kind he offered during his own inquiry on the same topic.

During the second summer workshop (before the second key drop episode), we emphasized the idea of mechanism more directly than we had the previous summer, and this idea worked its way into Mr. S's own inquiry and his sense of causal stories. For instance, one of the physical science inquiries during the second summer workshop involved the pendulum pictured below, with a peg approximately thirty-five centimeters below the attachment point of the string:

Figure 5-1. Pendulum used in inquiry in second summer workshop.

Teachers were asked to predict how high the pendulum would swing if it was released at twenty. Mr. S predicted that the pendulum would swing higher than twenty and gave the following reasoning:

> The reason I think it's gonna go higher than twenty is because – when you lower it from, when you drop it from twenty, that second pin, somehow the –

> momentum that was in the first part of the string is going to be transferred to that second part of the string, and it will have more momentum – after it hits that pin, causing that part to go higher… because it accelerates the speed of the string, and by accelerating it, it'll cause the, uh – the ball to go higher [Workshop, July 2010].

As in the key drop inquiry during the first summer workshop, momentum was a key consideration for Mr. S. Yet here, his explanation involved more of a story of how momentum mattered for the motion of the pendulum – once the string hit the pin or peg, the momentum at the top of the string would transfer to the bottom of the string and cause the bottom of the string to go higher. As he continued, he filled out more of the story, suggesting that increased momentum in the bottom of the string would cause that portion of the string to accelerate and therefore go higher[27]. Thus, instead of simply tying a causal factor to an outcome (e.g., momentum causing the pendulum to go higher), Mr. S spontaneously started to flesh out mechanistic connections between the two.

A closer look at an emergent debate between Mr. S and another teacher, Ms. R, during a teacher meeting prior to the second key drop episode demonstrates that mechanism became an integral part of how Mr. S thought about causal stories. At the meeting, teachers were looking at student work about sinking and floating, and Mr. S questioned why Ms. R considered "causal story" and "mechanism" to be distinct:

52. Mr. S: So the, so [the student] is saying that it's sinking because water's going through the holes, that's not a causal story?

53. Ms. R: That's her, I took it as that's her mechanism of what the holes are doing.

54. Mr. S: So, but how is it not a causal story? It's an explanation of how it takes place, how it floats, how it sinks, right? [Meeting, November 2010]

Later, Ms. R gave a clearer sense of what she meant by "mechanism," and Mr. S again related this to his sense of "causal story":

55. Ms. R: Mechanism is how is it working, what's causing it to, like the bicycle moving.

56. Mr. S: See, what I think is that your, from what you just said, mechanism is what we've been talking about as a causal story [Meeting, November 2010].

From these interactions, we can see evidence that the ideas of explaining how something takes place and mechanism are part of Mr. S's sense of causal stories. This likely

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[27] Of course, other parts of the story could be filled out as well – for instance, how does the momentum from the top of the string transfer to the bottom of the string? The point here is that Mr. S started to do this kind of work in his explanation.

contributed to his pushing beyond the identification of causal factors during the second key drop episode.

Positioning of the Discussion

Second, the discussion was situated differently with respect to other classroom activities in the pair of episodes. In the first key drop episode, Ayush's field notes indicated that the plan for the day was to "draw three trajectories of the falling keys and take kids' reasoning again on each trajectory… Then to ask them to think carefully about how they want to test their idea and what the test outcomes could tell" [Field notes, April 2010]. Engaging students in discussion about the key drop scenario, then, was intended as a precursor to designing experiments to test their ideas – a context in which identifying potential causal factors becomes important. In fact, as Mr. S made a bid to transition to the experimental design part of class, he explicitly asked students about relevant factors:

57. Mr. S: So what's a common theme- what's a common factor that we need to look at?

58. Student: Can we test it?

59. Mr. S: Yeah, but as we test it, what is something we need to look at? What's a common factor we need to look at?

60. Student: Speed [Episode, April 2010].

Note that the first factor a student raised in line 60 was the factor Mr. S pressed Diane for earlier in the discussion. It is likely that Mr. S's press for causal factors with respect to students' ideas was influenced by his sense that the factors would become useful in designing experiments later in the period.

Alternatively, in the second key drop episode, Mr. S did not anticipate testing students' ideas the same day – in fact, he pushed back when a student suggested doing so ("Well not ((holds hands toward Drake)), maybe not, maybe-" [Episode, March 2011]). Instead, the second key drop episode took place on what Mr. S called "inquiry-based Monday" [Meeting, January 2011], in which the whole period was devoted to discussing a scientific phenomenon. During a teacher meeting, Mr. S reflected on this as a major distinction from his first year in the project:

> Before it was like part of a lesson, so I wanted to make sure that, that I, that I had, like, an inquiry part of the lesson, and then I would get to the exploration part of the lesson? As opposed to let the inquiry sit- that, that's the key difference. This year, the inquiry is, is kind of sitting alone by itself, connected to what happens during the week, but not – not so integrated to it that, that the inquiry can't take its own, go in its own direction, you know?... I think when we, when we made a space for the other possible causes, causal stories, uh, the kids have been – so far, you know, they've been, they've been coming up with them, you know? [Meeting, January 2011]

Here, Mr. S reflected that inquiry-based Monday allowed the inquiry to takes it own direction. This more open version of inquiry created a space for other "possible causes, causal stories" that may not have had space the previous year. Without an experiment to get to, Mr. S was freer to follow students' ideas for an extended period of time and probe for more detail in the service of fleshing out causal stories.

Structure of the Discussion

Third, the discussion was structured differently in both episodes. In the first key drop episode, Mr. S facilitated a whole-class discussion, which he noted was similar to the structure he experienced as a participant in the key drop inquiry during the first summer workshop. He also recorded students' ideas on the board. Though he productively referred to the board in clarifying his understanding of students' ideas and later asking students to counterarguments to specific ideas, the act of recording may have reinforced his focus on causal factors as he could jot them down quickly and populate the board. In the second key drop episode, though, Mr. S did not take notes and used something called a "fishbowl" discussion structure. This structure involves approximately six students sitting in an inner circle (the "fishbowl") and discussing a topic while the rest of the students sit in an outer circle and listen and reflect on the inner circle's discussion. Eventually, students in the outer circle are allowed to contribute, and all students rotate through the "fishbowl" over the course of the discussion. Mr. S indicated at a teacher meeting that he's "able to listen more clearly to what kids are saying – because there are only four or five kids around the table, at the most six?" [Meeting, January 2011]. Thus, use of the "fishbowl" discussion structure in the second key drop episode afforded Mr. S the opportunity to delve more deeply into fewer students' thinking at a time, as compared to the whole-class discussion format.

Considerations of Stability

The influences described above provide some insight into the stability of the shift in Mr. S's attention and responsiveness to student thinking. To be clear, I am not claiming that the episodic shift *is* representative of a more stable shift on Mr. S's part – I am not sure what the evidentiary threshold would be to make such a claim at this point. I do, however, see evidence that is suggestive of and could contribute to such a claim.

The primary aspect suggestive of a more stable shift is how Mr. S came to draw on structures that he felt supported close attention to student thinking. In the first key drop episode, he mimicked what he had seen when he participated in the key drop inquiry in his first summer workshop experience. By the second key drop episode, though, he had clearly given much thought to how he could best facilitate such discussions in his own classroom. He felt that the structures of inquiry-based Monday and the fishbowl discussion gave him space to pursue students' causal stories in depth, and he indicated (and other video records bear out) that he drew on them repeatedly during his second year in the project. It is this strategic decision-making on Mr. S's part, accompanied by forethought in terms of what he's aiming for and developing metaawareness of what works for him, that make the shift seem more than merely episodic.

Conclusion and Implications

In Part 1 of this chapter, I demonstrated that the shift seen in Mr. S's attention and responsiveness to the substance of students' scientific thinking between the key drop episodes hinged on which aspects of scientific explanation he foregrounded in relation to students' ideas. In his first classroom implementation of the key drop inquiry, Mr. S foregrounded students' identification of the causal factors or force-like entities responsible for the motion they predicted, such as *gravity* moving the keys down, or *speed* resulting in the keys' forward motion. Mr. S's subsequent classroom implementation of the key drop inquiry the following year, though, involved a more sophisticated foregrounding – students' articulation of causal stories of what they thought would happen. Here, mechanism was more of an emphasis, e.g., gravity *pulling the keys* down, or a lingering question about how the keys still have speed once they're released. This analysis adds to current characterizations of favorable shifts in attending and responding to student thinking by bringing in disciplinary-specific considerations of what the teacher is recognizing and seeking to promote in student reasoning, and its appropriateness for the instructional context.

In Part 2, I explored likely influences on Mr. S's foregrounding in each case, highlighting distinctions in the nature of his own scientific explanations, other classroom activities that were planned, and structural differences in the discussions. While I would classify the shift as episodic, since only two observational points were noted, there are aspects of the data that are suggestive of a more stable shift in Mr. S's practice. Specifically, Mr. S's planning and implementation of structures that he felt afforded close attention to students' ideas indicate that he was actively and repeatedly attempting to work this kind of focus into his classroom activity.

To conclude, I consider the implications of this work for professional development and research in which students' disciplinary ideas are at the core of teachers' attention.

Implications for Professional Development

When students' disciplinary ideas are central to professional development efforts, a critical topic for ongoing discussion should be the various disciplinary aspects that participants (including professional developers) note with respect to student thinking. What could participants notice that is scientific, or mathematical, in what students are saying and doing? For instance, in this study, explicit discussion of mechanism in the second summer workshop likely influenced Mr. S's sense of what to pay attention to in students' explanations, and how and when to press students to fill in gaps. More explicit discussion of such disciplinary aspects could help teachers open up space for students to explore and develop a more holistic sense of a given discipline.

Moreover, more explicit discussion would promote metaawareness in teachers of what they are foregrounding in given moments. Mr. S used the terms causal factors and causal stories interchangeably until our interviews together in September and October of 2012, when I asked him how the terms related to each other. The relations he posed between causal factors and causal stories in lines 35-39 above occurred during our last interview together, after opportunity for reflection on my question and *far* after the analyzed episodes. Thus, it is important to note how different and pervasive his

foregroundings were in both episodes *without* his explicit awareness, and to recognize how much *more* powerful and purposeful these foregroundings could be *with* his explicit awareness. Such awareness might also facilitate teachers' shifting among aspects more responsively in the course of authentic disciplinary practice with students, demonstrating a sort of flexibility that might represent another avenue of growth for Mr. S and others.

Implications for Research

In terms of research, it would be beneficial to understand more about the impact different disciplinary foregroundings have on what students come to see as authentic disciplinary activity. For instance, shortly after Mr. S recapped Diane's idea as having to do with speed in the first key drop episode, a visiting member of our research team, Ayush Gupta, asked, "Folks, did you hear that reasoning?" [Episode, April 2010]. A student responded, "Yes, it's based on speed" [Episode, April 2010], suggesting that Mr. S's foregrounding of causal factors may have been picked up by students as a sufficient explanation. Exploring such potential connections between teachers' foregroundings and students' senses of the discipline is a ripe area for future research.

Future research could also target how explicit professional development discussions of various disciplinary aspects impact teachers' classroom practice. Do teachers exhibit enhanced metaawareness about what they are attending and responding to within students' ideas? If so, do they demonstrate more or less flexibility in what they foreground, and for what purposes? Such questions could be explored in continuing professional development projects aimed at enhancing teachers' attention and responsiveness to the substance of students' disciplinary thinking.

Finally, more work is needed on how we might assess whether shifts in teachers' attention and responsiveness to student thinking are more episodic or stable in nature. To claim that a shift is stable, multiple observational points would need to be examined for consistency over time, but I am not sure at what grain size or where the evidentiary threshold (or thresholds) would lie. This study has highlighted other sorts of evidence that may be marshalled in support of stability as well, such as evidence from how teachers plan for instruction or the metaawareness teachers demonstrate with respect to aspects of their classroom activity. If we hope to promote classroom instruction that is grounded in students' disciplinary ideas, we need to continue to refine our sense of what progress in teachers' attention and responsiveness to the substance of students' disciplinary thinking looks like.

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Chapter 6: Discussion and Future Directions

Recall the research question guiding this dissertation work: "What might stabilize teachers' attention and responsiveness to the substance of students' scientific thinking during sustained classroom episodes?" Chapters 4 and 5 each provided an in-depth look at pairs of classroom episodes exhibiting different characteristics[28]. In Chapter 4, I examined what may have contributed to teachers' attention and responsiveness to student thinking in two episodes where the discussions that ensued were not preplanned but rather came into existence due to what students offered. In both cases, teachers demonstrated intrigue with respect to aspects of the emergent discussions – in Ms. L's case, the scientific topic under discussion, and in Ms. R's case, the unexpected ideas students came up with. The teachers also saw the emergent discussions as ways to promote deeper content understandings among students, with content including both conceptual ideas in play and relevant epistemological understandings of scientists' processes and purposes. Finally, the teachers valued the discussions as ways to support students in seeing their own ideas as worthwhile.

In Chapter 5, I looked at two episodes in which the "same" lesson was enacted by Mr. S in consecutive years. Although he attended and responded to students' ideas both years, he foregrounded different facets of scientific explanation in relation to students' ideas, and his foregroundings were likely tied to the local coherences in each case. As discussed in Chapter 5, these local coherences included Mr. S's own evolving sense of what constituted a satisfactory scientific explanation, how the discussions were positioned relative to other classroom activities (whether they were tightly coupled with what came next or set apart), and the various structures Mr. S drew on in organizing the discussions.

Looking across these four episodes, there are many different types of elements that were co-occurrent, salient to the teachers, and plausibly involved in the local coherences. For instance, the intrigue evidenced by Ms. L and Ms. R could be considered *dispositional* in nature, likely reflective of their own personal tendencies to find certain things interesting. Other aspects reflect *goals* teachers have for their students, *knowledge* about science, and *material* or *structural* components of the environment that influence the flow of classroom activity. In what follows, I look more holistically across all nine selected episodes to highlight examples of the different types of elements in play.

Types of Elements

While completing my analyses, a point that I and others noted was that the kinds of aspects I was positing as parts of the coherences were varied. For instance, in Mr. S's second episode where students were discussing how dinosaurs became extinct, the fishbowl discussion structure was different in nature from Mr. S's intrigue with respect to a particular student's idea. In Ms. R's third episode where students proposed rules for energy, her use of the Word document to record what students said was different in

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[28] This is a point worth noting – even though all selected episodes met the criteria specified in Chapter 3, there was still much variability among the episodes.

nature from her attempts to hold students accountable to what they said. Here, I reflect on the major types of elements in play. Note that I do not consider this list to be exhaustive, but rather a synthesis of some of the primary categories that seemed to influence teachers' attention and responsiveness to student thinking in the classroom. Note also that these categories demonstrate considerable overlap and entanglement with each other in real time.

Beliefs

Teachers' beliefs about the process of learning at times played a role in their emphasis on students' ideas. For instance, in the effort to reconcile what counts as a crest in the first episode from Ms. R's classroom, Ms. R indicated that without discussion, students "probably would have just memorized whatever you said, but not understood" [Interview, December 2012]. This kind of statement is consonant with a more constructivist orientation toward learning (Hashweh, 1996), in which deep learning emerges when students substantively engage with their own and others' ideas.

Dispositions

As highlighted above, teachers' dispositions toward aspects of the discussions may support their sustained engagement with and pursuit of students' ideas. At times, teachers demonstrated curiosity about things they found interesting, such as the question of why the foxes got dropped in Ms. L's second episode, or Evan's idea about the meteor shower killing all the female dinosaurs in Mr. S's second episode. Teachers also demonstrated a deep sense of caring for their students, including their desires and ideas – Ms. L described how students "seem to come alive" when they realize that "their ideas… are considered valuable" [Interview, October 2012]. Tapping into these broader dispositions of what teachers find interesting or their care for their students may stabilize their focus on students' ideas.

Goals

Teachers' goals for their students, either preplanned or emergent, may also influence teachers' attention and responsiveness to the substance of students' scientific thinking. Goals that contributed to a focus on students' ideas in the selected episodes included promoting 1) deeper content knowledge among students, 2) a sense of accountability to their stated ideas, and 3) confidence in their abilities to contribute productively to class discussions and the creation of scientific understandings.

Knowledge

Additionally, teachers' knowledge of various facets of disciplinary practice, as well as how to marshal them in instruction with students, may impact teachers' attention and responsiveness to students' disciplinary ideas (see discussions of various categories of content knowledge in Shulman, 1986; or mathematical knowledge for teaching in Hill, Rowan, & Ball, 2005). This was most evident in the case of Mr. S, whose evolving sense of what constitutes a sufficient scientific explanation influenced his interactions with students' explanations in the key drop discussions. Also, Mr. S's sense of familiarity with

some of the ideas likely to come up in the key drop discussion afforded some comfort and may have helped Mr. S process some of the ideas students put forth in his initial enactment.

Materials

The materials used in the episodes also played a role in focusing teachers on students' ideas. For instance, in Ms. R's first episode, the nature of the wave created by the jumprope (with varying crest heights) and the positioning of the jumprope in the middle of the room (such that students on different sides of the room counted different numbers of crests) provided the initial fodder for discussion. Moreover, as students articulated how many crests they counted, Ms. R regularly asked them to point out the specific crests on the jumprope, using the jumprope as a common representation to clarify understanding of students' ideas. Teachers also used a variety of means to record students' ideas, including a projected Word document, the board, and their own notes.

Outcomes

A kind of element that seemed particularly salient for teachers was the outcomes they observed from students when they made students' ideas central to instruction. Ms. L repeatedly emphasized how "into it" students were and the sorts of intellectual work they were doing, and indicated that students' substantive engagement with discussions made continuation "unavoidable" in the moment [Interview, October 2012]. Mr. S also regularly noted the participation of students who did not typically participate and felt that in discussing their own ideas, they were able to "demonstrate their strengths" [Conversation, April 2010]. This focus on the outcomes seen when teachers attended and responded to students' scientific ideas is consistent with work from CGI illustrating the power of teachers seeing what students actually do when they alter their instruction (Fennema et al., 1993; Fennema et al., 1996; Franke et al., 1998).

Structures

Finally, various structures that teachers experienced or put in place helped to sustain their attention and responsiveness to students' scientific ideas. For instance, many of Ms. R's and Mr. S's plans explicitly built in opportunities to emphasize and build on students' ideas, with Mr. S in particular trying out and adopting structures that facilitated his close attention to student thinking (like inquiry Monday and the fishbowl discussion structure).

Complicating Existing Models of Teacher Behavior

The presence and interaction of all of the kinds of elements described above complicate the use of any particular construct, or even models that incorporate multiple constructs, to explain teacher behavior in the classroom. Here, I will focus primarily on Schoenfeld's (1998) theory of teaching-in-context, as it is a well-cited and detailed model that strives to represent the world of the classroom as seen by the teacher. Schoenfeld argues that in any given moment, a teacher's goals, beliefs, and knowledge interact in a manner that can explain the teachers' moment-to-moment decision-making. These goals,

beliefs, and knowledge may be present at a variety of grain sizes. For instance, goals may be general, overarching goals for the year or specific goals for a portion of a lesson. Beliefs may include a teacher's beliefs about the nature of the subject matter he is teaching, the teaching and learning process as a whole, and his particular students and classes. Knowledge may include broader categories such as subject matter knowledge and general pedagogical knowledge but also smaller bits of knowledge such as a classroom routines. According to Schoenfeld, "At any given moment, there is a constellation of highly activated beliefs, goals, and knowledge" (p. 16) that are consistent and mutually supportive, with the highest priority components dictating the composition of the constellation and the activities that ensue in the classroom. As the context changes, the highest priority components and resultant constellations and activities change in concert.

From my analyses, I have two primary concerns with Schoenfeld's (1998) model. First, I am not sure how to think about the role of dispositions with his framework. Take Ms. L's second episode in which she and her students pursued an explanation of why the foxes got dropped from the textbook diagram as an example. One could conceivably model Ms. L's activities with Schoenfeld's model. When Albert asked the question about the fox, the context of the lesson drastically changed. Ms. L realized that she did not know the answer to Albert's question (*knowledge*), and recognized the question as a great opportunity for students to engage in the process of classification (fulfilling one of Ms. L's *goals* that was potentially tied to a *belief* about how to most effectively learn about classification). Yet what is absent from this explanation is the role of Ms. L's own curiosity about why the foxes got dropped. Her curiosity came as a result of a lack of knowledge, but it is not quite knowledge itself, nor is it a belief. It could be modeled as an emergent goal of understanding why the foxes got dropped, which influenced her classroom activity. But simply accounting for it as an emergent goal loses the driving force behind the goal – namely, her curiosity. An important piece of the coherence would be missing if Ms. L's curiosity was not taken into account.

Second, Schoenfeld's model would likely relegate materials, outcomes, and structures to the *context* that influences the constellation, rather than as part of the constellation itself. This would position materials, outcomes, and structures as aspects that influence teachers' behavior only through their influence on teachers' goals, beliefs, and knowledge. However, it is at least plausible that in the moment, these aspects directly influence teachers' behavior, as suggested by Ms. L's sense that students' excitement and engagement (an *outcome*) made continuing the discussions unavoidable (a *behavior*). One could build in intermediary links involving Ms. L's goals, beliefs, or knowledge, but it is unclear why one would need to do so.

In short, what I am arguing for is a more grounded, empirical approach to determining what is part of a given local coherence or constellation. Schoenfeld's (1998) model is one example of an approach that defines relevant constructs to consider a priori, and while the constructs are certainly useful and provide explanatory power, I worry that they may in effect limit attention to other important aspects of what is going on. Seeking to identify aspects that are in play in the data, and taking a complex systems approach to understanding the positioning of and interactions among those aspects, may provide a better empirical "fit" at this point.

Ramifications for Working with Teachers

In terms of working with teachers, there are dimensions that cut across the identified aspects that might be salient to consider. Below, I describe several of these dimensions and their implications. I later highlight particular aspects that were salient for individual teachers, demonstrating the importance of being responsive as professional developers, as well as aspects that cut across teachers, which might serve as meaningful foci for professional development efforts.

Preplanned vs. Emergent in Interaction

One dimension along which elements differed was whether they were preplanned by the teacher or emerged from the interaction in some way. For instance, Ms. R setting aside space for students to articulate their ideas or rules about scientific phenomena and using a Word document to record their ideas are reflective of preplanning on Ms. R's part, and all of Mr. S's episodes involved some amount of preplanning as well. But there were also aspects that arose during the episodes that were salient but not preplanned, such as Ms. R's attempts to get students to offer ideas that made sense to them (rather than textbook answers) or Mr. S's awareness of who was participating in the discussion.

As evidenced in Chapter 4, it is easier to work with teachers on preplanned matters, such as brainstorming questions likely to spark discussion or identifying structures that help teachers keep track of students' ideas. Yet emergent matters are critical to understand as well. Work from CGI (Fennema et al., 1993; Fennema et al., 1996) suggests that seeing what students do when they are given space to share their ideas in the classroom is meaningful and convincing for teachers, and I further argue that seeing what teachers find meaningful and convincing, specifically, gives professional developers insight into what matters to teachers. For instance, Ms. R's sensitivity to students' appeals to the textbook as they emerged during discussions reflects a matter of real import to her – whether students are thinking about what makes sense to them and deepening their own understanding. In fact, she now expects this issue to emerge and plans to focus on it more directly at the beginning of each school year, illustrating how something that was emergent can transition into something that's taken into account in the planning process.

Additionally, capitalizing on salient, emergent elements ties closely to the second sense of responsiveness I described in Chapter 4, in which teachers alter plans in response to directions or ideas from students. Specific aspects that teachers notice and find salient might influence the ways in which they alter their plans. For instance, Ms. L engaged in discussion with students around Albert's emergent question in the second episode from her classroom in part because she saw it as aligned with the understandings she wanted to promote about classification and its underlying logic.

Stable vs. Episodic

Another dimension along which elements differed was whether they themselves were relatively stable during the episode or more episodic in nature. For instance, while watching video of the first episode from her classroom, Ms. L repeatedly commented on how students were so "into it," meaning the discussion that was happening. Even though

this aspect of what occurred was emergent – Ms. L noted it in interaction with her students – her repeated commentary suggests that it may have been a fairly continuous consideration on her part throughout the episode. In contrast, in Mr. S's third episode, he and his students periodically created local representations of the key drop scenario they were discussing, indicating where various objects would be positioned relative to each other. This only occurred in an episodic manner, as needed to facilitate communication.

In terms of working with teachers, more stable aspects are likely to be more influential than fleeting aspects. However, this depends on the timescale on which we determine stable vs. episodic. Above, I considered stable vs. episodic within a given episode; yet if the timescale was extended to several episodes, we see that Mr. S's use of representations or other means to record and understand what students said was relatively stable across episodes. Thus, in interacting with a teacher, it makes sense to consider multiple timescales – if something is fleeting in a given episode and seemingly idiosyncratic, not appearing in other episodes, it may not be particularly useful to draw on in working with the teacher. If an aspect is relatively stable within an episode and/or across episodes, it may be a meaningful focal point. Aspects that appear across episodes but in a fleeting manner may be most productive in working with teachers, as teachers regularly draw on them but not as stably as they could.

Explicit vs. Implicit

A third dimension to consider is whether the teacher is explicitly aware of the impact of the element or not. As stated in Chapter 3, my analytical approach drew heavily on teachers' reflections, meaning explicit saliences were particularly apparent. Teachers described how they planned for the episodes (if they did), what stood out to them as important about what students were doing, and what they thought they were trying to do during the episode. Understanding these explicit saliences is important from a professional development standpoint, as we can interact most readily with these.

Yet there were also aspects that teachers did not seem to be as aware of, such as Mr. S's focus on causal factors in the first episode from his classroom. In fact, it wasn't until our interviews together that Mr. S was asked to attend to the distinction between causal factors and causal stories, which seemed largely undifferentiated to him previously as described in Chapter 5. While such aspects are more difficult to discuss, raising teachers' awareness might give teachers more agency over them in the classroom.

Salient Aspects for Individual Teachers

In this section, I describe aspects that were likely parts of the coherences across episodes for individual teachers. For Ms. L, her own interest in the scientific phenomena under discussion played a role in the first two episodes, and its absence in the third episode may have contributed to the episode's generally less stable nature. Ms. R showed a strong proclivity to react to students providing book-like knowledge rather than their own ideas, which cut across all three episodes. And Mr. S demonstrated more attention to structures that would help him facilitate inquiry than the other teachers, as well as attention to the increased participation of marginalized students in the discussions. While these salient elements were not absent from other teachers' episodes, they appeared most consistently as part of a given teacher's practice.

Ms. L's own interest in the topic under discussion was most apparent in the second episode when Ms. L inquired about the foxes with her students, hoping to resolve why they were separated from the coyotes and wolves in the classification scheme. Her own interest may have also been in play in the first episode, particularly given that the question of whether magnets work underwater later turned into a week-long unit driven largely by students' ideas. In the third episode, however, Ms. L noted that the topic did not capture her interest. This point of contrast between the episodes highlights a relationship between Ms. L's level of interest and her responsiveness – her interest in the question in the second episode was accompanied by fairly stable attention and responsiveness to students' ideas about the question, whereas her relative lack of interest in the question in the third episode was accompanied by more variability in her focus.

A notable commonality across episodes for Ms. R was her sensitivity to students providing book-like responses. This was most prominent in the second episode, when Arielle and several other students provided a formula for density and Ms. R pressed them on what density meant to them. It also occurred in the first episode with Rosie and in the third episode with the orange group, in each case sustaining Ms. R's attention to the student or group of students and the sense they were making of the book-like response. This sensitivity to appeals to the book or other perceived sources of authority likely connects to Ms. R's articulated goal for her students to be critical thinkers and to work to make sense of ideas for themselves.

For Mr. S, one commonality was the strong role that preplanning seemed to play in his inquiry discussions. In each episode, the opening question and often follow-up questions were brainstormed ahead of time, as were the structures that Mr. S used for facilitation – taking notes on the board in the first episode, and setting up the structures of inquiry Monday and the fishbowl discussion in the second and third episodes. Moreover, many of these plans were brainstormed in collaboration with other colleagues on the project. For instance, Mr. S commonly cited conversations with Ayush as integral to the planning process, and the fishbowl discussion structure was in part borne out of conversation with Ms. R about how she used it in her classroom.

Another commonality was the extent to which Mr. S attended to *who* was speaking in inquiry discussions, in light of students' previous participation in class. In the first episode, Mr. S noted several students who participated in new ways relative to how they had participated before, and Nat's participation in particular remained salient for Mr. S years after the fact. Similarly, Mr. S commented on Drake's participation in the third episode as atypical for Drake. Noticing who is talking does not necessarily stabilize attention and responsiveness to the *substance* of what students are saying, but Mr. S felt that part of what supported such students' increased participation was their sense that their ideas were respected and valued in inquiry discussions. Thus, he promoted their participation by closely attending and responding to what they were saying, potentially reinforcing their participation, and so on.

Such commonalities across episodes for individual teachers demonstrate that teachers have their own approaches and saliences with respect to attending and responding to student thinking. What might work to engage Ms. L in focusing on students' ideas might not engage Mr. S, and vice versa. This suggests that professional development programs would benefit from building in one-on-one interactions with teachers, in which professional developers could be responsive to individual teachers'

needs and preferences. Yet there were also elements that cross-cut numerous teachers' episodes, which I describe next.

Aspects that Cut Across Teachers

Two aspects that were apparent in at least one episode from each focal teacher (and often numerous episodes) were teachers' intrigue with respect to aspects of the discussions and their care and respect for their students. I address each aspect in turn.

Intrigue with Respect to Aspects of the Discussions

All teachers demonstrated some amount of intrigue with respect to the discussions that occurred in their classrooms, but their intrigue was distinct in nature. For Ms. L, she more often demonstrated curiosity with respect to the scientific topic under consideration, as seen most clearly in the second episode from her classroom. After Albert raised the question about why the foxes got dropped from the classification scheme, Ms. L repeatedly indicated that she did not know the answer but found the question interesting. She oriented to students' ideas as possibilities to consider and build on herself, and her evident interest may have promoted students' continued posing of ideas.

Ms. R and Mr. S, on the other hand, tended to be intrigued by what students were thinking. In the first episode from Ms. R's classroom after students had provided numerous responses to how many crests there were on the jumprope, Ms. R demonstrated close attention to novel ideas from students, even if she did not draw on them further in her instruction. Similarly, in the second episode from Mr. S's classroom, Mr. S was intrigued by Evan's unusual idea that a meteor shower would kill off the female dinosaurs. His intrigue spurred curiosity and further pursuit of Evan's idea in the moment. In these cases, the teachers' intrigue was not directed toward the scientific topic itself, but rather students' ideas about the scientific topic. Students' ideas were objects of inquiry for the teachers – as teachers attended to students' ideas, they were intrigued by what they heard, which sustained their attention and responsiveness to student thinking.

Thus, one cross-cutting aspect of what likely supported teachers' attention and responsiveness to student thinking was the teachers' intrigue, but with respect to different aspects of what was happening – for Ms. L, to the scientific topic itself, and for Ms. R and Mr. S, to students' ideas about the scientific topic.

Care and Respect for Students

A second cross-cutting aspect was the care and respect teachers exhibited for their students and, more specifically, their students' ideas. Again, this manifested in different ways across the teachers. For instance, recall how Ms. L treated Kimmy's desire to contribute in the first episode from her classroom:

> So here's the procedure- did you have a comment, Kimmy? ((addresses student with hand raised)) Kimmy, I'm going to wait because you are so polite. ((to class)) And I know- I'm glad you're excited about this, but this ((points at Kimmy)) is the most important part. So Kimmy? [Episode, April 2010]

Here, Ms. L indicated that listening to Kimmy's idea took precedence over moving on to the experiment that she was beginning to describe and students' more general excitement. Ms. L recognized that for some students, they are "really astonished that their ideas, um, are considered valuable" [Interview, October 2012], and she never wants "to make the kids feel like, well, that question's not worth us talking about" [Interview, October 2012]. By foregrounding students' contributions and striving to make students feel like their ideas are valuable, Ms. L demonstrated care and respect for her students.

Ms. R demonstrated respect for her students as scientific thinkers when she largely left it up to them to resolve their own debate in the first episode from her classroom. She repeatedly asked students to share their reasoning about how many crests they counted and weigh in on each other's ideas, asking, "What do you all think about that?" or "How do you solve that problem?" [Episode, April 2010]. Moreover, she let the question remain unsolved for the entirety of the class period and into the next class, at which time the students posed a satisfying reconciliation. Her confidence in her students' abilities to tackle the issue at hand illustrated her regard for students as intellectual agents.

For Mr. S, his care for students was evident in his concern for who contributed to the discussion. In the first and third episodes from his classroom, he acknowledged that some of the students who participated in the inquiry discussions did not typically participate and suggested that the format and focus on students' ideas "allows some kids to, to, um, demonstrate their strengths that normally wouldn't be able to" [Conversation, April 2010]. In particular, Mr. S noted that "some of those kids that were, to me, the most, had some of the greatest ideas of all, some of them, some of the kids were also the kids who didn't have ac- a lot of academic skills" [Interview, September 2012]. Inquiry discussions served as a place where students who did not otherwise experience much success in school were able to meet with success.

In all cases, focusing on students' ideas was entangled with care and respect for students. Teachers wanted students to see their ideas as worthwhile, and validating students' contributions and giving them space to resolve their own issues were ways for teachers to demonstrate their care and contribute to students' senses of self. Moreover, as students saw their ideas being taken up in this way, they were more likely to put themselves and their ideas on the line, creating ongoing opportunities for this sort of interaction to occur.

These foci – teachers' intrigue about scientific topics and students' scientific ideas and teachers' care and respect for students – might be particularly meaningful for professional development aimed at promoting teachers' attention and responsiveness to student thinking. Although these aspects cut across the practice of three focal teachers whom I did not select to be representative of teachers more broadly, I have seen such intrigue and care from many teachers with whom I have worked and suspect that these aspects would be productive grounding points in working with teachers. As professional developers, we could frame part of our work as supporting teachers' intrigue about scientific topics and students' scientific ideas, remaining alert and open to examples that

spark their curiosity and flexibly pursuing those[29]. Part of our work could also be to draw teachers' attention to the connection between caring for students and caring for students' ideas – that attending and responding to students' ideas is a way to help students see their own contributions and ideas as worthwhile.

Future Directions

My dissertation work also raises numerous questions that may offer future directions I could pursue stemming from this work. As I continue to work with science teachers, I hope to be able to incorporate some of the suggestions I made for how to support teachers in attending and responding to the substance of students' scientific thinking. Specifically, I would like to understand the impact of being more responsive in terms of pursuing examples and topics teachers are curious about, as well as how teachers respond to the questions I posited in Chapter 4 for discussion while examining classroom video or student work. When asked about promoting deeper content understandings, what kinds of next instructional steps do teachers put forth, and how are these steps related to students' ideas? Do teachers become more responsive in their own classrooms, particularly with respect to topics their students are curious about? This latter question highlights both a methodological *point* – the importance of professional development or teacher education programs having a classroom component to facilitate study of teachers' practice – and a methodological *question* of how to substantiate connections between teachers' classroom practice and their experiences in such programs. I also anticipate that further analyses of classroom episodes that meet my criteria for inclusion will shed light on other aspects that might stabilize teachers' attention and responsiveness to student thinking and how we can continue to refine our work with teachers.

This study has also provoked many questions about stabilities across local episodes (as emphasized here) and broader timescales. As I previously indicated, my analytical approach in this study allowed me to create plausibility cases for what might have been involved in the coherences supporting teachers' attention and responsiveness to student thinking. By focusing on exemplars, I was able to flesh out a wide range of aspects that might be involved and see what cross-cut episodes within and across teachers. However, supplementing my approach with other approaches may lend more credibility to the involvement of particular aspects. For instance, if Mr. S evidenced relatively stable attention and responsiveness to students' ideas when he used the fishbowl discussion structure in several episodes, and a general lack of focus on students' ideas when he did not use the fishbowl, I would feel more confident in my sense that the fishbowl discussion structure was part of what stabilized Mr. S's attention and responsiveness to student thinking. Drawing on contrasting cases like this, with an eye toward posited aspects from my analyses, could help me understand more about which aspects are most integrally involved.

The question of how to model the coherences supporting the emergence and stability of teachers' attention and responsiveness to the substance of students' scientific

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[29] This might also serve as a model of what it looks like to be responsive in the second sense discussed in Chapter 4 – altering plans in response to directions or ideas from participants.

thinking is open as well[30]. The aspects that I posited for each episode were mutually consistent on the whole, but it would be worthwhile to unpack how they might have reinforced each other, contributing further to the overall stability. Which aspects were most tightly coupled with each other? Which aspects were more peripheral to the stability? Does it make sense to think of the aspects cohering into one coherence, multiple overlapping coherences, or nested coherences for a given episode? (Or none of the above?) For instance, in the third episode from Ms. R's class, a possible coherence underlying the entire episode involved mutual reinforcement between having students come up with rules for energy and recording students' ideas on a projected Word document. As students stated their rules, Ms. R had ideas to record; as Ms. R recorded students' rules, the focus on coming up with and sharing rules was maintained. When Ms. R got to the orange group, she interacted with them for an extended period of time. Part of what seemed to stabilize her focus on their rule specifically was another pair of mutually reinforcing elements – holding the orange group accountable to their rule and pressing on an idea they included from the book. In this example, I do not think it makes sense to think of there being one coherence, but I could see arguments for the two coherences I described being distinct but overlapping (i.e., the initial coherence is backgrounded when the orange group coherence is active) or nested (i.e., the orange group coherence is nested in the initial coherence, with possible combinatory effects). I am not sure that we can distinguish between these possibilities, but they may have different implications for the stability of Ms. R's attention during the orange group interaction.

Finally, future work could examine the relationship between local stabilities and broader stabilities with respect to teachers' attention and responsiveness to the substance of students' scientific thinking. As Hammer, Elby, Scherr, and Redish (2005) noted, "when the same locally coherent set of resources becomes activated again and again, it can eventually become sufficiently established to act as a unit" (p. 102), suggesting that repeated coherences may develop their own structural integrity over time. This represents one way that broader stabilities can arise from local stabilities – repeated co-activation can strengthen the connections between elements, making it more likely for them to be co-activated in the future. For instance, consider the connection for Mr. S between inquiry discussions and matters of social justice. As he started facilitating inquiry discussions, he noticed students participating in ways they had not previously. Their unexpected participation may have stabilized his focus on students' ideas, as he recognized that validating their ways of thinking created space for them to participate. As Mr. S had repeated experiences of this sort, the feedback loop between student participation and his attention and responsiveness to students' ideas likely grew stronger, resulting in him focusing on students' ideas as a more regular part of his classroom practice. In this way, a local connection, repeated over time, may contribute to a larger-scale stability in practice – the kind we hope to see with respect to teachers' attention and responsiveness to the substance of students' scientific thinking in the classroom.

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[30] Appendix C includes an initial attempt to model the first episode from Ms. R's classroom more fully.

Appendix A: Descriptions of Original Categories of Responsive Utterances

Here, I briefly describe the rationale for each of my five original categories of responsive utterances, which I created as I coded transcripts in the process of episode selection. These categories arose when I felt given utterances were responsive to students' ideas, but I lacked language from previous work to describe them.

Acknowledging Attempts to Answer

Description: Acknowledging a student's attempts to answer a question, especially in the face of continued questioning

Example:

> S1: Why did the meteor shower only hit the females and not the males?
> S2: It only hit, it hit both of them, but, um, some of them stayed, some of them were still there.
> …
> S3: How come they only killed all the females, not all the males?
> T: Okay, he just tried to answer that question.

Rationale: In the classroom, students may not always present fully articulated ideas; often they are constructing explanations on the spot or unsure of how to take their ideas further. Recognizing a student's attempts to respond serves as evidence of attention to what the student has offered (particularly if the teacher has previously grappled with the student's idea in other ways like the teacher in this example, who had asked S2 similar questions himself) and validates this contribution while letting the student off the hook in the moment.

Altering Activity

Description: Changing the activity or broadening its scope in response to a student's idea

Example:

> S1: I say maybe we put one part of the magnet in the water, and the other like maybe a little bit higher, so there's still a lot amount of space?
> …
> T: If you want to try it- and then try it the way S1's suggestion, with one underwater and one not.

Rationale: At times, a teacher may respond to a student's idea by taking action and altering the planned activity in some way that is consonant with the student's idea. The change may be minor, e.g., offering the student's idea as another alternative (as in the example above), or more drastic in nature, e.g., changing the lesson plan for the day.

Attempting to Hear

Description: Consistently attempting to hear the entirety of a student's idea when it is difficult to do so

Example:

> S1: Uh, walk past it kind of fast and then – test if it'll go-
> T: Hold hold hold, hold on. On the outside, everybody, including S2, we are in the listen-only mode. Okay? Um, and inside, we're one at a time.
> S3: I have a question.
> T: Uh, just hold on, just hold on. Uh, S1, what did you say now?

Rationale: Classroom discussions can be noisy as students clamor to share their ideas, engage in side conversations, etc. If it is difficult to hear or understand a student's idea, a teacher's consistent attempts to do so demonstrates the teacher's attention to the student's idea (particularly if the teacher eventually succeeds and responds to the student's idea in other ways).

Clarifying Scenario

Description: Clarifying the question or scenario under discussion in response to a student's question or comment

Example:

> S1: So like, are you walking right by the trash can, or are you walking, stopping, and then-
> T: I'm walking right by the trash can.

Rationale: In scientific discussions, it is critical to define and bound the phenomenon of interest. A teacher may respond to a student's idea by describing the scenario under consideration if the student's idea calls the scenario into question, lending clarity to the discussion and helping to ensure that students are all contributing ideas about the same phenomenon.

Identifying Similarities

Description: Identifying similarities between students' ideas

Example:

> S1: So you gotta do- have you noticed that when you try to do it at that time when it's there, it doesn't work out if you do it after? But then when you do it before, it gets to the little thingie () get it. So it's related to this.
> T: So yours is similar to what S2 said a little while ago about timing.

Rationale: This category is the counterpoint to Lau's (2010) category of noting differences in students' ideas. As Lau described, "To have picked up on the differences between the details or the main points of different ideas, the teacher needed to have heard and processed the substance of what students stated" (pp. 90-91). The same holds true for identifying similarities between students' ideas.

Appendix B: Transcriptional Notations

After initial transcription of the selected episodes, I returned for iterative passes through the transcripts to layer in details like emphases, gestures, pauses, etc. Table B-1 depicts the transcriptional notations I used, adapted from Sacks, Schegloff, and Jefferson (1974). The examples provided are from the first selected episode from Mr. S's classroom.

Table B-1

Transcriptional Notations Adapted from Sacks, Schegloff, and Jefferson (1974)

Meaning of Notation	*Example from First Mr. S Episode*
"… the equals sign (=) indicates 'latching' – i.e., no interval between the end of a prior and start of a next piece of talk" (p. 731).	Mr. S: So based on speed, right? Mr. G: = Folks, did you hear that reasoning?
"Numbers in parentheses indicated elapsed time in tenths of seconds" (p. 732). I have altered this convention slightly, replacing the numbers with the word "pause" as I care more about the presence of a noticeable pause than the precise length.	Mr. S: Okay, any other, any other reasons for going, uh, releasing the keys before? Any other reasons? (pause) Now somebody said yesterday, after would be better. Why after?
"The long dash… indicates an untimed pause, e.g. a 'beat'" (p. 732).	Mr. S: ((faces board, writes)) So this one depends on – how quickly.
"Colon(s) indicate that the prior syllable is prolonged. Multiple colons indicate a more prolonged syllable" (p. 732).	Diane: Because I thi:::nk that – well, let me try to give you an example, li::::ke…
"The relationship between stress and prolongation markers indicate pitch change… in the course of a word" (p. 733). For instance, in the example provided, pitch drops at the end of "<u>GRA</u>::vity."	Mr. S: ((faces board, writes)) Maybe <u>GRA</u>::vity. <u>GRA</u>::vity.
"The short dash indicates a 'cut off' of the prior word or sound" (p. 733).	Diane: … you're not going to get there right when you're at the grass or else you're gonna- because the car's fast…
"Upper case indicates increased volume" (p. 733).	Edwin: That's what YOU said.
"Empty parentheses indicate that no 'hearing' was achieved" (p. 733).	Jack: The weight – the weight weighs ().
"Materials between double parentheses indicate features of the… materials other than actual verbalization" (p. 733).	Mr. S: Anybody have an argument for dropping the keys over? So I take the keys, I have some keys ((gets out keys)), and I'm walking with the keys ((walks with keys)),

	and I, and I drop it over the, the container.

Appendix C: Discussion of Stability

In this appendix, I explore notions of stability in more detail. I ground my discussion in an example from ecology and tie general principles illustrated by this example to teacher attention and responsiveness to student thinking. I also provide an initial attempt to model the dynamics of one of my selected episodes as a complex system, considering how various identified aspects dynamically interacted with each other to generally support the teacher's focus on students' ideas.

Theoretical Approach to Stability

I begin by articulating my current perspective on stability[31], drawing on notions of dynamic systems and work from ecology and physics education. In what follows, I analogize between a particular element in an ecological system, such as the population density of a flowering plant species, and teacher attention and responsiveness as situated within an open system. This analogy is productive due to two main parallels – population density and attention both have numerous possible states and are often in flux depending on interactions with other parts of the system. I use the population density analog and ideas from ecology to illustrate the general principles under discussion below, then consider the implications for teacher attention and responsiveness.

Variability in Complex Dynamics

> *"A complex, heterogeneous, and noisy system has an enormous amount of potential behavioral variability and a large number of potential cooperative modes" (Thelen & Smith, 1994, p. 55).*

The first premise I consider is that both the population density of a flowering plant species and teacher attention and responsiveness are part of larger open systems, influencing and being influenced by other factors that come and go. At times, these influences are predictable. For instance, population density may increase when a drought breaks and the plants can get enough water, or it may decrease when a new consumer moves into the area and eats the plants. At other times, influences may be more novel or surprising – i.e., a dominant genetic mutation may arise that, as the plants proliferate, results in the population becoming susceptible to a pathogen in the environment that previously caused little harm. Positive feedback loops may also form between the flowering plants and other organisms in the system, such as pollinators. As honeybees consume nectar from the plants, they inadvertently pick up pollen from the plants; then, as the bees move to other plants, the pollen is transported as well. Cross-pollination augments the flowering plant population, providing more nourishment for the bees and augmenting *their* population, and the cycle continues.

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[31] This subject is far more vast than my treatment of it here, and I look forward to ongoing discussion of various perspectives on stability and how they might inform educational research.

Yet imagine what would happen if the genetic mutation described above arose in the midst of this amplifying feedback loop. The bees would then contribute to the spread of the mutation within the plant population, and the plant population density would begin to decrease as plants fell subject to the pathogen. As the plant population diminished, the bees would have a diminishing food source, and their population would also be negatively affected. In other words, the same interaction between the bees and the flowering plants may change from a positive to a negative feedback loop due to the impact of the genetic mutation.

I provide all of these examples to illustrate how a particular element – here, the population density of the flowering plant species – may influence and be influenced by a myriad of internal and external factors. Moreover, these factors may also interact with each other and combine in ways that differentially impact the plant population density. The state of the plant population density at any given time, therefore, is governed by this self-assembly of factors and their interactions.

Teacher attention and responsiveness is also enmeshed in a complex dynamic involving teachers' own manifold knowledge and orientations (e.g., Schoenfeld, 2011), interactions with students (e.g., Fennema et al., 1996), institutional mandates (e.g., Levin, 2008), and other factors. Lau's (2010) dissertation demonstrated how quickly such attention can fall into different patterns during the course of a conversation. The major implication here is that due to the variability evident in teacher attention and responsiveness, any relative stability is something to be explained.

What it Means to be Stable

In terms of ecological systems, stability has been defined as the "ability of a system to return to an equilibrium state after a temporary disturbance" (Holling, 1973, p. 17). However, there are several distinctions in terms of how this definition has been applied to real ecological situations. For instance, Connell and Sousa (1983) distinguished between remaining at an equilibrium state in the face of a disturbing force and returning to an equilibrium state if perturbed by the force. The first situation – remaining at an equilibrium state in the face of a disturbing force – can be thought of in terms of *resistance*. For example, if an announcement interrupted the flow of classroom conversation, a teacher's attention and responsiveness to student thinking might be considered resistant to perturbation if he simply continued the conversation at hand. The second situation – returning to an equilibrium state if perturbed by the force – can be thought of in terms of *resilience*. This would be akin to the teacher's attention being diverted by the announcement but returning to the previous conversation relatively quickly. Connell and Sousa also acknowledged the work of researchers who describe *constancy*, which involves the maintenance of a particular equilibrium without reference to a disturbing force – as if the announcement had never occurred.

Yet in a complex system, it is questionable as to whether there is ever really a state of true constancy. Particular disturbing forces may not be observable or obvious in a given situation, but they may be present and influential nonetheless. For instance, with respect to teacher attention and responsiveness, the current push for more accountability and standardization makes it likely that curricular coverage is never far from teachers' minds (e.g., Levin, 2008; Valli, Croninger, Chambliss, Graeber, & Buese, 2008), even if it does not appear particularly influential in a given episode. In fact, one reason it might

not appear influential is if the teacher has taken measures to minimize its influence ahead of time, as seen in several episodes from Mr. S. That he felt the need to ward off his concerns about curricular coverage belies their presence and influence, and suggests that what looks like constancy in situ may actually involve resistive measures. Thus, I drew primarily on the notions of resistance and resilience in my selection of classroom episodes in which teachers' attention and responsiveness to student thinking is stable or sustained. Constancy played a role in that the episodes I selected were extended in duration, but I took the teacher remaining with or returning to the substance of students' scientific ideas in the face of perturbations as the strongest evidence of stability.

The Nature of Stability

"It is important to think of any seemingly stable human thought or action to reside on these cusps of quasi-stability, visiting areas of tight coordination…"
(Thelen & Smith, 1994, p. 68)

Yet simply identifying a stable state does not *explain* its stability. For instance, returning to the population density analog, one can imagine numerous ways in which the plant population density remains in a given state. The plant population density during a drought may be the same as the plant population density if the drought breaks but a new consumer moves into the area. It may remain the same if pollinator population density increases but space for continued growth becomes limited. In other words, the plant population density may remain in a stable equilibrium state due to a variety of distinct self-assemblies of factors and their interactions.

As described in Chapter 3, I take such a self-assembly to *constitute* a stability, from which the state of interest (a particular plant population density, or teacher attention and responsiveness to student thinking) emerges. In this view, identifying relevant aspects that are part of the self-assembly (or self-assemblies) is an important part of explaining a stable state, which is what I have focused on in this dissertation. However, to actually model stabilities, one must also consider how the identified aspects dynamically interact with each other. Below, I attempt to model the first episode from Ms. R's classroom – the waves discussion featured in Chapter 4 – as a complex system.

Another Look at Episode 1 from Ms. R's Classroom

Recall that students in Ms. R's sixth-grade science class disagreed about how many crests were present in a wave created by shaking a jumprope, leading to a lengthy conversation on what should count. In my analysis of this episode in Appendix E (which would be useful to read prior to engaging with this modeling), I identified the following five aspects as plausibly stabilizing Ms. R's attention and responsiveness to students' ideas:

- Interest in understanding what students were thinking (noted as "Interest in Ideas" in Table C-1)
- Reference to the jumprope for clarity ("Jumprope Reference")
- The need to reconcile what counts as a crest in order to count wavelengths ("Need to Reconcile")

- Her desire for students to reconcile the matter for themselves ("Student Reconciliation")
- Pushing students past appeals to authority ("Authority Appeal")

Here, I trace the dynamics and interrelations of these aspects throughout the episode, using the transcript provided in Table C-1 to organize my analysis.

At the beginning of the discussion, Ms. R noted that students were counting different numbers of crests and sought to get more information about what they were counting, often asking them to point out what they were counting on the jumprope itself.

Table C-1

Transcript and Mapping of Dynamics for First Ms. R Episode

Transcript		Aspects Plausibly in Play
1.	Ms. R: All right, how many crests do we have?	Interest in Ideas Jumprope Reference
2.	Student: Two? Two.	
3.	Student: Three?	
4.	Student: Two.	
5.	Student: One.	
6.	Student: You're counting the numbers wrong.	
7.	Student: Two!	
8.	Rolland: No, three!	
9.	Ms. R: All right, somebody- please don't touch anything there. Somebody come count. ((Marcelo, who was counting the ten-second intervals, gets up)) Somebody else outside the counter, go ahead. Not you, counter, get back over there! ((Michele stands up)) All right, () tell me what you see.	
10.	Michele: ((crouches near rope)) Uh, this. ((points at #2))	
11.	Marcelo: She's confusing me.	
12.	Michele: Uh, that. ((points at #4))	
13.	Ms. R: Okay. Anybody else see something- okay, so *let me point out what she saw, what she said*. ((walks along rope)) *This one, this one, this one, and this one, right?* ((has indicated #2, #3, #4, and #5; Michele nods)) *That's four*.	
14.	Student: Yay!	
15.	Ms. R: Anyone else?	
16.	Student: Four.	
17.	Ms. R: Go ahead. Uh, no, no, no, no, no ((to Keven, who's messing with the end of the rope)). Go ahead, Carmen. Point to the ones	

	that you see.	
18.	Carmen: ((near rope)) That. ((points at #3))	
19.	Ms. R: *One*.	
20.	Carmen: And that. ((points at #5))	
21.	Ms. R: *Two*.	
22.	Gloria: What? There's more!	
23.	Ms. R: *If you say it's more, point 'em out. Go ahead*. ((Gloria points at #1, #3, and #5))	
24.	Sterling: No!	
25.	Ms. R: Wait, wait, wait, wait, wait, wait ((to Horacio, trying to move rope)). We gonna talk about it afterwards.	
26.	Rolland: ((near rope)) One, two, three, four, five. ((points at all numbered options))	
27.	Ms. R: *That's what, that's what-*	
28.	Student: No.	
29.	Rolland: It's going like this ((moves hand in curvy motion))!	
30.	Ms. R: *Michele said*. Okay.	
31.	Horacio: Okay, okay, okay, okay. ((goes to move rope))	
32.	Ms. R: No, no, no, no ((to Horacio)). Don't, don't- anyone else? *You have a different opinion?*	
33.	Sterling: No.	
34.	Ms. R: *Yeah you did, you said "no"! So tell me what you see.*	
35.	Student: You have to say something.	
36.	Ms. R: *Tell me what you see.*	
37.	Sterling: I see four.	
38.	Ms. R: *Can you come point 'em- point 'em out please?*	
39.	Horacio: *Comment in Spanish.*	
40.	Ms. R: ((touches Horacio on the shoulder)) I'm gonna need you to calm down, whatever you said to me before? () ((Sterling stands and points at what she counted)) *Can you point, I can't see- or put your foot by 'em?*	
41.	Horacio: Uno, dos, tres, quatro. ((while Sterling puts foot by #1, #2, #3, and #4))	
42.	Ms. R: *You said one, two, three, four*. ((points at each))	
43.	Marcelo: Uno mas!	
44.	Ms. R: Okay. ((5-second pause, puts hand to chin)) All right, *so we have- some people said*	

four, some people said five-	

At this point, Ms. R had numerous combinations on the table. In the section that follows, she started to push toward reconciliation, with her language suggesting that students would be involved in the process (e.g., line 46, "We gotta settle this"). Note that in doing so, she pressed for more information about why students thought what they did, moving away from what they were specifically counting on the jumprope.

45.	Student: Three.	Interest in Ideas Need to Reconcile Student Reconciliation
46.	Ms. R: *Some people said three. We gotta settle this. Why you all- whoever said four, why you think it's four? Michele, we'll start with you.*	
47.	Horacio: She said five.	
48.	Ms. R: *Or five, why do you think it's five?*	
49.	Student: I thought she said four.	
50.	Michele: Um, because, um, this one ((points at #2)), that one ((points at #3)), that one ((points at #4)), and that one ((points at #5)).	
51.	Ms. R: *So everywhere, tell me like – you're saying every time the rope curves is one.* ((Michele nods)) *So the top and the bottom.* ((Michele nods)) Okay. That makes sense. Anyone else?	
52.	Gloria: I say, um, the crests are at the bottom-	
53.	Ms. R: Gloria is speaking. Say it a little louder, please.	
54.	Gloria: I say three because the crests are the bottom.	
55.	Ms. R: *The crests-*	
56.	Student: Top part.	
57.	Gloria: Or the top.	

At this point, reference to the jumprope came back into play as Ms. R sought to understand Gloria's reasoning. Ms. R continued to pose questions that elicited more information from students and supported them in interacting with each other's ideas.

58.	Ms. R: *What about, what part- where's the bottom part?*	Interest in Ideas Jumprope Reference Need to Reconcile Student Reconciliation
59.	Rosie: The crest is the highest point. ((Gloria points to what would be the top of the schematic; she is seated on that side of the rope))	
60.	Ms. R: *Over there?*	
61.	Student: It depends on what side of the room you're on.	
62.	Ms. R: *Well, what if I'm on this side?*	

63.	Horacio: That's the same thing!	
64.	Ms. R: *It's the same thing?* I don't know. *Can you- can you clarify that for me? What do you mean? How about if you point at it so I'll know what you're talking about?* I'm a visual learner, I need to see. (pause) *Can you point it out, what you're talking about?* You know all these people, you can get up. ((Gloria stands))	
65.	Horacio: *Comment in Spanish.*	
66.	Ms. R: ((Gloria points at #3)) Uh-huh. ((Gloria points at #1 then #5)) *So you're saying if I'm counting these up here* ((points to the ones Gloria just pointed to)), *then I can't count these down here* ((points at #2 and #4)) *as crests?* ((Gloria shrugs)) *You don't know?* ((Gloria shakes head)) Okay. All right. Um, calm down ((to Horacio)).	

In an interview about the episode, Ms. R highlighted that Rosie's question in line 67 below used wording directly from the textbook. In response, she drew attention explicitly to *Rosie's* thinking on the matter.

67.	Rosie: Isn't the crest like the highest point, the highest point of the wave?	Interest in Ideas Authority Appeal
68.	Ms. R: *Is the crest the highest point of the wave?*	
69.	Student: Yes.	
70.	Ms. R: Okay. *So what are you saying by that? What are you saying, what do you mean by that? I mean, why did you ask that?*	

As Rosie articulated more of what she noticed about the wave, Ms. R returned to asking students to reflect on each other's ideas in an effort to move toward consensus (e.g., line 81, "How do you solve that problem?").

71.	Student: Uh-	Interest in Ideas Need to Reconcile Student Reconciliation
72.	Rosie: Because, because like-	
73.	Ms. R: Shh, I can't hear ().	
74.	Rosie: Because like, from where I am, it seems like there's three-	
75.	Horacio: ((to Gloria)) Hey, are you looking in my book?	
76.	Rosie: But from the other side, it looks like there's two.	
77.	Ms. R: *I'm sorry, I can't hear you.*	
78.	Rosie: From where I am, it looks like there's	

	three crests, and from where Lisa is, it looks like there's two.	
79.	Ms. R: *Mmm. I think I understand what you're saying. She's saying because she's on this side of the rope, right, it looks like there's three. But on this side of the rope, it would look like it's two, that same part that she's looking at. Does that make sense? What do you all think about that?*	
80.	Willis: Good.	
81.	Ms. R: *How do you solve that problem?*	
82.	Willis: That's good.	
83.	Ms. R: *What's good?*	
84.	Willis: The weight?	
85.	Ms. R: (pause) *What are you talking about?* ((chuckles))	
86.	Willis: I don't know. I'm just answering.	

At this point, the nature of the conversation shifted. Ms. R took a more active role in introducing ideas into the mix, differentiating between a crest and a trough. In this section, Ms. R still seemed to be striving toward reconciliation on what counts as a crest, but she was less focused on students' ideas in doing so.

87.	Ms. R: I have a question. What's the opposite of a crest? ((Marcelo gets up to fix part of rope near Horacio))	Need to Reconcile
88.	Students: The trow. Trough. ((repeating and struggling with pronunciation))	
89.	Ms. R: The trough is the opposite part, right?	
90.	Marcelo: It was messed up.	
91.	Student: ().	
92.	Student: Yes it was, it looked like this.	
93.	Marcelo: That's what I'm saying.	
94.	Student: It's like, it's like a crest flipped over.	
95.	Student: Well, then why'd you move it?	
96.	Ms. R: *It's like a crest flipped over?* So do-would you count the crest and the trough?	
97.	Student: Um-	
98.	Rosie: Like, it, it depends on which side you're on.	
99.	Ms. R: So…	
100.	Horacio: So like I might count the ditches on this side but not on this side?	
101.	Rosie: No, I mean like, like, if you're on this side, when you're looking at it, there's three. And if you're on that side, when you're	

	looking at it, there's two. Because the crest is like the highest point.	
102.	Horacio: "It's the highest point." ((imitating Rosie))	
103.	Ms. R: And what's the lowest point?	
104.	Student: The tr, tr-	
105.	Ms. R: Trough?	
106.	Student: The trough.	

Here, Ms. R made a shift back to focusing on and pursuing students' ideas.

107.	Ms. R: Okay, Carmen. Rosie, thank you very much. We're gonna come back to that because that's basically the question. I asked a question, write down- and I'm gonna pose it right after I get to what Carmen was gonna say. *Carmen, why did you say- how many did you say it was? Five?*	Interest in Ideas
108.	Carmen: No.	
109.	Student: She said two.	
110.	Ms. R: *Two. Why did you say it was two?*	
111.	Carmen: I said it because, um, that's the highest, um, point, and that's the highest point.	

Ms. R then asked Carmen to demonstrate what she was talking about on the jumprope.

112.	Ms. R: *Can you, can you show, show me, please? Can you get up and point to what you're talking about?*	Interest in Ideas Jumprope Reference
113.	Carmen: ((near rope)) This is the highest point ((points at #3)), and that's the highest point ((points at #5)).	
114.	Ms. R: *Okay, so you're saying since those two are higher* ((points at #3 and #5)), *that's why you didn't count that one* ((points at #1))?	
115.	Carmen: Uh-huh.	

As Ms. R got a sense of what Carmen was talking about, she again abstracted from the jumprope while retaining her focus on Carmen's idea and asking if other students wanted to contribute.

116.	Ms. R: *She said because those two are higher than the other ones, we only count the highest ones and not the lower ones.*	Interest in Ideas
117.	Horacio: Oh, I have to sit up again.	
118.	Student: Keven, where you going?	

119.	Keven: ((scooting away)) I ain't gotta tell you.	
120.	Ms. R: Where are you going?	
121.	Keven: Back here! So it's cool.	
122.	Student: What?	
123.	Ms. R: He's not talking to you. Don't add any disturbance to the area. Okay, so… ((off-camera, can hear writing on the chalkboard)) All right, anyone else want to say what they felt about the numbers? So how many numbers do we have?	

At this point, Ms. R again compared students' responses and asked students to weigh in on each other's ideas.

124.	Horacio: Four, three, two, one.	Interest in Ideas Need to Reconcile Student Reconciliation
125.	Student: Three.	
126.	Ms. R: *We have three numbers?*	
127.	Gloria: We have four numbers.	
128.	Student: I've got four.	
129.	Ms. R: I'm sorry, Gloria's writing it, so I'm getting- *you put two* ((likely to a student nearby, off-camera))? *No, how many did people say? They said three, three different numbers, right?*	
130.	Student: Yeah.	
131.	Gloria: Three, four, and five.	
132.	Ms. R: *Three, four, and five?*	
133.	Gloria: And two.	
134.	Student: Three and five.	
135.	Ms. R: *Oh, you add- you added two, put two on there. Someone else had two*. So, let's go back to these questions. *Does it matter which side of the rope that you are on, when you counted your crests and your troughs?*	
136.	Students: No. Yes.	
137.	Ms. R: *We have some yeses, I hear some nos. I need to know why. Why you feel that way?* Marcelo?	
138.	Marcelo: They're the same.	
139.	Ms. R: *Why, what makes them the same?*	
140.	Marcelo: Because, they look the same.	
141.	Ms. R: *How so?*	
142.	Marcelo: ().	
143.	Ms. R: *What'd you say?* ((student laughs)) Are you contributing to the conversation? ((to	

	Marcelo)) *What do you mean, so you're saying it's because they look the same what?*	
144.	Marcelo: It doesn't matter where you look.	
145.	Ms. R: *It doesn't matter which one you count. Do you count both?*	
146.	Marcelo: I don't know.	

Below, Ms. R shifted back to introducing ideas into the conversation herself, in a seeming effort to help students see counting crests as distinct from counting troughs and thus make progress on the matter of what counts as a crest.

147.	Ms. R: So if you look in the mirror, what are you gonna see?	Need to Reconcile
148.	Student: Yourself.	
149.	Student: Your reflection.	
150.	Ms. R: Is it the same?	
151.	Students: No. Yeah.	
152.	Ms. R: So, is, are there two of you then?	
153.	Students: No.	
154.	Ms. R: Or do you count yourself once?	
155.	Students: Once.	
156.	Ms. R: So if you're saying- can you watch the scissors ((likely to a student nearby, off-camera))? If you're saying the crest is the same as the trough on the other side, how many times would you count that?	
157.	Student: The floor's dirty.	
158.	Rolland: Five.	

As Rolland provided his count, Ms. R pursued his thinking on the matter but still retained her focus on keeping crests and troughs separate.

159.	Ms. R: *You would count it five times? Why would you count it five?*	Interest in Ideas Need to Reconcile
160.	Rolland: Five of that.	
161.	Ms. R: *What's that?*	
162.	Rolland: The stuff that's windy.	
163.	Ms. R: *It's five crests or five troughs?*	
164.	Rolland: Fi-five ((students laugh)), uh, I don't know.	
165.	Marcelo: No, one-	
166.	Rolland: There's just five things.	

Finally, when Marcelo asked Rolland whether something counted in line 167, evidence from an interview with Ms. R indicated that she may have taken Marcelo's move as an

appeal to Rolland's authority on the matter. Her response refocused Marcelo on his own thinking and was shortly followed by a move to have students think individually about a question arising from Rosie's earlier observation that it might matter which side of the jumprope you are on. In this way, Ms. R ultimately left it up to students to reconcile what mattered and what counted as a crest, which they pursued for the rest of the class period and resolved the following day.

167.	Marcelo: Look, does this count? ((points at #1))	Interest in Ideas Need to Reconcile Student Reconciliation Authority Appeal
168.	Rolland: Yes.	
169.	Ms. R: *Does it count for you?*	
170.	Rolland: Yes.	
171.	Marcelo: No.	
172.	Ms. R: This is what I want you to write in your journal right now. *Write the question, does it matter which side of the rope you are on? And then tell me your response and why.*	
Note. Italicized sections of transcript reflect responsive utterances (as coded in Table E-1).		

By tracing the identified aspects throughout the episode, important patterns emerged. For instance, the "jumprope reference" always cooccurred with "interest in ideas," but "interest in ideas" occurred without "jumprope reference," suggesting that directing students to point out what they were talking about on the jumprope was one of several means that Ms. R used to better understand their ideas. Additionally, tracing "need to reconcile" throughout the episode demonstrated its duality with respect to Ms. R's attention and responsiveness to student thinking. When "need to reconcile" was coupled with "student reconciliation" in a coherence, it seemed involved in promoting Ms. R's focus on students' ideas. Yet when "need to reconcile" was either on its own or even coupled only with "interest in ideas," Ms. R's interactions with students tended to be more directive in nature. Thus, "need to reconcile" and even "interest in ideas" were not always stabilizing forces for Ms. R's responsiveness to students' ideas during the episode. Finally, certain tipping points in Ms. R's attention and responsiveness became more clear through this modeling. For example, in lines 147-158, Ms. R attempted to lead students through a line of reasoning about mirror images to highlight you do not count two of you when looking in a mirror, so you should not count both a crest and a trough. When Rolland continued to count both crests and troughs, Ms. R tried to get him to distinguish between the two (line 163, "It's five crests or five troughs?"), pressing for differentiation. Yet when Marcelo asked Rolland whether something counted in line 167, Ms. R's perception of Marcelo's move as an "authority appeal" seemed to tip her into refocusing on students' ideas and the importance of students reconciling the debate for themselves, rather than her pressing them to do so in certain ways.

In conclusion, this analysis demonstrates that it would not be appropriate to model Ms. R's attention and responsiveness to the substance of students' scientific thinking during this particular episode as a single coherence. Instead, different aspects seemed more or less active at different times throughout, and interacted with each other in

variable, nonlinear ways. Further modeling would need to be done to determine what the coherence or coherences might look like in other episodes.

Appendix D: Episodes from Ms. L's Classroom

This appendix includes analyses of three episodes from Ms. L's classroom, focusing on identifying parts of the local coherences supporting her attention and responsiveness to the substance of students' scientific thinking. Each analysis includes a description of the context in which the episode is situated, full transcript of the episode with coded responsive utterances, justification of why the episode was selected for inclusion, and candidates for what may have stabilized Ms. L's attention during the episode. At the end I also synthesize a bit across the three episodes.

Episode 1: Can Magnets Work Underwater?

Situating the Episode

The first episode from Ms. L's classroom occurred on April 15, 2010, during Ms. L's first year in the project. In a debrief conversation after class, Ms. L referenced a statewide standardized test coming up the following week and that she had not yet discussed forces. Specifically, students were responsible for knowing that a force is a push or a pull and for identifying various forces, such as gravity and magnetism.

To review forces in class, Ms. L posed a question that a student, Elijah, had come up with previously: "Can magnets… work underwater?" [Class, April 2010]. She explicitly connected this question with the idea of forces, saying, "I was really intrigued by [Elijah's question] because we're going to a new topic today, um, forces, and, um, it seemed to me that that kind of went with forces in a way" [Class, April 2010]. After a brief discussion of where else students heard the term forces, Ms. L directed their attention to two things in reference to Elijah's question:

> Two things I want you to think about. First is what the answer is, yes or no. Um, and the second one is not so much why that's happening because we're gonna have to- we can't really talk about the whys of magnetism right now ((apologetic, pained tone)), but we'll come back to it. But also I want you to think about why that question fit in with a discussion of forces [Class, April 2010].

In this statement, Ms. L indicated that she wanted students to think about Elijah's question, but more in the sense of what the question has to do with forces than how magnetism works. This was a point of tension for Ms. L; in the debrief conversation after class, she was bothered by having to go over forces instead of having a "full-fledged discussion about why it's happening" [Conversation, April 2010], but she also felt a sense of "commitment to the kids that I don't want them to see something on the test that we've never even talked about" [Conversation, April 2010].

The episode below occurred after Ms. L had students talk in groups about whether they thought magnets would work underwater.

Full Transcript and Coding

Table D-1 contains the full transcript and coding for the first episode from Ms. L's classroom. The transcript in the left column comes from approximately twelve minutes of a whole-class discussion. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table D-1

Transcript and Coding for First Ms. L Episode

Transcript		Coding
1.	Ms. L: Okay, um (pause) so let's kind of go by table and see. ((points at group)) What did you, did you guys agree? Did you come up with a consensus? No- yes and no on your team? Okay.	
2.	Student: We think it is going to work because-	
3.	Ms. L: ((snaps fingers)) Shh. ((points at group sharing))	
4.	Student: It's still underwater, the forces are gonna like try to connect with each other, so ().	
5.	Ms. L: *You don't think the water's going to have anything to do with it?* Okay, anybody at your table feel differently? Everybody agrees? Okay, how about back at Jackson's table, what do you guys, everybody agree or-	Confirming
6.	Jackson: Everybody said that, uh, it will work because even- even though it depends on how strong the magnet is, we think that it, that it will work.	
7.	Ms. L: *You all think it will work.* ((Jackson nods)) Okay, um, Elena?	Maintaining
8.	Elena: We didn't think that, we don't all agree if the magnet will, um, work underwater, but I say that it won't work because when you put magnet and magnet together, there's sometimes a force in the middle of them, and it won't, it won't ((moves fists together and apart)), it won't stick.	
9.	Ms. L: Yeah *((moves fists together and apart like Elena)), so Elena's talking about sometimes when you put magnets together, they're- you feel them resisting. It's like they're pushing each other apart, aren't they? Um, but*	Revoicing, eliciting

	does that happen on land as well?	
10.	Elena: Yes.	
11.	Ms. L: *So what do you do to overcome that?*	Eliciting
12.	Students: Turn it around.	
13.	Joe: You turn it over.	
14.	Ms. L: *So you put the other ((flips one fist over))-*	Maintaining
15.	Elena: ((moves fists together and apart again)) But maybe they're both just having, um, you know?	
16.	Ms. L: *So you're saying like in the water we'd still have to be sure that we had 'em going the right way-*	Inserting
17.	Joe: I think she means that the pressure-	
18.	Ms. L: *Is that what you're saying, or you just think that the water's going to keep 'em from going together at all?* ((Elena nods))	Confirming
19.	Caroline: Yeah, the water will keep them apart.	
20.	Joe: Yeah because the pressure-	
21.	Ms. L: *So the water is too much of an obstacle.*	Maintaining
22.	Caroline: Yeah because, um, what we learned about the, uh, um, magnet, or the () didn't have that much mass when it sinks to the, um, sinks to the like, the bottom? The, the force of the water when it pushes it down, like the, um, force pushes, pushes, pushes it down, it probably, um, won't, like, stick together because all the pressure, all the water-	
23.	Ms. L: *The pressure from the water is going to be- overcome the magnetism?*	Confirming
24.	Caroline: Yeah, so I say no, but Wendy says yes. ((points to Wendy, who has her hand up – many students start contributing))	
25.	Ms. L: Shh, yeah, it gets a little bit (), we have a couple people who want to talk. Shh, guys ((snaps fingers)). We've gotta remember our active listeners, okay? When we're talking in our groups, we're talking in groups, but when one person is talking, where should- what should you be doing?	
26.	Students: Looking at them.	
27.	Ms. L: Looking at them. Listening to them. On topic. Um, *Allan, why do you say no?*	Pressing
28.	Allan: Because, just like Elena said, there's too much force on them for them to stick together.	
29.	Ms. L: *The water pressure is too much?*	Confirming

30.	Allan: Yeah because sometimes if the waves are strong, the magnets will separate and fall apart ().	
31.	Student: What if it's just a little bit of water?	
32.	Ms. L: Okay, so that's just what I was going to ask you, we're going to try this, so maybe I should (). ((walks to equipment – many students start contributing))	
33.	Joe: How much water is there?	
34.	Ms. L: Okay, so let's, let me show you what we're going to do. ((holds up small container)) So *we're not gonna do this, you know, in the ocean, the situations that Caroline and Allan are talking about*. You're gonna each get- we're gonna pretty much fill this to the top, and, um, and then you're gonna get- you've all seen the little magnets I had sitting over here so you're gonna get one set of those magnets to try it out. So this is the water you're gonna do it in. So based on that, um, *would anybody's idea change about whether the magnets are gonna- so it sounds like we've got one idea going that it doesn't matter if the water's there, the magnetism will still be there? But some people are saying the force of the water will actually be too much for the magnets.* What do you think, Joe?	Clarifying scenario, pressing, maintaining
35.	Joe: I thought there was going to be a lot more water than that. I thought we were going to do it in the sink.	
36.	Ms. L: Yeah, *that's why I thought I better show you this*. No, because I want each little group to do it. So we're going to do it in this, and then, I guess, you know, once we try this, if you're not convinced, we could see if we could find a bigger thing of water at some point to try it in as well. But- so Caroline, Allan, anybody else, Elena, what do you think? *Still no?*	Clarifying scenario, pressing
37.	Elena: No.	
38.	Ms. L: *No, still no?*	Pressing
39.	Allan: I disagree ()! I think it's going to go together because it's only a little bit of space.	
40.	Caroline: Why did you change your mind now?	
41.	Ms. L: *You're changing your mind?*	Confirming
42.	Allan: There's only a little bit of space in that	

	cup. ((many students contributing))	
43.	Ms. L: So what- so Allan, what- shh shh shh shh. *So Allan, what does space have to do with your answer? Why would, why are you changing your answer?*	Pressing
44.	Allan: Because there's not a lot of circulation, so, well there's not a lot of water and stuff, so it won't ().	
45.	Ms. L: And I'm gonna wait for these folks to be listening. *So Allan, you (pause) now think that because it's in a small space, that the water won't be able to interfere with it as much? Like the waves wash it away or something like that?* Okay.	Confirming
46.	Allan: I say let's put it in a, in a pool.	
47.	Joe: I say let's put it in the sink.	
48.	Students: Yeah!	
49.	Ms. L: Um, let's, let's try it individually first, and um, *I think the biggest body of water we can generate in here is the sink*, so let's let each group try it, and then I'll see if I- *I don't even know if I can stop up the sink over there, but um, I'll see if I can, and then we can try it* in a slightly (pause) Shh, guys. Shh. So here's the procedure- did you have a comment, Kimmy? ((addresses student with hand raised)) Kimmy, I'm going to wait because you are so polite. ((to class)) And I know- I'm glad you're excited about this, but this ((points at Kimmy)) is the most important part. So Kimmy?	Altering activity
50.	Kimmy: Are you all, are you saying that – it's based on- the force is based on the amount of space the water has in the ()?	
51.	Ms. L: Well – Allan and Caroline, you want to answer Kimmy's question?	
52.	Caroline: Well, () in the cup, um, there's not enough water because the magnets are going to be like right next to each other because of the cup. But say if we put it in the sink, they'll probably be far away, so all the pressure from the water will probably keep them apart. And basically it's about how much water and how much space ().	
53.	Kimmy: Are you saying that when- if there's a small space, then the magnets will stay together because there's no space for them to	

	move around, and the sink is a bigger space?	
54.	Caroline: Yes, yeah so say if you put a magnet at one end of the, uh, one end of the container and the other, it'll be probably right next to each other, so it'll probably snap right together? But say if you put it in a big body of water, it probably won't go because all the pressure from the water ().	
55.	Ms. L: Okay.	
56.	Lisa: I say maybe we put one part of the magnet in the water, and the other like maybe a little bit higher, so there's still a lot amount of space? See if they'll still stick.	
57.	Elena: But we say it's in the water, how we gonna or, you're just-	
58.	Caroline: Maybe we can do it in two containers together and like stick them together and put the magnets-	
59.	Students: No!	
60.	Caroline: No because we could tape it together.	
61.	Student: () on the inside and on the outside.	
62.	Caroline: Or glue it together, I don't know.	
63.	Ms. L: Okay, this is, this is what I'm gonna do, I think you guys have a lot of great ideas. I, you know, I'm-	
64.	Student: What about if we use small magnets?	
65.	Ms. L: What I'll do is I'll give each team a cup of water and a pair of magnets, and then if you want to try it both underwater, you can, or *if you want to try it- and then try it the way Lisa's suggestion, with one underwater and one not. I'm not sure, um, Caroline, how we can-*	Altering activity, countering
66.	Caroline: Tape 'em.	
67.	Ms. L: *Yeah, I'm not sure how we could do that*, so let's try ((students laugh)) this for now, maybe we'll think through some other ways we can test it. Let's try this for now and then see where that takes our questions, okay?	Countering
68.	Cassie: Ms. L, I have another idea!	
69.	Ms. L: *You have another idea, Cassie?*	Maintaining
70.	Cassie: Um, if you have like, okay, you can get the water, if you have like the little um – plastic wrap things, you could put one magnet in the water, and one on top of the container, container, and then, and then the one in the	

	water can just be like- if it does-	
71.	Joe: Attract.	
72.	Cassie: Attract, it can just be like ((moves one hand to meet other above)) and like, attach.	
73.	Caroline: What if the plastic blocks it?	
74.	Joe: No, the plastic's so thin.	
75.	Caroline: Oh yeah.	
76.	Kimmy: What if the force of the water is pushing, pushing the magnet down so it won't be able to come up to stick to the other magnet?	
77.	Ms. L: Okay, so that's what we're kind of wondering because – think about on land. If, you know, we're just dealing with magnets in general. If I have a set of magnets ((gets a set of magnets)), and I give one to Amy ((gives Amy a magnet)), and I keep the other one, um, Amy, here ((positions herself far from Amy in combative stance)), magnet showdown ((students laugh)). Um, you know, what's happening?	
78.	Student: It can't touch.	
79.	Student: The air-	
80.	Student: It's too far.	
81.	Ms. L: What's the problem?	
82.	Student: It's too far away.	
83.	Ms. L: *They're too far away, so what do I need to do?*	Maintaining, eliciting
84.	Students: Get closer!	
85.	Ms. L: But this is not water here ((gestures to space between magnets)), this is just what?	
86.	Students: Air!	
87.	Ms. L: Air, so that whole problem of magnets being-	
88.	Mark: Isn't there air in water though?	
89.	Student: Uh-oh.	
90.	Ms. L: Yeah. That whole problem ((moves closer to Amy, comments to student nearby)) oops, I've got the wrong force now ((moves closer to Amy until magnets attract)).	
91.	Elena: Oh my gosh.	
92.	Ms. L: So ((students laugh)), so think that even on land, um, you know, if I have, if we're a distance apart, can, can the ne- can the magnets necessarily go through the air if you're that far apart?	

93.	Students: No!	
94.	Mark: But there's air in water.	
95.	Ms. L: *There's air in water*, but, so magnets have this, this power, don't they? But, but the power isn't strong enough to even overcome about six on land. So what we're sort of trying to figure out is – two things. First of all, will they work at all in water? *But then Caroline, you guys have sort of also brought up the whole idea of how close they have to be* to- ((to Amy, still playing with magnets)) we gotta go in the ((magnets attach)) – how close they have to be. So, um, Caroline?	Maintaining, returning to idea later
96.	Caroline: Um, I had- what was I going to say? () Oh yeah, as I, as I was saying, um, you said it would work in air, right? In gas?	
97.	Ms. L: *Well that's what we were doing right here, right?*	Clarifying scenario
98.	Caroline: Yeah, the whole gas thing. But it probably won't work in the water because I think water's kind of stronger than air because air we can just, you know, walk around and stuff-	
99.	Ms. L: *So air seems like something-*	Maintaining
100.	Caroline: We can push it.	
101.	Ms. L: *We can push out of the way more.*	Maintaining
102.	Caroline: Yeah, and you said it can like take the shape of its container, gas or air, so it probably took the shape of (), and if I put my hand through it, it will probably like, be like a cloud?	
103.	Ms. L: *And just get out of the way.*	Inserting
104.	Kristin: But if you move in water, you need some force to push on it.	
105.	Caroline: It's like when you swim-	
106.	Ms. L: So you think you need, okay.	
107.	Caroline: It's like when you swim, it's hard for your, um, the force of your arm to push through the water, so say if you put two magnets and say if they were your arms, it probably would be kind of hard-	
108.	Ms. L: Okay, so *it sounds like a lot of you guys are saying that water is, uh, more of a force working against the magnets than air is.*	Maintaining
109.	Caroline: Like erosion, when we were talking about the Grand Canyon and how the water	

	just pushed the rocks-	
110.	Student: Yeah () and weathering.	
111.	Ms. L: Okay, so *you're saying water and erosion is a, is a good sign of the power of water*. Okay. Well, let's just go- I'm gonna give you about five minutes to play with this.	Maintaining
Note. Italicized sections of transcript reflect responsive utterances.		

The remainder of the class period was spent trying out various ways to test if magnets work underwater and discussing students' findings. Ms. L only returned to how Elijah's question relates to forces in the last five minutes of the class period.

Justifying Inclusion

The above episode met the criteria for inclusion in my dissertation. First, of Ms. L's 43 speech turns in the episode, 29 contained responsive utterances. This represents a percentage of 67.4%, meaning the majority of Ms. L's utterances during the episode were responsive to students' ideas. Second, the conversation seemed resistant to the anticipated perturbation of connecting to forces specifically. In fact, there were a few times when students used the term "force" or "forces" in their explanations, and Ms. L did not in her recaps (e.g., lines 5, 29). Third, Ms. L reflected on this discussion in a debrief conversation immediately after class and at a teacher meeting in May of 2010.

Plausible Parts of the Coherence(s)

In what follows, I provide evidence for what might be part of the coherence(s) supporting Ms. L's attention and responsiveness to student thinking during this episode:

- How "into" the discussion students were
- Caring for students and their ideas
- Her desire to clarify the scenario under discussion

How "Into" the Discussion Students Were

One of the most salient aspects of this discussion to Ms. L was how invested students were in discussing the question. This is one of the first things Ms. L noted as we watched video of the episode together – when many students started contributing in line 32, Ms. L shook her head and exclaimed, "They were so into this!" [Interview, October 2012]. She repeated this sentiment three more times during the interview, and there is also evidence that she noted their excitement during the episode, stating, "I'm glad you're excited about this" [line 49].

Later in the interview, Ms. L articulated more about what she took as evidence of their excitement:

> And it just keeps going and going, and it's just fun. It's just, to me, it's really fun. It's fun when the kids, you know, and they keep coming up with one thing after another. We could have spent the whole rest of the year on this. It was so cool.

> And it truly was so authentic, and the kids were so into it. I mean, the way you can hear 'em talking in there, you know. They were so into it because this was all something they were coming up with, and I just- I just love it [Interview, October 2012].

Here, Ms. L noted that the kids kept "coming up with one thing after another," and the way in which they were talking is what gave her the impression they were engaged. She later noted that students were particularly invested in figuring out "the whys about this" [Interview, October 2012] rather than just jumping "into playing with the stuff" [Interview, October 2012]; her rhetoric was similar in the debrief conversation after class when she mentioned students looking for reasons why things were or were not happening. This focus on the "whys" is notable given Ms. L's initial framing of the discussion, in which she stated "we can't really talk about the whys of magnetism now" [Class, April 2010], suggesting that she got caught up in the students' excitement and direction. At the end of the interview, I noted that her original intent was not to go into the whys of magnetism, but "this whole thing happened anyway" [Interview, October 2012]:

> Ms. L: Just, it just ballooned. ((laughs)) Yeah, it did. Yeah, because they were obviously so into it that it was like unavoidable, you know? It was like, well, we, we have to do this because they were so into it.
>
> Jen: Yeah. No, that makes sense.
>
> Ms. L: Yeah. And it was definitely so rewarding. I, I've, I mean personally, to me, it was very rewarding, to hear all this going on. And I felt like the kids definitely, I mean, they were so into it [Interview, October 2012].

This exchange suggests two possible ways in which students' excitement during the discussion reinforced Ms. L's attention and responsiveness to their ideas. First, there's a sense that the kids being into it made it "unavoidable" for Ms. L. Her language here makes it seem like she had no choice but to follow their direction. In part, this is borne out in the episode – there were several times when Ms. L made a bid to test the magnets underwater and students offered ideas instead (like when Kimmy wanted to contribute in line 49, and Cassie had an idea in line 68). Yet Ms. L *could* have moved the class along if needed, which suggests that continuing the discussion was "unavoidable" *for Ms. L* since students were really invested. Moreover, Ms. L's continuing attention and responsiveness to students' ideas may have reinforced students' excitement with respect to the discussion.

Second, Ms. L indicated that "it was very rewarding" for her, suggesting that she personally derived some positive affect from students' engagement in the discussion. Ms. L corroborated this interpretation when she provided written feedback on this analysis: "The kids' excitement is definitely the strongest stabilizer for me, although when I think about it, it is actually a very selfish stabilizer, because I have so much fun teaching like this when the kids are so excited" [Feedback, January 2013]. Thus, Ms. L's excitement with respect to the students' excitement likely contributed to her continuing focus on the

ideas they were putting forth, and again, excitement may have begot excitement and the contribution of more ideas from students.

Caring for Students and Their Ideas

Ms. L's description of the discussion as "unavoidable" in light of students' investment demonstrates Ms. L's care for her students and their desires. Moreover, there is also evidence from the episode that Ms. L cared for her students' *ideas*[32]. For instance, the very fact that the leading question came from a student, Elijah, illustrates how Ms. L elevated a student's idea to prominence in the classroom. Moreover, during the episode, Ms. L's treatment of Kimmy's desire to contribute was particularly telling in terms of Ms. L's priorities:

> So here's the procedure- did you have a comment, Kimmy? ((addresses student with hand raised)) Kimmy, I'm going to wait because you are so polite. ((to class)) And I know- I'm glad you're excited about this, but this ((points at Kimmy)) is the most important part. So Kimmy? [line 49]

Although Ms. L was about to describe the experimental set-up, she paused and addressed Kimmy. Ms. L also indicated that "this ((points at Kimmy)) is the most important part," even beyond the students' excitement. I clarified what Ms. L meant by "this" in an interview:

> I think I was saying this discussion part. Because we were waiting- I was waiting to get the kids to listen to Kimmy. Um, I think that's what I meant, is that, yeah, we all need to be listening to each other [Interview, October 2012].

For Ms. L, listening to Kimmy's idea took precedence over moving on to the experiment and students' more general excitement. She noted that for some students, having their ideas taken seriously is a new experience:

> Ms. L: Some of them are used to being treated seriously, oh, but some of them are- some of them are really astonished that their ideas, um, are considered valuable…
>
> Jen: How can you tell, do you think?
>
> Ms. L: Because they just seem to come alive [Interview, October 2012].

Later, Ms. L commented on the changes she sees in students when the lessons focus on their ideas:

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[32] I do not necessarily think of caring for students and caring for students' ideas as distinct, but from an analytical standpoint, it is useful to highlight evidence for both separately.

> … that's why I think this whole thing is so powerful because of, you know, what I see happen with kids that do it. You know, maybe they don't get any smarter, but they sure are more out there about their id- you know, trying things out and contributing and stuff [Interview, October 2012].

These statements illustrate that Ms. L's care for her students, and their confidence and sense of self worth, is closely connected with caring for their ideas. It is likely that these senses of caring were bound up in the selected episode and supported her attention and responsiveness to students' ideas. I also note that these senses of caring may be tied to her attention and responsiveness to students' ideas beyond the selected episode, as her more general statements in the interview in October of 2012 seemed to stem from repeated experiences of seeing students "come alive" when their ideas were valued. Furthermore, these statements highlight a likely feedback loop between Ms. L and her students – as Ms. L cared for her students by attending and responding to their ideas, students became "more out there" about contributing their ideas, providing more ideas to which Ms. L could attend, and so on.

Her Desire to Clarify the Scenario Under Discussion

Another matter that was salient to Ms. L both during the episode and upon reflection was the emergent need to clarify the scenario under discussion. Toward the beginning of the discussion, Caroline talked about "all the pressure, all the water" [line 22], and Allan stated that "sometimes if the waves are strong, the magnets will separate and fall apart" [line 30]. In response, Ms. L held up a small container and indicated, "So we're not gonna do this, you know, in the ocean, the situations that Caroline and Allan are talking about" [line 34]. This exchange was the beginning of Ms. L's sense that she and the students were thinking of different scenarios, and much of the rest of the episode for Ms. L revolved around trying to both understand how students were thinking of the situation and reach some consensus on the matter. This focus both afforded and constrained Ms. L's attention and responsiveness to students' ideas.

In some ways, attempting to clarify the scenario supported Ms. L's attention and responsiveness to student thinking. Recognition of the need to do so emerged from Ms. L's attention to Caroline's and Allan's ideas, and she returned to their ideas after describing the experimental set-up she had ready, asking, "So based on that, um, would anybody's idea change?" [line 34]. In line 36, she followed up with Caroline, Allan, and Elena specifically, and between lines 39 and 45 she attended closely to why Allan's idea changed. She also allowed for variants on the experimental set-up, indicating that they could try it in the sink (line 49) or the way another student, Lisa, suggested (line 65).

Ms. L also attempted to clarify a specific issue students seemed to be conflating – whether magnets work underwater versus how close magnets have to be to work at all. For instance, Caroline described how the magnets would behave if they were "far away" [line 52] or "right next to each other" [line 54], and Ms. L later attributed "the whole idea of how close [the magnets] have to be" [line 95] to Caroline. Yet Ms. L indicated during an interview that Caroline may have been conflating the question of working underwater with the question of distance:

> So I think at this point ((flips through transcript)), I'm starting to realize that what Caroline is basically saying is if we pull them far enough apart ((holds hands apart)), they're not gonna attract, and it took a, and- I don't think she ever ((flips through transcript)), it's interesting, I don't think she ever acknowledged that. I think I finally even did it like okay, on land if we have them this far apart ((holds hands apart)), they're not gonna attract, so are we really talking about something different, or are we just talking about how far apart the magnets are? [Interview, October 2012]

Here, Ms. L recalled the demonstration that she did with the distance between magnets on land before it came up in the video, further supporting the salience of this matter for Ms. L. In fact, even earlier in the interview (when we had just watched Allan's statement about waves in line 30, before Caroline's explanation in lines 52 and 54), Ms. L recalled Caroline's explanation-to-come:

> Now we're trying- I think what we were trying to get at (pause) is that, like I think Caroline, and I think she goes into ((starts moving hands apart)), is that, you know, if there's, if there's a lot of water and they're really far apart, they're obviously probably not gonna work. So then we were trying to narrow it down to what, but what if we're just, you know, doing it like we do on land, but there's just a little bit of water in between 'em? Yeah, so that- it took awhile to ki- I remember that, trying to get to that [Interview, October 2012].

What is evident in the above interactions and recollections is that Ms. L attended to students' ideas about the scenario and the impact of distance between the magnets, and she engaged with them in sorting out their ideas.

However, Ms. L also pushed students to see the question of working underwater and the question of distance as separate in lines 77 through 95, which constrained her attention and responsiveness to students' ideas that were not immediately related to the point she was trying to make. In this part of the episode, Ms. L demonstrated how close magnets have to be on land in order for them to attract through the air, suggesting that magnets have a certain "power" [line 95]. In the debrief conversation after class, Ms. L indicated that she wanted students to see "that magnets have a limited force anyway, even on land" [Conversation, April 2010]. In a teacher meeting shortly after the episode, Ms. L related this idea of power or force to a magnetic field, "that at some point, magnets are no longer capable of – pulling each other, you know, because they're too far" [Meeting, May 2010].

As Ms. L was attempting to communicate this point to students during the episode, one student, Mark, offered the idea that there's air in water (lines 88, 94). In response, Ms. L simply said "Yeah" [line 90] the first time and repeated Mark's idea but reverted back to her point the second time: "There's air in water, but, so magnets have this, this power, don't they?" [line 95]. In this instance, the salience of the point Ms. L was trying to communicate in response to the discussion that had been happening among the students diminished her responsiveness to Mark's idea, which she likely perceived as tangential to the matter at hand. Ms. L agreed with this interpretation in her written feedback on this analysis: "By that time I was narrowing the ideas down in my own head,

and was basically so focused on those that I didn't give his idea much thought" [Feedback, January 2013]. In other words, her focus on students' ideas about the impact of distance between the magnets, and her attempt to help students see this issue as related to but distinct from the question of whether magnets work underwater, precluded her responsiveness to this new idea from Mark.

Summary

In the first episode from Ms. L's classroom, there were several aspects that stood out as plausibly reinforcing her attention and responsiveness to the substance of students' scientific thinking. The first was the level of engagement and excitement she noted among students during the discussion – this made it difficult for her to move on as she wanted to honor the students' investment and found their investment personally rewarding. Closely related was the importance that Ms. L attributed to honoring students' ideas as the means by which students *become* invested and feel that their ideas have value, offering more ideas in turn. The third was Ms. L's desire to clarify the scenario under discussion once she realized that students were thinking of different scenarios. She focused in particular on the possible conflation between whether magnets work underwater and how close magnets have to be to work at all, attending and responding to students' ideas on the matter and its implications for the experimental set-up but evidencing less responsiveness to ideas she perceived as tangential.

Episode 2: Why Did the Foxes Get Dropped?

Situating the Episode

The second episode from Ms. L's classroom occurred on September 29, 2010, at the beginning of Ms. L's second year in the project. The class was in the midst of a unit on classification. Ms. L was reviewing the idea that as we move from kingdom down to species, the groups of organisms get smaller, but what we know about the organisms gets larger. She used the diagram from the textbook in Figure D-1 to illustrate this point, moving sequentially from the top of the diagram toward the bottom:

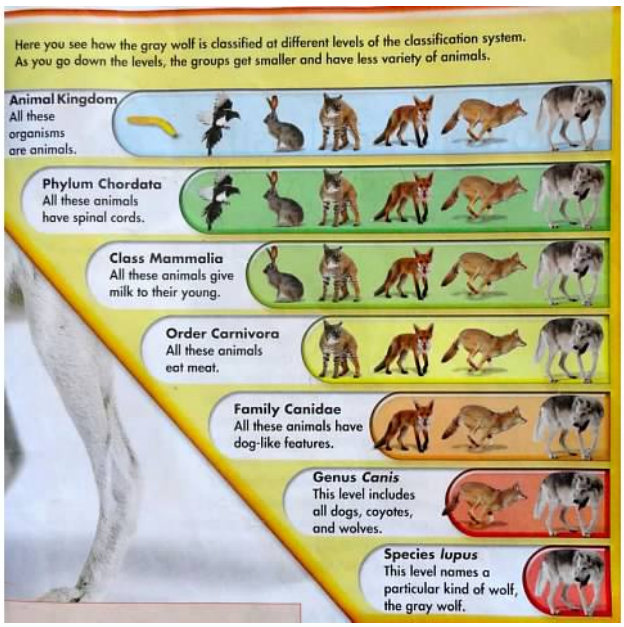

Figure D-1. Textbook classification diagram in question during second Ms. L episode.

At each level, the textbook explained why given organisms were still included in the group; for instance, all of the animals in "Order Carnivora" eat meat. However, at "Genus *Canis*," the textbook simply listed the organisms included. The episode below occurred when a student, Albert, asked why the fox was no longer included at this level.

Upon reflection at a teacher meeting shortly after the episode, Ms. L identified that she had not noticed this lack of explanation in the textbook until Albert's question:

> I didn't even notice this ((points at book))… it was one of the kids who brought this up, and then I went like, yeah, wait a minute, I get this ((points at class level)), and I get this ((points at order level)), and I get this ((points at family level)), but I don't get that ((points at genus level)). I don't know what's going on at that step [Meeting, October 2010].

Thus, the discussion that ensued was unplanned and emerged from Albert bringing his observation to public awareness during class.

Full Transcript and Coding

Table D-2 contains the full transcript and coding for the second episode from Ms. L's classroom. The transcript in the left column comes from approximately fourteen minutes of a whole-class discussion. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table D-2

Transcript and Coding for Second Ms. L Episode

Transcript		Coding
1.	Ms. L: Who'd we get rid of, um, Raymon?	
2.	Raymon: The fox.	
3.	Student: Why?	
4.	Ms. L: *The fox because* (pause) *I, and I'm not exactly sure why the foxes get dropped out at this point*. That would be an interesting thing to think about, wouldn't it ((Shavonne raises hand)), because somehow the wolves and the coyotes are more closely related than the-	Maintaining, inserting
5.	Shavonne: Fox.	
6.	Ms. L: Fox, yeah, so it would be interesting to see why we lose that one. You think you know, Shavonne?	
7.	Shavonne: Um, because aren't the coyotes the most, don't they, aren't they a type of, aren't they like a little related in a certain way?	
8.	Ms. L: Well, *they must be, you're right, because they end up in the same-*	Maintaining, inserting
9.	Shavonne: Genus.	
10.	Ms. L: *Genus, and some, for some reason, the fox got dropped out of that group*. In appearance, they do look a little bit different, don't they, I mean, I'm not sure, I don't know exactly why coyotes and wolves are more closely related than-	Maintaining, inserting
11.	Shavonne: Doesn't the fox look a little catish than the- they look more like a regular dog, but we know that, coyotes and wolves.	
12.	Ms. L: *Yeah* ((Randy raises hand)), *in appearance they do look more like a regular dog, don't they. Um, I'm not sure I can pinpoint exactly what it is that makes them look more doggy*, um, but something happens there, doesn't it, according to our classification stuff. Um, Randy?	Maintaining, inserting
13.	Randy: Um, it says as- on family, in the family part, it says that all these animals have dog-like features, so when they say features, that mean it kind of looks like a dog.	
14.	Ms. L: Yeah, so – I wonder what happens in this step ((between family and genus on diagram)), you know? What happens between family and genus that they kick the fox out of the group? There must be some trait that, I'm	

	not sure what it is.	
15.	Randy: I, I think it, it has dog-like features, but I- it probably is related to a cat more than a dog.	
16.	Ms. L: *Well, we ditched the cats up here, didn't- or somewhere we ditched the cat, here, didn't we? We ditched that really obvious looking cat*. So that's, that's an interesting question because it kind of comes down to (pause) you know, cats and dogs all have four legs, two ears, a tail, and all that stuff, so what is it about a cat that puts it in a different group from a-	Countering
17.	Shavonne: Fox.	
18.	Ms. L: From a fox, or from a- and then the fox from the other dogs. Um, so that might be something we want to pursue a little bit when we come-	
19.	Student: Questions for later?	
20.	Ms. L: *Should we put it in our questions for later?* ((gets questions for later board)) *Yeah, let- let's do that*, and then we'll, um (pause) but I mean that, that sounds pretty interesting, that might be something over the weekend, I might try to get you guys to do a little, uh, so what are we really figuring out, we want to know-	Altering activity
21.	Shavonne: Why the fox are not related- why did the fox give up at the genus group with the coyotes?	
22.	Ms. L: *Okay, yeah,* ((writing)) *so why fox is dropped* (pause) *from, in the genus level is what we're talking about, right?*	Revoicing
23.	Randy: Maybe that's just a certain type of wolf, like it is the grey wolf.	
24.	Ms. L: ((returns questions for later board)) *You know, turn to your partner and talk for a minute, if you think you see something.* I mean, all we have to go on right now is their picture, so if your science book would be out, turn to your partner and talk to 'em a minute and see why do you think we, we lost the fox at this level? ((students talk to partners, Ms. L claps to get attention)) Okay, so anybody got any ideas, what happened to the fox here? Why it- Luciano?	Altering activity

25.	Luciano: It, like, it hadn't or had changed, like, got out the-	
26.	Ms. L: Why between, why between- I can understand why we lost the cheetah because that's sort of a cat-like thing-	
27.	Shavonne: More of a cat.	
28.	Ms. L: But, yeah, but we get to this level, and I really see having the fox, the wolf, and the coyote together, but then here we lose the, we lose the fox in the genus level, and we're trying to figure out why. What is it that makes the fox separate from- why when, uh, scientists classified, why is the fox get in a different group? You think you know, Luciano?	
29.	Luciano: Because at the genus (), it says, "This level contains all dogs, coyotes, and wolves." And since a wolf- a fox is not either a dog, coyote, or wolf, it's not a genus.	
30.	Ms. L: *Right, it's in a different genus, but I guess what we're trying to figure out is what trait were they using* – that separated the- because remember, we, we've been doing traits, and we know that when we classify, it's gotta be for a reason, right? So, um, you think- Shavonne, you think you know?	Revoicing, clarifying question
31.	Shavonne: Um, I know why the- well, I think I know why the fox got dropped out. Because with the family, when it says family, that section only says dog-like feat::ures, not, like, you know, dog – family, but it has the feat::ures of a dog.	
32.	Ms. L: *Okay, so you're saying this part* ((points to family level)) *might be based on like the physical appearance, features-*	Maintaining
33.	Shavonne: Yeah.	
34.	Ms. L: *And then maybe something else is happening at this level* ((points to genus level))?	Pressing
35.	Shavonne: With the genus part, I think it's like, because a fox, not a fox, a coyote and a wolf, they, like, basically are dogs. They just had- they're just in the wild, and they have a different name. Because-	
36.	Ms. L: Yeah, but I'm still trying to figure, what is the specific thing? What's the trait? Because we, we know, we use traits to classify, what's	

	the trait that a fox doesn't have that a wolf and a-	
37.	Randy: I think I know.	
38.	Ms. L: *You think you know, Randy?*	Maintaining
39.	Randy: If, if you read the genus part, it, it says individually, in this level, it has coyotes and wolves.	
40.	Ms. L: *Yeah, yeah, I see that they're saying that, but I guess when I've- you know how, when we say something, like if I say to you, um,* ((gets mollusk)) *this is a mollusk*. We were- we started looking at these yesterday, and we're gonna get to that today ((glances at clock)) eventually. *And I say this is a mollusk, me saying in- it's a mollusk, it has, there has to be something about this that is mollusky, right? There has to be some reason I called it a mollusk. So there has to be some reason they decided that the fox is over here in this group, and those other three are over here-*	Maintaining, clarifying question
41.	Shavonne: Other two.	
42.	Ms. L: *The other* ((glances at diagram)) – *two, I'm sorry. Um, so what I'm trying to figure out is what was the reason?* What is there about a fox – I, 'cause I don't think we say, well, it's a fox because we call it a fox, and we call these other things – there's some – there's some trait there.	Maintaining, clarifying question
43.	Randy: Maybe-	
44.	Ms. L: Go ahead, Randy, I'm sorry.	
45.	Randy: Maybe we just gotta find out if a fox is a cat or not.	
46.	Ms. L: *So if it has a little more in common with a cat*, there's something about it-	Revoicing
47.	Student: But before we eliminated it, it said dog-like features.	
48.	Ms. L: *Cat, yeah, cats were eliminated, we know we're stuck with the dog-like animals*, but then somehow when they got even more specific, the fox got booted off the island or whatever, right? Um, Latrisha? Hold on a second.	Maintaining
49.	Latrisha: Maybe it's because of their fur color.	
50.	Ms. L: *The fur color*. Because that, um-	Maintaining
51.	Daria: But then why are the coyotes and the wolves together still because they have	

	different colored fur?	
52.	Ms. L: So did, does – say that to Latrisha. I don't know if Latrisha heard you. *So Latrisha suggested maybe it was the, the coat color*.	Maintaining
53.	Daria: But then the difference between a coyote and a wolf, um, they have different colors, but they're still in the same group.	
54.	Ms. L: *Yeah, so that would sort of – argue against that, but* (pause) *when Latrisha said fur, there – there might be something about a – fox's fur that is a little bit different. Something popped in my- see if you guys think of it*. Um, Albert?	Identifying differences, maintaining, inserting
55.	Albert: I said size?	
56.	Ms. L: *Eyes? You think the eyes may be different?*	Confirming
57.	Albert: Size.	
58.	Ms. L: *Or size, did you say? Oh, size*. (pause) Oh, that's an interesting one too. I, so I don't know. I mean, *foxes are generally smaller*, aren't they? Um-	Confirming, inserting
59.	Shavonne: Features?	
60.	Ms. L: *So what, but we're trying to get to the specific feature*, which we might not be able to do. We may, this may be something we have to-	Clarifying question
61.	Shavonne: Look up.	
62.	Ms. L: Go look up, yeah. I don't know, that might be- um, Wanda?	
63.	Wanda: Um, maybe the fox () because like others have already gone () then, um, the birds leave, and then () how the animals leave is they're different ()-	
64.	Ms. L: *Well, yeah, they're definitely leaving, but we can, we can- it's pretty obvious why they're leaving in the other ones*. Like here we know, um, they gotta have a spinal cord, here we know they gotta be mammals, so the bird has to go. Here we know they gotta be meat-eaters, so the rabbit goes because it doesn't eat meat. And here they're looking for dog-like animals, so I can kind of see the cheetah's more like a cat. But what I can't figure out is exactly what happens here that we lose the fox. *So Latrisha suggested maybe it was the coat color. Um, Albert said maybe size has*	Maintaining, inserting, returning to ideas later

	something to do with it. Oswaldo, you got an idea?	
65.	Oswaldo: Um, maybe because of the different places they live?	
66.	Ms. L: *Maybe habitat* – might be it? And- I don't know enough about the differences between these to know quite what it is. Um, Sung?	Revoicing
67.	Sung: Maybe how they react? How- what they do?	
68.	Ms. L: *What they do, some kind of behavior that they have? So we've got possibilities of physical things, like coat color and size, and possibilities about habitat or behavior*. Um, Amanda?	Maintaining, identifying similarities
69.	Amanda: What about gender?	
70.	Ms. L: *Pardon?*	Attempting to hear
71.	Amanda: Gender.	
72.	Ms. L: Well, *gender is what? What do we mean by gender?*	Pressing
73.	Julio: Boys.	
74.	Amanda: If there's more girl foxes than boy foxes-	
75.	Ms. L: *Than boys? But – um, anybody have a response to that? About it maybe being gender that the foxes were dropped?* Anybody have a – response to that, Kevin?	Confirming, reflecting
76.	Kevin: Um, okay, I have two things to say.	
77.	Ms. L: I'm gonna ask that, um (pause) people, people to remember their active listening skills? (pause) Thank you. Selena. Thank you. Go ahead, Kevin.	
78.	Kevin: I have two things, but I told you, I think I know why the foxes got dropped out.	
79.	Ms. L: *You think you do know? Why?*	Maintaining, pressing
80.	Kevin: It's mostly because if you look at the fox closely, you see that it has like a really long tail ((Ms. L looks at diagram)), and just like a regular cat's would be too. And um, if you look at the coyote, it's got a short tail like regular dogs. And-	
81.	Ms. L: *So a longer tail – more, more of a cat-like tail?*	Confirming
82.	Kevin: And there's another way that you could see that, since the wolf is all the way down, it seems like () because the wolf like hunches	

	down (), they're all ().	
83.	Ms. L: So there are, there are, *there's something physically different, and the longer tail is one of them, and I think Latrisha got on the coat, um – seems a little silky or something in a fox*. I don't know, I'm not sure what it is. Um ((sighs)), Wanda, Brandy?	Maintaining, returning to idea later, inserting
84.	Brandy: Um, I think um, like the ears, the ears are-	
85.	Ms. L: *The ears?* ((looks at diagram))	Confirming
86.	Brandy: Because the ears are pointier than the other ones. They're more like a cat-like ear.	
87.	Ms. L: *More like a cat-like ear, cat-like tail.* What do you think, Janis?	Maintaining
88.	Janis: Um, I kind of want to add on because like maybe if like you go back to the beginning where they were getting ready to let the bunny go, maybe the bunny () get eaten by one of them. Like, kind of like how their behavior is?	
89.	Ms. L: *Oh, so you're thinking like, uh-*	Maintaining
90.	Janis: Food chain.	
91.	Ms. L: *Somewhere, where they are on the food chain.*	Maintaining
92.	Janis: Yeah.	
93.	Ms. L: *Okay. So that would be behavior. So we've got physical things, we've got behavioral things*, don't we. So it all depends on the trait they're using, isn't it. It's like the mystery trait, and we're, we're having trouble identifying what that trait is.	Identifying similarities
94.	Gloria: () the wolf and coyote look more alike, but they have () different?	
95.	Ms. L: Okay.	
96.	Gloria: And the fox is like a little smaller than the wolf and coyote.	
97.	Ms. L: *So a combination of those physical like Al- size, coat, tail, ears*. Luciano?	Identifying similarities
98.	Luciano: Like, my, my version of what I'm saying is a little different.	
99.	Ms. L: Okay.	
100.	Luciano: I think the, if the coyote and the wolf like changed, like – if the coyote was dropped and the fox was still in the genus, but it'll still be out because it said, when it says species, um ((looks down)) species, the wolf will still get- the wolf, the wolf will still be in.	

101.	Ms. L: *Yeah, eventually the wolf is gonna be by itself, isn't it? Because that's a separate species. Um, but I guess I'm still confused why the fox goes*. But why don't we do this? Are, are some of you guys pretty interested in this topic?	Revoicing, inserting
102.	Students: Yes!	
103.	Ms. L: *So basically what the question we're asking, how can we phrase the, the question we're asking here?* Shavonne?	Eliciting
104.	Shavonne: Um, why does the, why does the fox get dropped out when it comes to the genus?	
105.	Ms. L: *So why is the fox not in the same genus as the-*	Revoicing
106.	Shavonne: Coyote and wolf.	
107.	Ms. L: *Wolf and the coyote*. Um, so I'm gonna make this, um, a bonus homework question for tonight.	Maintaining
Note. Italicized sections of transcript reflect responsive utterances.		

After this discussion, Ms. L returned to her planned lesson about invertebrates, in which students determined the characteristics of worms and arthropods using their textbooks for reference.

Justifying Inclusion

The above episode met the criteria for inclusion in my dissertation. First, of Ms. L's 53 speech turns in the episode, 40 contained responsive utterances. This represents a percentage of 75.5%, meaning the majority of Ms. L's utterances during the episode were responsive to students' ideas. Second, the conversation experienced a perturbation when Ms. L started to add the question to the list of questions for later (line 20). However, Ms. L changed her mind (line 24), and the conversation continued uninterrupted from that point, exhibiting resilience in the face of the intended lesson plan for the day. (I consider why Ms. L might have changed her mind in the analysis that follows.) Third, Ms. L reflected on the discussion during a teacher meeting a few days later in October of 2010.

Plausible Parts of the Coherence(s)

In what follows, I provide evidence for what might be part of the coherence(s) supporting Ms. L's attention and responsiveness to student thinking during this episode:

- Alignment with desired content understandings
- Ms. L's interest in figuring out the answer
- How "into" the discussion students were

Alignment with Desired Content Understandings

A brief point to note is the alignment between the emergent question at hand – why foxes got separated from coyotes and wolves – and the more general focus of the classification unit. During the unit, Ms. L repeatedly tried to convey that classification occurs for a reason, and how and why organisms are classified depends on their traits. In an interview, she identified the fox discussion as "so relevant to what we were doing" [Interview, October 2012] with the larger topic of classification; her written feedback on this analysis reiterated that it "totally reinforced the basic concept we were working on (basically couldn't have come up with a better one myself)" [Feedback, January 2013]. This connection can be seen in the classroom episode as well when Ms. L reminded students, "We've been doing traits, and we know that when we classify, it's gotta be for a reason, right?" [line 30]. It is likely that as students started proposing traits that might be distinct between the fox and the other organisms, Ms. L noted that they were reasoning about classification, which further promoted her attention to their ideas, and so on.

Furthermore, she worried about what might have happened if she did not pursue Albert's question:

> And I just thought we would, it would, you know, that would be like, well, just accept my word for it, guys, there's some reason- when the whole point is we were trying to figure out the reasons [Interview, October 2012].

By not following up on Albert's question, Ms. L thought students would have to rely on her authority rather than make sense of the situation for themselves – and as she said, "the whole point" of the unit was for students to see the logic in classification. This also played out in the episode when Ms. L pushed students to think beyond what the textbook said. For instance, a student, Luciano, simply read what the book stated about the genus level and how foxes were not part. Ms. L acknowledged what he said but also clarified that "what we're trying to figure out is what trait they were using" [Episode, September 2010]. Later, another student, Randy, stated that the genus level has coyotes and wolves, and Ms. L again acknowledged this but tried to get students to think about the *reason* the fox is no longer included. During the interview, Ms. L articulated what concerned her about this approach on the part of the students:

> Ms. L: They're just stuck on, it's almost like how they regard authority. It was like they're gone because the chart says they're gone.
>
> Jen: Gotcha.
>
> Ms. L: Yeah, that's alm- that's how I felt they were doing it. They, they still, a lot of them still weren't really thinking. They were like, well, they're gone because that's what the book says [Interview, October 2012].

Ms. L interpreted responses like Luciano's and Randy's as literal appeals to the authority of the textbook. While she acknowledged those responses, she responded by pressing students to think about *why* the fox would have been dropped at the genus level. In other

words, responses that did *not* address why may have also stabilized Ms. L's attention and responsiveness to student thinking during the episode; these were often moments in which she pushed and listened for more from her students. Thus, for Ms. L, the intended "concept" or content was more expansive than traditional notions of what classification is and different ways in which scientists classify organisms; she also wanted students to understand the purpose and process of classification, and the fox discussion served as a natural extension of this objective.

Ms. L's Interest in Figuring Out the Answer

One of the most salient aspects throughout this discussion was Ms. L's own interest in figuring out the answer to the question. Looking more closely at Ms. L's participation during the episode, there is evidence that she did not know the answer to Albert's question. Her immediate response was "I'm not exactly sure why the foxes get dropped out at this point" [line 4], and she reiterated not being sure about why the foxes got dropped throughout the discussion (e.g., lines 10, 14, 36, 42, 64, 83, 101). She referenced a "mystery trait" [line 93] that must be in play.

While Ms. L's moves suggest that she didn't know why the fox was dropped from the genus, an alternative interpretation is that she *did* know and was acting as if she did not to get the students thinking about the matter, or to indicate that it's okay to not know. I raised this alternative with Ms. L in an interview as we were watching video of the episode, right after she stated, "I guess I'm still confused why the fox goes" [line 101]:

> Jen: I just want to make sure that this is an accurate interpretation, like, 101, for example.
>
> Ms. L: Mm-hmm?
>
> Jen: You know, "I guess I'm still confused why the fox goes." Sometimes I feel like I'll say that if I feel like others in the class are confused and I don't want to put it on them-
>
> Ms. L: No, but I really-
>
> Jen: But sometimes it's because I really am.
>
> Ms. L: Yeah, I was still confused. I really had absolutely no – I mean, to me, it was like the- I was, this was totally, um, real. There was nothing, yeah, it wasn't, um- you know because I do that sometimes, where I act like I don't know.
>
> Jen: I do too, yeah.
>
> Ms. L: Yeah. But in this case, I was totally, um, befuddled by it. I really did not have any idea [Interview, October 2012].

In this response, Ms. L indicated that she recognized the kind of move I was positing ("where I act like I don't know"), but that her confusion about why the foxes got dropped was authentic.

What is particularly noteworthy is that this confusion seemed motivating for Ms. L rather than stifling. Immediately after saying she did not know why the foxes got dropped, she acknowledged, "That would be an interesting thing to think about" [line 4]. Ms. L repeated that the question was interesting three other times early in the conversation (lines 6, 16, and 20), with her raised pitch at one point – "So that, th::at's an int::eresting question…" [line 16] – suggesting that she was enthused by the question and the possibility of pursuing it with her students. During an interview, she excitedly recalled her confusion:

> I had NO idea! It was fun::ny, I just hadn't even ever really tho::ught about it. I'm not sure I ever really no::ticed it – that closely. And, but we were trying to work our way down ((mimics moving through diagram)) through o::ne, and it was like ((sits back with furrowed brow and pursed lips)) – why is this- I, I had NO idea. It was so cool! [Interview, October 2012]

In this statement, Ms. L indicated twice that she "had NO idea" why the foxes got dropped and appeared puzzled as she described working her way through the diagram. Furthermore, the emphatic way in which she described this experience and her tagging of it as "so cool" indicated that not only was she okay with not knowing something, but she was actually enthused by the idea of exploring the topic. As she indicated in her written feedback on this analysis, "I LOVE authentically trying to figure stuff out with the kids" [Feedback, January 2013].

Indeed, Ms. L's participation in the discussion suggested that she was actively processing students' ideas and often referencing her own thinking in conjunction. For instance, when a student, Shavonne, suggested that coyotes and wolves look more like regular dogs (line 11), Ms. L agreed but indicated she wasn't sure what she was attending to that made her think that: "Yeah… in appearance they do look more like a regular dog, don't they. Um, I'm not sure I can pinpoint exactly what it is that makes them look more doggy" [line 12]. Similarly, when a student, Latrisha, offered that fur color might be relevant (line 49) and another student, Daria, marshaled a counterargument against this idea (lines 51 and 53), Ms. L indicated that the idea of fur color sparked her thinking about a different fur characteristic: "When Latrisha said fur, there – there might be something about a – fox's fur that is a little bit different. Something popped in my- see if you guys think of it" [line 54]. Ms. L brought up the silkiness of the fox's fur later in the discussion (line 83). Thus, in striving to figure out why the foxes got dropped, Ms. L iteratively attended and responded to students' ideas as possibilities to consider and sparks for her own thinking on the matter. Her rhetoric in describing the discussion at a teacher meeting shortly thereafter reiterated that she and the students were in it together:

> Ms. L: We were looking at this chart, and it was neat because this was like taking the grey wolf and working your way down. And so, like, it made sense here, we dropped out, you know, these are animals, vertebrates, and every time the kids, we could understand the characteristic that was being used… and then all of a

> sudden, here they just drop it, and their explanation is just that this group just includes the-
>
> Ayush: Huh.
>
> Ms. L: And they don't really give a-
>
> Jen: Say why.
>
> Ms. L: They don't say why, and so the one kid said so, so why do they do it there? And then we were all I don't know why, I don't know why the fox goes one way and the others, so it was pretty cool [Meeting, October 2010].

In this description, Ms. L included herself with the kids, stating that at first "we could understand the characteristic that was being used," but when the fox got dropped, "we were all I don't know why." Her repeated use of "we" indicates that she and the kids were striving to figure it out together.

How "Into" the Discussion Students Were

Yet Ms. L's decision to address Albert's question was not absolute from the beginning of the episode. An interesting shift occurred between Ms. L adding the question to the list of questions for later (line 20) and resuming the conversation in real time (line 24). Upon watching this section of video more closely, I noticed that students still had their hands up as Ms. L wrote the question on the questions for later board. Additionally, students continued discussing the question, including Daria, who talked directly to Ms. L as she wrote on the board. Thus, Ms. L's decision to continue the conversation was probably influenced by students continuing to talk about the question.

In the interview, Ms. L corroborated this interpretation:

> Jen: It seemed, you know, for a minute that it was going up on the questions for later, maybe to be-
>
> Ms. L: Yeah, and then we, it was just too clear that everybody was really into it… I think we were just trying to get through all this stuff today, that day, and it just was too cool to pass on… I had no idea, and they seemed to be coming up with these great ideas, and they really seemed to be very interested in it [Interview, October 2012].

Here, Ms. L explicitly tied her decision to continue discussing the question to student interest in the topic – similar to what we saw in the first episode from Ms. L's classroom. Additionally, her attention to students' ideas may have supported their continuing interest, as they saw that she was interested in what they were saying. Ms. L also reiterated that she did not know the answer to the question, so students' "great ideas" may have helped her make sense of the situation herself.

Summary

In the second episode from Ms. L's classroom, several aspects cohered and supported her attention and responsiveness to the substance of students' scientific thinking. The discussion about why the fox got dropped at the genus level related to Ms. L's desire for students to see the logic and meaning in classification – she wanted students to move beyond citing what the textbook said and think more deeply about the question. Moreover, Ms. L was interested in figuring out the answer to the question, and she sensed that students were interested in doing so as well. Both sources of interest were likely mutually reinforcing and supported Ms. L's continued focus on students' ideas as possible answers and sparks for her own thinking on the matter.

Episode 3: Are Ice and Snow Both Solids?

Situating the Episode

The third episode from Ms. L's classroom occurred on February 1, 2011, midway through Ms. L's second year in the project. Ms. L and another teacher at her school used several activities to spark discussion about states of matter and the water cycle. One activity involved applying a wet sponge to a piece of construction paper and predicting what would happen if the paper was allowed to sit out. Another activity asked students to observe what happened to snow remaining from a recent snowfall over the course of a few days.

In class, Ms. L began by recapping some of the main ideas from the sponge/paper activity. One idea was that the paper soaked up the water, with possible evidence being that the paper curled as the water became less visible. Another idea was that the water disappeared, but clarification was needed on where the water went. Then Ms. L asked students to share their snow observations. A student, Rodrick, said the snow became harder; another student added it turned into ice. Several students noted the snow decreased in depth, and one student, Houston, said there was water left behind. The episode began shortly after Ms. L asked where the water came from, and a student responded that the snow melted.

Full Transcript and Coding

Table D-3 contains the full transcript and coding for the third episode from Ms. L's classroom. The transcript in the left column comes from approximately eleven minutes of a whole-class discussion. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table D-3

Transcript and Coding for Third Ms. L Episode

Transcript	Coding

1.	Ms. L: Um, so when we say the snow melted, what specifically are we talking about? What did it do, when something melts, what does it do? Um, Timika?	
2.	Timika: Increases and like dissolves some of the water and evaporates?	
3.	Ms. L: Well, let's stick with j- okay, *you said it evap- when something melts, it evaporates*. But if I took some ice cubes and left 'em in a cup out for a couple hours-	Maintaining
4.	Student: In the sun.	
5.	Ms. L: In here, *or out in the sun*. What would you expect to see in my cup?	Maintaining
6.	Students: Water!	
7.	Ms. L: *You would, so, well, wasn't there water in my cup to start with?*	Countering
8.	Students: Yes.	
9.	Students: No.	
10.	Janis: It was ice!	
11.	Student: Ice is frozen water!	
12.	Janis: Glaciers!	
13.	Ms. L: Turn to your table and talk about that question. ((students talk to table, Ms. L claps to get attention)) Okay, so ((Ms. L claps to get attention)) Okay, so, I have these ice cubes, so *somebody said okay now, you're going to have water in your cup, so my question was didn't- what did I have in my cup to begin with then?*	Maintaining, pressing
14.	Students: Ice.	
15.	Brandy: Frozen water.	
16.	Ms. L: So who wants to comment on that, Brandy?	
17.	Brandy: Frozen water, you have frozen water already, like when you have, um, when you like want to get ice cubes right, when you have in- you have your freezer and you have your little, um, little spatula, and you put water-	
18.	Selena: Spatula? ((Brandy laughs))	
19.	Ms. L: *Spatula, yeah, she's a cook*. Okay.	Maintaining, inserting
20.	Brandy: The water, um, and you put it in your freezer?	
21.	Ms. L: Mm-hmm.	
22.	Brandy: And it starts- and maybe like an hour or two hours later, it's ice?	
23.	Ms. L: Okay.	
24.	Brandy: So literally all it is is frozen water.	

25.	Ms. L: *So those ice cubes were still water, you're saying, it's just that they were frozen instead of – what do we call-*	Maintaining, eliciting
26.	Janis: Liquid.	
27.	Ms. L: *Instead of what?*	Attempting to hear
28.	Janis: Liquid.	
29.	Brandy: Liquid.	
30.	Ms. L: *Liquid, okay*, so we've got, um ((turns to overhead)), so we've got-	Maintaining
31.	Brandy: Do we need to write this down?	
32.	Ms. L: Let me just kind of write some of these down. We've got liquid water, don't we? ((writes liquid))	
33.	Brandy: Do we need to write this?	
34.	Ms. L: Um, uh, no. Just for now, just think. All I want you guys to do is think. I got liquid water, and then those ice cubes, or- is that kind of the same, are the ice cubes kind of the same as the snow out there?	
35.	Student: Yes.	
36.	Randy: No.	
37.	Student: Yes and no.	
38.	Student: They're bigger.	
39.	Ms. L: *Yes and no, sort of*, but-	Maintaining
40.	Student: The snow's just soft.	
41.	Student: It's shorter!	
42.	Ms. L: Okay, so-	
43.	Brandy: But snow and water-	
44.	Ms. L: Let's think about the, um-	
45.	Brandy: () just do water.	
46.	Janis: Shush!	
47.	Ms. L: Let's, let's think about the relationship between like an ice cube and the snow out here. So Oswaldo, are those ice cubes – if we're trying to say which, which it's most like, *are those ice cubes more like the snow out here, or more like the water I could get out of that tap?*	Pressing
48.	Oswaldo: Snow.	
49.	Randy: The water.	
50.	Janis: The snow!	
51.	Ms. L: *You think they're more like the water?*	Confirming
52.	Randy: Yeah.	
53.	Ms. L: *So why do you think they're more like the water, Randy?*	Pressing

54.	Randy: Oh, uh – I think they're more like the water because they're made out of the water, and snow I think is kind of like water because if you pick up a little bit of snow and put it in your hand and just wait a few seconds, it'll just turn into water straight in your hand.	
55.	Student: Body heat.	
56.	Ms. L: So what are we- what it, when it – when it, when something melts, what is it doing?	
57.	Janis: It turns into liquid.	
58.	Ms. L: *It's turning into a liquid, and what did it start off as?*	Maintaining, eliciting
59.	Student: Solid.	
60.	Janis: Solid.	
61.	Ms. L: *It was a solid, right? So Randy, this- and everybody, this snow out here, what is that? Is that a liquid or a solid?*	Maintaining, pressing
62.	Janis: Solid.	
63.	Brandy: It's a solid right now.	
64.	Randy: It's a liquid!	
65.	Janis: A solid.	
66.	Ms. L: Turn to your partner, turn to your table. ((students talk to table, Ms. L claps to get attention)) Okay, so let's see if we can get this straight. We got that stuff out there, snow.	
67.	Janis: Let's take a vote.	
68.	Ms. L: And *Timika just made a comment, so I want Timika to share her comment*.	Maintaining
69.	Timika: I forgot what I said.	
70.	Ms. L: You do not, you're just being shy. You said if I took it- *I'll start you off. You said if I took some of that snow and put it in my hand, what would happen to it?*	Revoicing, pressing
71.	Timika: It'll melt.	
72.	Ms. L: *And so what does it become when it melts?*	Eliciting
73.	Timika: A liquid.	
74.	Ms. L: *It's a liquid. But what did it start off as?*	Maintaining, eliciting
75.	Janis: ((stands up, to Randy)) Thank you.	
76.	Ms. L: *A solid*. Janis, excuse me. So did you guys – *did you guys hear what Timika said?* I'm not saying she's right or wrong-	Maintaining
77.	Student: But how is it a solid?	
78.	Ms. L: *But what she's saying is that the snow, when you start off with it in your hand, is-*	Revoicing

79.	Janis: Solid.	
80.	Ms. L: *A solid, but as soon as it's in your hand for even a short period of time, it's going to melt-*	Revoicing
81.	Janis: So it can be both?	
82.	Ms. L: *And it becomes a liquid*. So what do we mean by melt then, scientifically? In, in science, melting – if everybody's agreeing if I put the snow in my hand, and let it sit there, and it turns into a liquid, we- would we all agree that that's what we call melting?	Revoicing
83.	Students: Yes.	
84.	Ms. L: So in scientific terms, what has happened to the snow that was in my hand? It's gone from a what to a what?	
85.	Students: Solid to a liquid.	
86.	Ms. L: Because definitely – that's not liquid out there right now, is it?	
87.	Students: No.	
88.	Ms. L: It's, it is, *it's a little goofy, we're not totally sure if it's a solid yet-*	Maintaining
89.	Janis: Because the ice is the liquid, but the snow is the solid.	
90.	Ms. L: Now, so hold on one second. So we're getting this idea that when something melts, it turns into a liquid, right? We're not exactly sure what it's starting from yet. But I heard Janis, as we were discussing this, *I heard Janis say so it can be both?*	Returning to idea later
91.	Brandy: I said that.	
92.	Ms. L: So- and *did you say that as well Brandy?*	Maintaining
93.	Janis: No.	
94.	Brandy: Yes.	
95.	Ms. L: So, what is that snow out there? And just like-	
96.	Janis: A liquid!	
97.	Ms. L: But what is the stuff, like those ice cubes? What are those ice cubes?	
98.	Students: Solid!	
99.	Student: They're a liquid.	
100.	Ms. L: They're frozen-	
101.	Students: Water.	
102.	Ms. L: And then – excuse me – when I, when I let it melt, is it still water?	
103.	Janis: Yes, it's still a liquid.	

104.	Ms. L: But now it's the-	
105.	Janis: Liquid!	
106.	Ms. L: Liquid form of water. Okay, so – say, so Amanda, what are you saying?	
107.	Amanda: ().	
108.	Ms. L: Yeah? But if you're not contributing to our conversation-	
109.	Student: She's talking about the snow.	
110.	Ms. L: *I know she is, and she's saying something good, and I want to hear what she's saying.*	Maintaining
111.	Amanda: Like if you pick, if- it's both because if you pick it, like pick () of snow, it'll just like drop out of your hands, but if you pick up the – the snow that's outside, it won't break apart because () solid ().	
112.	Ms. L: So, do you think – *okay, so you hear what Amanda's saying? Regular snow-*	Maintaining
113.	Student: ((falls over)) Ow.	
114.	Student: You okay?	
115.	Ms. L: You okay over there? Um, is there some ice under your seat? Um, *so Amanda made this really good distinction. She's saying that there's some snow out there, if I pick it up, it'll just break apart and fall, but then there's some other stuff out there that is frozen solid together, it won't separate into – but is it- so any comments on what Amanda said?* On that observation, um, Randy?	Maintaining, reflecting
116.	Randy: ((shakes head))	
117.	Ms. L: No?	
118.	Randy: Uh-uh.	
119.	Ms. L: Selena?	
120.	Selena: I have a question. Doesn't it start as liquid because when the snow falls down, it's liquid- I mean, liquid, but then it starts to form into a solid.	
121.	Malik: No.	
122.	Selena: Yes.	
123.	Ms. L: So, *so how, how does that-*	Pressing
124.	Malik: When the clouds get-	
125.	Ms. L: *How does it get-* Malik, answer Selena.	Pressing
126.	Malik: When the clouds get, when the clouds get colder, it forms as, first it forms as hail, then – whatever that is, snow.	
127.	Ms. L: Okay? (pause) *So now, Selena's*	Maintaining

	brought in the idea that, you know, maybe there's just- did that snow that they're, didn't it start off as water up there?	
128.	Janis: Yes.	
129.	Ms. L: *And then Malik is suggesting that something about its movement through the air turned it into, first you said hail and then-*	Maintaining
130.	Malik: Then snow.	
131.	Ms. L: *Snow? So comments on that one?* Um, Latrisha?	Maintaining, reflecting
132.	Latrisha: I have something on Amanda's.	
133.	Ms. L: Okay, wait, we got too many conversations going at once here. So let me, *let me stop and summarize the two ideas we're tackling right now. Um, Amanda is saying that there are some, a couple things out there that are not liquid water, aren't there? There are things that look like snow that are sort of separated stuff, and then there's the stuff that's all compacted together. So I think in general terms, don't we call the stuff that sort of separates a little bit snow and the stuff that's compacted together-*	Revoicing, inserting
134.	Janis: Ice?	
135.	Ms. L: *We call that ice, don't we? Is that- am I kind of thinking-*	Inserting
136.	Student: Yeah but-	
137.	Ms. L: *A distinction that at least in my mind that's what's going on?*	Inserting
138.	Student: Isn't ice ()?	
139.	Ms. L: *But then, then we also have Selena's idea that this started off-*	Maintaining
140.	Janis: As a liquid.	
141.	Ms. L: *As a liquid, and then got transformed somehow-*	Maintaining
142.	Janis: Into a solid.	
143.	Ms. L: *Into a solid.*	Maintaining
144.	Janis: Because it's a combination- wait, but how does, but if, but if it starts out as a liquid, liquid doesn't turn into a solid.	
145.	Students: Yes it does!	
146.	Ms. L: Shh, shh, shh. Hold on a minute. *So Janis's saying liquid can't turn into a solid.* ((multiple students talking)) Shh, active listeners. *Let her continue.*	Maintaining
147.	Janis: It, it can because, like, if – if you put	

	water in the freezer, it's gonna turn into a solid, but the snow came down as a liquid, and then it forms into a solid.	
148.	Selena: Yes, that's what I'm trying to say. That's what I said.	
149.	Malik: You just said it can't.	
150.	Ms. L: Hold on, hold on a sec. ((points toward Janis))	
151.	Janis: But what Amanda said, that's kinda like the snow going through a phase. Like kinda like the moon? Like the snow, like, if – Amanda, what'd you say? You said it turns into a liquid?	
152.	Selena: She said-	
153.	Amanda: No.	
154.	Ms. L: *I think Amanda was making the distinction out there between snow and ice, weren't you?* ((Amanda nods)) But, um-	Confirming
Note. Italicized sections of transcript reflect responsive utterances.		

As the discussion continued, Ms. L asked if snow, ice, and water are all made of the same thing, and students generally agreed they are. They also recapped the definition of melting, the differences between solids and liquids, and what it takes for something to melt. At the end of the class period, Ms. L identified remaining questions to address the following day.

Justifying Inclusion

The above episode met most of the criteria for inclusion in my dissertation. First, of Ms. L's 63 speech turns in the episode, 41 contained responsive utterances. This represents a percentage of 65.1%, meaning the majority of Ms. L's utterances during the episode were responsive to students' ideas. Ms. L also reflected on the discussion at a teacher meeting later the same day.

However, I selected this episode in part because it took Ms. L longer to follow the students' direction than it did in the other episodes from her classroom, creating a natural point of comparison between this episode and the others. On the whole, this conversation was more variable in nature and embodied tensions not as evident in the other episodes, which I explore in the analysis that follows.

Plausible Parts of the Coherence(s)

Analytically, this episode can loosely be divided into two sections – lines 1-106 and lines 106-154. I briefly describe each section before considering what stabilized Ms. L's attention and responsiveness in the second section, in which she focused more clearly on students' ideas.

In the first section from lines 1-106, Ms. L repeatedly returned to the question of what it means for something to melt (lines 1, 56, 72, 82, 90). The example that follows represents the particular understanding Ms. L wanted students to have:

> Ms. L: So what do we mean by melt then, scientifically? In, in science, melting – if everybody's agreeing if I put the snow in my hand, and let it sit there, and it turns into a liquid, we- would we all agree that's what we call melting?
>
> Students: Yes.
>
> Ms. L: So in scientific terms, what has happened to the snow that was in my hand? It's gone from a what to a what?
>
> Students: Solid to a liquid [lines 82-85].

Ms. L specifically wanted students to understand that melting involves a change from a solid to a liquid, as indicated by her prompting. Upon watching the video during an interview, Ms. L had a similar impression of what her goal was despite not remembering explicitly: "I guess I was trying to get them to understand what we mean scientifically when we say something melts, how melting is that phase change. I guess that's what I was going for there" [Interview, October 2012].

Ms. L's activity during the first section involved interaction with students' ideas, but in a way that was mediated by the understanding she wanted students to come to. For instance, debate erupted over whether snow could really be considered a solid, and students expressed varying opinions on the matter. Ms. L asked whether ice cubes are more like snow or water (line 47) and initially followed up with a student, Randy, who answered water (line 49):

> Ms. L: So why do you think they're more like the water, Randy?
>
> Randy: Oh, uh – I think they're more like the water because they're made out of the water, and snow I think is kind of like water because if you pick up a little bit of snow and put it in your hand and just wait a few seconds, it'll just turn into water straight in your hand.
>
> Student: Body heat.
>
> Ms. L: So what are we- what it, when it – when it, when something melts, what is it doing? [lines 53-56]

In his response, Randy noted that ice cubes are more like water because they're made of water, and snow is kind of like water because it turns into water in your hand. Yet Ms. L's response did not address Randy's specific ideas. Instead, she returned to the idea of

melting[33] and used the definition of a solid turning into a liquid to prompt Randy and other students to see the snow as solid: "It was a solid, right? So Randy, this- and everybody, this snow out here, what is that? Is that a liquid or a solid?" [line 61]. When students still disagreed, Ms. L had them talk to their neighbors about their ideas and then elevated Timika's idea in lines 68-76, which framed snow as a solid. These examples illustrate that Ms. L was attending and responding to students' ideas to some extent in the first section, but ultimately in the service of getting them to see snow as a solid.

In contrast, in the second section from lines 106-154, Ms. L pursued the senses in which snow is *not* a typical solid, as well as other ideas students raised. For instance, rather than elevating an idea that framed snow as a solid, Ms. L drew attention to Amanda's idea in lines 106-115, which focused on a difference between snow and ice. Note that I am not saying there was a hard line between the sections – the first section contained moments in which Ms. L acknowledged the confusion about snow, describing it as "a little goofy, we're not totally sure if it's a solid yet" [line 88] and revoicing a student's question about whether it can be both in line 90. Rather, I consider the distinction between the sections to be a matter of foregrounding, with the first section foregrounding the idea of snow as a solid that can melt and the second section foregrounding the confusion about snow and other ideas from students. Ms. L recognized these as two different directions in an interview, stating, "I think I was struggling with myself in the moment trying to think of which way we should go with this conversation" [Interview, October 2012].

Here, I specifically consider what might be part of the coherence(s) supporting Ms. L's attention and responsiveness to student thinking in the second section, in which she flowed more with students' ideas:

- Seeing students' confusion about snow as "valid"
- Respecting students as contributors

Seeing Students' Confusion About Snow as "Valid"

In an interview, Ms. L noted that discussing both snow and ice was confusing but also worthwhile. She stated several times that she understood the students' distinction between the two, as "snow isn't a solid in the sense that we think of things as… it's not hard, and it breaks apart and goes into little pieces, and melts real easily" [Interview, October 2012]. This is part of what made the pursuit "valid" to her:

> Jen: And what do you mean by "valid"?
>
> Ms. L: That it seems like it's a good question… they're genuinely confused about something, or there's something they really want to figure out… like if I can see that they're really not understanding what's going on, but it's definitely when I don't get what they're talking about [Interview, October 2012].

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[33] The idea of melting may have been loosely connected to Randy's sense of snow turning into water in your hand, but this connection was not clear or explicit.

Here, Ms. L indicated that a question is valid if students are genuinely confused or seeking an answer, and even more valid if she is also confused. The question about whether snow and ice are both solids fit all parameters, as Ms. L highlighted her own confusion later in the interview:

> And you know, honestly, with this whole thing, with the snow and the ice cube – I, you know, am not sure. I mean, you can feel there's a difference, but I'm not sure – what it is or how that all – how that all works… Like is snow just a really fragile solid or something like that? [Interview, October 2012]

In part, then, Ms. L's focus on students' ideas about the nature of snow was supported by her sense that it was a valid topic to ponder. Through listening to students' differing responses, she noted that students seemed to be seeking understanding of something she did not fully understand either, which supported her continued focus on the ideas they posited on the matter.

Respecting Students as Contributors

Moreover, once Ms. L deemed the topic valid, she did not want to brush over it. As she stated in an interview, "I don't like to just slough off when they say... something that's really pretty – valid. I don't like to just ((brushes hand to side)), um, ignore it" [Interview, October 2012]. She indicated that she wants students to feel valued and agentive in her classroom, which involves taking their contributions seriously: "I don't want to make the kids feel like, well, that question's not worth us talking about" [Interview, October 2012]. Moreover, she tied this to what she called "the spirit of inquiry" [Interview, October 2012], in which anyone should be able to raise a topic or question for discussion.

Summary

The third episode from Ms. L's classroom was more fraught with tension than the previous episodes, with the first section foregrounding the idea of snow as a solid that can melt and the second section foregrounding the confusion about snow and other ideas from students. I specifically considered what might have contributed to Ms. L's focus in the second section, in which she was more clearly attending and responding to students' ideas. One aspect in play was that she saw the question of whether snow was a solid as valid – something that students were genuinely wondering about in the moment, and that she strove to support them in by attending and responding to their ideas on the matter. Another aspect in play was her desire to respect students' contributions in the classroom, both to help them see their own ideas as worthwhile and to teach in a manner that she saw as congruent with inquiry.

Synthesizing Across Episodes

Looking across the three episodes from Ms. L's classroom, something that stands out is how Ms. L's care and respect for her students and their ideas supported her attention and responsiveness to their thinking. This care and respect manifested in several

ways. In the first episode, for instance, it was most apparent when Ms. L highlighted listening to Kimmy's contribution as the most important thing she and the students could be doing. It was also evident in the second episode when Ms. L continued the conversation about the foxes in part because the students were so "into it." In fact, her awareness of students' engagement and desire to make sure they knew their ideas were valuable contributed to her focus on student thinking in all three episodes, making her pursuit of students' ideas "unavoidable" (in her words).

Additionally, it is useful to consider the role that Ms. L's own interest in the topic under discussion played across episodes. Such interest was most apparent in the second episode when Ms. L inquired about the foxes with her students, hoping to resolve why they were separated from the coyotes and wolves in the classification scheme. Her own interest may have also been in play in the first episode, particularly given that the question of whether magnets work underwater later turned into a week-long unit driven largely by students' ideas. In the third episode, however, Ms. L noted a difference in her interest level when she provided written feedback on that analysis:

> As I reread it, and your comments, I realized it was similar to the fox in that I wasn't sure of how to distinguish the states of ice and snow from one another, so it was definitely an authentic question for me, and one that I had not anticipated, like the fox. But in this episode, I didn't jump on it the way I did with the fox, but did acknowledge it. Trying to think WHY… in my heart it might have had to do with my level of interest and comfort with the topic. Life sciences are much dearer to me than chemistry, so I'm wondering if this affected how I reacted, subconsciously? [Feedback, January 2013]

In this reflection, Ms. L distinguished whether something was an "authentic question" from her "level of interest" in answering it. In other words, some authentic questions are more interesting to her than others, and in the context of the episodes, the fox question was more interesting to her than the snow question. This point of contrast between the episodes highlights a relationship between Ms. L's level of interest and her responsiveness – her interest in the question in the second episode was accompanied by fairly stable attention and responsiveness to students' ideas about the question, whereas her relative lack of interest in the question in the third episode was accompanied by variability in her focus.

Appendix E: Episodes from Ms. R's Classroom

This appendix includes analyses of three episodes from Ms. R's classroom, focusing on identifying parts of the local coherences supporting her attention and responsiveness to the substance of students' scientific thinking. Each analysis includes a description of the context in which the episode is situated, full transcript of the episode with coded responsive utterances, justification of why the episode was selected for inclusion, and candidates for what may have stabilized Ms. R's attention during the episode. At the end I also synthesize a bit across the three episodes.

Episode 1: What Counts as a Crest?

Situating the Episode

The first episode from Ms. R's classroom occurred on April 6, 2010, during Ms. R's first year in the project. The class was learning about types and properties of waves and briefly reviewed the differences between transverse and longitudinal waves before moving onto the day's activity. Ms. R laid a jumprope on the floor in the center of the classroom and had a student, Keven, hold one end still while another student, Horacio, shook the other end of the rope to create a wave. When the student shook the rope at a steady rate of once per second for ten seconds, students agreed that the resulting wave had one crest. Then the student shook the rope faster, at a steady rate of twice per second for ten seconds. Figure E-1 depicts the wave that resulted.

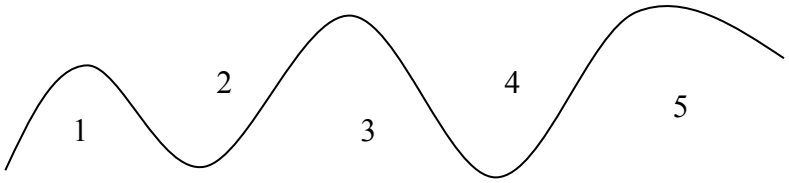

Figure E-1. Schematic of jumprope on floor of Ms. R's classroom during first episode, with crests and troughs numbered for reference purposes.

During an interview, Ms. R noted that "the rope thing is in the textbook" and indicated that the purpose "was really just to count wavelengths, but it turned into something else from here" [Interview, December 2012]. One wavelength is the distance from crest to crest or trough to trough, so Ms. R asked students how many crests there were in the wave in Figure E-1. The episode below occurred when students provided numerous unexpected answers to Ms. R's question.

Full Transcript and Coding

Table E-1 contains the full transcript and coding for the first episode from Ms. R's classroom. The transcript in the left column comes from approximately ten minutes of a whole-class discussion. Italicized sections of the transcript in the left column are

what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table E-1

Transcript and Coding for First Ms. R Episode

Transcript	Coding
173. Ms. R: All right, how many crests do we have?	
174. Student: Two? Two.	
175. Student: Three?	
176. Student: Two.	
177. Student: One.	
178. Student: You're counting the numbers wrong.	
179. Student: Two!	
180. Rolland: No, three!	
181. Ms. R: All right, somebody- please don't touch anything there. Somebody come count. ((Marcelo, who was counting the ten-second intervals, gets up)) Somebody else outside the counter, go ahead. Not you, counter, get back over there! ((Michele stands up)) All right, () tell me what you see.	
182. Michele: ((crouches near rope)) Uh, this. ((points at #2))	
183. Marcelo: She's confusing me.	
184. Michele: Uh, that. ((points at #4))	
185. Ms. R: Okay. Anybody else see something- okay, so *let me point out what she saw, what she said*. ((walks along rope)) *This one, this one, this one, and this one, right?* ((has indicated #2, #3, #4, and #5; Michele nods)) *That's four*.	Confirming
186. Student: Yay!	
187. Ms. R: Anyone else?	
188. Student: Four.	
189. Ms. R: Go ahead. Uh, no, no, no, no, no ((to Keven, who's messing with the end of the rope)). Go ahead, Carmen. Point to the ones that you see.	
190. Carmen: ((near rope)) That. ((points at #3))	
191. Ms. R: *One*.	Maintaining
192. Carmen: And that. ((points at #5))	
193. Ms. R: *Two*.	Maintaining
194. Gloria: What? There's more!	
195. Ms. R: *If you say it's more, point 'em out. Go*	Maintaining

	ahead. ((Gloria points at #1, #3, and #5))	
196.	Sterling: No!	
197.	Ms. R: Wait, wait, wait, wait, wait, wait ((to Horacio, trying to move rope)). We gonna talk about it afterwards.	
198.	Rolland: ((near rope)) One, two, three, four, five. ((points at all numbered options))	
199.	Ms. R: *That's what, that's what-*	Identifying similarities
200.	Student: No.	
201.	Rolland: It's going like this ((moves hand in curvy motion))!	
202.	Ms. R: *Michele said*. Okay.	Identifying similarities
203.	Horacio: Okay, okay, okay, okay. ((goes to move rope))	
204.	Ms. R: No, no, no, no ((to Horacio)). Don't, don't- anyone else? *You have a different opinion?*	Pressing
205.	Sterling: No.	
206.	Ms. R: *Yeah you did, you said "no"! So tell me what you see.*	Attempting to elicit when little evidenced
207.	Student: You have to say something.	
208.	Ms. R: *Tell me what you see.*	Attempting to elicit when little evidenced
209.	Sterling: I see four.	
210.	Ms. R: *Can you come point 'em- point 'em out please?*	Pressing
211.	Horacio: *Comment in Spanish.*	
212.	Ms. R: ((touches Horacio on the shoulder)) I'm gonna need you to calm down, whatever you said to me before? () ((Sterling stands and points at what she counted)) *Can you point, I can't see- or put your foot by 'em?*	Pressing
213.	Horacio: Uno, dos, tres, quatro. ((while Sterling puts foot by #1, #2, #3, and #4))	
214.	Ms. R: *You said one, two, three, four*. ((points at each))	Maintaining
215.	Marcelo: Uno mas!	
216.	Ms. R: Okay. ((5-second pause, puts hand to chin)) All right, *so we have- some people said four, some people said five-*	Identifying differences
217.	Student: Three.	
218.	Ms. R: *Some people said three. We gotta settle this. Why you all- whoever said four, why you think it's four? Michele, we'll start with you.*	Identifying differences, pressing
219.	Horacio: She said five.	

220.	Ms. R: *Or five, why do you think it's five?*	Pressing
221.	Student: I thought she said four.	
222.	Michele: Um, because, um, this one ((points at #2)), that one ((points at #3)), that one ((points at #4)), and that one ((points at #5)).	
223.	Ms. R: *So everywhere, tell me like – you're saying every time the rope curves is one.* ((Michele nods)) *So the top and the bottom.* ((Michele nods)) Okay. That makes sense. Anyone else?	Revoicing, confirming
224.	Gloria: I say, um, the crests are at the bottom-	
225.	Ms. R: Gloria is speaking. Say it a little louder, please.	
226.	Gloria: I say three because the crests are the bottom.	
227.	Ms. R: *The crests-*	Maintaining
228.	Student: Top part.	
229.	Gloria: Or the top.	
230.	Ms. R: *What about, what part- where's the bottom part?*	Pressing
231.	Rosie: The crest is the highest point. ((Gloria points to what would be the top of the schematic; she is seated on that side of the rope))	
232.	Ms. R: *Over there?*	Confirming
233.	Student: It depends on what side of the room you're on.	
234.	Ms. R: *Well, what if I'm on this side?*	Pressing
235.	Horacio: That's the same thing!	
236.	Ms. R: *It's the same thing?* I don't know. *Can you- can you clarify that for me? What do you mean? How about if you point at it so I'll know what you're talking about?* I'm a visual learner, I need to see. (pause) *Can you point it out, what you're talking about?* You know all these people, you can get up. ((Gloria stands))	Maintaining, pressing
237.	Horacio: *Comment in Spanish.*	
238.	Ms. R: ((Gloria points at #3)) Uh-huh. ((Gloria points at #1 then #5)) *So you're saying if I'm counting these up here* ((points to the ones Gloria just pointed to)), *then I can't count these down here* ((points at #2 and #4)) *as crests?* ((Gloria shrugs)) *You don't know?* ((Gloria shakes head)) Okay. All right. Um, calm down ((to Horacio)).	Confirming
239.	Rosie: Isn't the crest like the highest point, the	

	highest point of the wave?	
240.	Ms. R: *Is the crest the highest point of the wave?*	Maintaining
241.	Student: Yes.	
242.	Ms. R: Okay. *So what are you saying by that? What are you saying, what do you mean by that? I mean, why did you ask that?*	Pressing
243.	Student: Uh-	
244.	Rosie: Because, because like-	
245.	Ms. R: Shh, I can't hear ().	
246.	Rosie: Because like, from where I am, it seems like there's three-	
247.	Horacio: ((to Gloria)) Hey, are you looking in my book?	
248.	Rosie: But from the other side, it looks like there's two.	
249.	Ms. R: *I'm sorry, I can't hear you.*	Attempting to hear
250.	Rosie: From where I am, it looks like there's three crests, and from where Lisa is, it looks like there's two.	
251.	Ms. R: *Mmm. I think I understand what you're saying. She's saying because she's on this side of the rope, right, it looks like there's three. But on this side of the rope, it would look like it's two, that same part that she's looking at. Does that make sense? What do you all think about that?*	Maintaining, reflecting
252.	Willis: Good.	
253.	Ms. R: *How do you solve that problem?*	Reflecting
254.	Willis: That's good.	
255.	Ms. R: *What's good?*	Pressing
256.	Willis: The weight?	
257.	Ms. R: (pause) *What are you talking about?* ((chuckles))	Pressing
258.	Willis: I don't know. I'm just answering.	
259.	Ms. R: I have a question. What's the opposite of a crest? ((Marcelo gets up to fix part of rope near Horacio))	
260.	Students: The trow. Trough. ((repeating and struggling with pronunciation))	
261.	Ms. R: The trough is the opposite part, right?	
262.	Marcelo: It was messed up.	
263.	Student: ().	
264.	Student: Yes it was, it looked like this.	
265.	Marcelo: That's what I'm saying.	

266.	Student: It's like, it's like a crest flipped over.	
267.	Student: Well, then why'd you move it?	
268.	Ms. R: *It's like a crest flipped over?* So do- would you count the crest and the trough?	Maintaining
269.	Student: Um-	
270.	Rosie: Like, it, it depends on which side you're on.	
271.	Ms. R: So…	
272.	Horacio: So like I might count the ditches on this side but not on this side?	
273.	Rosie: No, I mean like, like, if you're on this side, when you're looking at it, there's three. And if you're on that side, when you're looking at it, there's two. Because the crest is like the highest point.	
274.	Horacio: "It's the highest point." ((imitating Rosie))	
275.	Ms. R: And what's the lowest point?	
276.	Student: The tr, tr-	
277.	Ms. R: Trough?	
278.	Student: The trough.	
279.	Ms. R: Okay, Carmen. Rosie, thank you very much. We're gonna come back to that because that's basically the question. I asked a question, write down- and I'm gonna pose it right after I get to what Carmen was gonna say. *Carmen, why did you say- how many did you say it was? Five?*	Confirming
280.	Carmen: No.	
281.	Student: She said two.	
282.	Ms. R: *Two. Why did you say it was two?*	Pressing
283.	Carmen: I said it because, um, that's the highest, um, point, and that's the highest point.	
284.	Ms. R: *Can you, can you show, show me, please? Can you get up and point to what you're talking about?*	Pressing
285.	Carmen: ((near rope)) This is the highest point ((points at #3)), and that's the highest point ((points at #5)).	
286.	Ms. R: *Okay, so you're saying since those two are higher* ((points at #3 and #5)), *that's why you didn't count that one* ((points at #1))?	Confirming
287.	Carmen: Uh-huh.	
288.	Ms. R: *She said because those two are higher than the other ones, we only count the highest ones and not the lower ones.*	Maintaining

289.	Horacio: Oh, I have to sit up again.	
290.	Student: Keven, where you going?	
291.	Keven: ((scooting away)) I ain't gotta tell you.	
292.	Ms. R: Where are you going?	
293.	Keven: Back here! So it's cool.	
294.	Student: What?	
295.	Ms. R: He's not talking to you. Don't add any disturbance to the area. Okay, so… ((off-camera, can hear writing on the chalkboard)) All right, anyone else want to say what they felt about the numbers? So how many numbers do we have?	
296.	Horacio: Four, three, two, one.	
297.	Student: Three.	
298.	Ms. R: *We have three numbers?*	Confirming
299.	Gloria: We have four numbers.	
300.	Student: I've got four.	
301.	Ms. R: I'm sorry, Gloria's writing it, so I'm getting- *you put two* ((likely to a student nearby, off-camera))? *No, how many did people say? They said three, three different numbers, right?*	Maintaining, confirming
302.	Student: Yeah.	
303.	Gloria: Three, four, and five.	
304.	Ms. R: *Three, four, and five?*	Confirming
305.	Gloria: And two.	
306.	Student: Three and five.	
307.	Ms. R: *Oh, you add- you added two, put two on there. Someone else had two*. So, let's go back to these questions. *Does it matter which side of the rope that you are on, when you counted your crests and your troughs?*	Maintaining, returning to idea later
308.	Students: No. Yes.	
309.	Ms. R: *We have some yeses, I hear some nos. I need to know why. Why you feel that way?* Marcelo?	Maintaining, pressing
310.	Marcelo: They're the same.	
311.	Ms. R: *Why, what makes them the same?*	Pressing
312.	Marcelo: Because, they look the same.	
313.	Ms. R: *How so?*	Pressing
314.	Marcelo: ().	
315.	Ms. R: *What'd you say?* ((student laughs)) Are you contributing to the conversation? ((to Marcelo)) *What do you mean, so you're saying it's because they look the same what?*	Attempting to hear, pressing

316.	Marcelo: It doesn't matter where you look.	
317.	Ms. R: *It doesn't matter which one you count. Do you count both?*	Maintaining, pressing
318.	Marcelo: I don't know.	
319.	Ms. R: So if you look in the mirror, what are you gonna see?	
320.	Student: Yourself.	
321.	Student: Your reflection.	
322.	Ms. R: Is it the same?	
323.	Students: No. Yeah.	
324.	Ms. R: So, is, are there two of you then?	
325.	Students: No.	
326.	Ms. R: Or do you count yourself once?	
327.	Students: Once.	
328.	Ms. R: So if you're saying- can you watch the scissors ((likely to a student nearby, off-camera))? If you're saying the crest is the same as the trough on the other side, how many times would you count that?	
329.	Student: The floor's dirty.	
330.	Rolland: Five.	
331.	Ms. R: *You would count it five times? Why would you count it five?*	Pressing
332.	Rolland: Five of that.	
333.	Ms. R: *What's that?*	Pressing
334.	Rolland: The stuff that's windy.	
335.	Ms. R: *It's five crests or five troughs?*	Eliciting
336.	Rolland: Fi-five ((students laugh)), uh, I don't know.	
337.	Marcelo: No, one-	
338.	Rolland: There's just five things.	
339.	Marcelo: Look, does this count? ((points at #1))	
340.	Rolland: Yes.	
341.	Ms. R: *Does it count for you?*	Pressing
342.	Rolland: Yes.	
343.	Marcelo: No.	
344.	Ms. R: This is what I want you to write in your journal right now. *Write the question, does it matter which side of the rope you are on? And then tell me your response and why.*	Returning to idea later
Note. Italicized sections of transcript reflect responsive utterances.		

Ms. R provided students with time to write their thoughts in their journals, then share with partners and eventually with the whole class. When she invited students to

share their thoughts with the whole class, she recorded their ideas on a projected Word document at the front of the classroom. This matter remained unresolved at the end of class.

Justifying Inclusion

The above episode met the criteria for inclusion in my dissertation. First, of Ms. R's 68 speech turns in the episode, 49 contained responsive utterances. This represents a percentage of 72.1%, meaning the majority of Ms. R's utterances during the episode were responsive to students' ideas. Second, there was some evidence of perturbation with respect to the "correct" understanding (i.e., Ms. R pushing students to think about the opposite of a crest in lines 87-107, introducing the mirror analogy in lines 147-156), but this focus did not predominate; she remained generally open to the range of ideas students were putting forth[34]. Her attention and responsiveness to student thinking also exhibited resistance and resilience to problematic student behavior, which she either ignored or dealt with quickly and returned to the discussion at hand. Third, Ms. R reflected on this episode at two teacher meetings in April of 2010.

Plausible Parts of the Coherence(s)

In what follows, I provide evidence for what might be part of the coherence(s) supporting Ms. R's attention and responsiveness to student thinking during this episode:

- Interest in understanding what students were thinking
- Reference to the jumprope for clarity
- The need to reconcile what counts as a crest in order to count wavelengths
- Her desire for students to reconcile the matter for themselves
- Pushing students past appeals to authority

Interest in Understanding What Students Were Thinking

Ms. R's surprise with respect to the variety of options students put forth and desire to understand where they were coming from supported her focus on students' ideas. After students pointed out numerous combinations on the jumprope, there was a five-second pause as Ms. R stepped back from the class and put her hand over her mouth. In an interview, Ms. R reflected on this pause as a time in which she was thinking about what to do next: "That's why when I did like this ((puts hand over mouth)), I was thinking ((both laugh)). I was like, oh" [Interview, December 2012]. During the episode, she followed this pause with the following statement: "We gotta settle this. Why you all-whoever said four, why you think it's four?" [Episode, April 2010]. Her response in the

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[34] As mentioned in my description of my analytical approach in Chapter 3, moments when Ms. R's attention shifted from promoting the desired understanding to listening to students' ideas were particularly useful in terms of unpacking what supported her attention to student thinking.

moment was to shift from the intended activity of counting wavelengths to seeking further explanation from students about how they were identifying crests.

What is underdetermined at this point is exactly *why* Ms. R wanted to understand more about what students were thinking. At times, understanding students' ideas seemed to serve an instrumental purpose for Ms. R – she needed to understand how students were thinking about crests in order to decide what to do next, instructionally. For instance, consider how Ms. R described her pursuit of students' ideas during this episode in an interview:

> Imagine if you didn't ask, and then they would have just kept it in their brains. You wouldn't know, you wouldn't know wh::y they thought what they thought… having that opportunity to have all those numbers come out at least makes me think okay, now what do I need to do, so they can – say, this is al::ways what it is [Interview, December 2012].

Here, Ms. R referred to the importance of knowing "wh::y [students] thought what they thought," but primarily for the purpose of figuring out what she needed to do as the teacher to help them solidify their understanding of crests. Consonant with this purpose, Ms. R strategically used students' ideas in the episode to push the class' thinking forward. When a student, Rosie, indicated that the number of crests depended on which side of the jumprope you were on, Ms. R recapped her idea for the class and asked other students to weigh in:

> I think I understand what you're saying. She's saying because she's on this side of the rope, right, it looks like there's three [crests]. But on this side of the rope, it would look like it's two [crests], that same part that she's looking at. Does that make sense? What do you all think about that? [Episode, April 2010]

Later, Ms. R wrote the following question on the chalkboard: "Does it matter which side of the rope that you are on, when you counted your crests and your troughs?" [Episode, April 2010]. In an interview, Ms. R indicated that she decided in the moment "this is gonna be the application question" [Interview, December 2012] – the question she would pose to help students further explore and clarify their own thoughts.

Yet there was also an element of interest in simply understanding students' ideas on their own terms, not necessarily for a particular instructional purpose. For instance, after watching video of the episode in a teacher meeting, Ms. R reflected on her surprise at how a student, Carmen, only counted #3 and #5 as crests:

> I didn't expect like one student Carmen, when she said, you know, she didn't count the one little crest because she said it was smaller than the oth::er one, I didn't expect that. I had to try to fi- figure out what they saw- what did they think qualified as a crest? [Meeting, April 2010]

In part, Ms. R's general sense of needing to figure out what students thought "qualified as a crest" likely related to figuring out how to deal with their ideas instructionally, as indicated above. But her detailed recap of ideas like Carmen's, which she did not use for

any particular instructional purpose during the episode, indicated that Ms. R may have been intrigued by some of the ideas that came up, especially ones that she did not anticipate. Additionally, note how Ms. R responded to other teachers highlighting students' confusion during the episode: "I was com- sur::prised that they, like you all said, were con::fused about what to count, so I had to – just go and investigate what you're talking about, and that's how it basically went down. It was fun" [Meeting, April 2010]. Ms. R agreed with and explained her actions in light of her colleagues' focus on students' confusion, yet quietly added "It was fun," suggesting that her investigations were not just about remediating students' ideas – she also seemed to enjoy hearing what they had to say.

Thus, Ms. R's interest in understanding what students were thinking likely reinforced and was reinforced by her attention and responsiveness to their ideas. She needed to understand what they were thinking in order to decide where to go instructionally, so she listened closely to their ideas and used some of their ideas to push the conversation forward. And as she attended to students' ideas, some of their unexpected lines of reasoning seemed to intrigue her, plausibly supporting her interest in unpacking their ideas.

Reference to the Jumprope For Clarity

In the discussion, Ms. R regularly had students point out which specific sections of the jumprope they were referencing (lines 17, 23, 38, 64, and 112). She also used the rope as a way to confirm her understanding of what students meant (lines 66 and 114). At a teacher meeting shortly after the episode, Ms. R informed the group that students "could come up, if they wanted to, and explain exactly- count how they got whatever it is" [Meeting, April 2010]. In practice, she often asked students to come up and demonstrate what they were talking about, even if students were reticent to do so.

The clearest example of this sort of interaction can be seen in lines 52 through 66, when Ms. R pursued Gloria's idea about the crests being at the bottom. For instance, Ms. R asked Gloria to show her what she was talking using the rope:

> Can you- can you clarify that for me? What do you mean? How about if you point at it so I'll know what you're talking about? I'm a visual learner, I need to see. (pause) Can you point it out, what you're talking about? You know all these people, you can get up. ((Gloria stands)) [line 64]

Here, Ms. R indicated that seeing what Gloria was talking about would provide more clarity, more exactness (to draw on her language from the teacher meeting data). Additionally, Ms. R used the rope to confirm that she understood students' ideas correctly, as seen in the continuing interaction with Gloria:

> ((Gloria points at #3)) Uh-huh. ((Gloria points at #1 then #5)) So you're saying if I'm counting these up here ((points to the ones Gloria just pointed to)), then I can't count these down here ((points at #2 and #4)) as crests? [line 66]

Thus, using the rope as a common reference point in discussion enhanced Ms. R's understanding of students' ideas.

The Need to Reconcile What Counts as a Crest In Order to Count Wavelengths

Another important aspect supporting Ms. R's attention and responsiveness to student thinking in the episode is that the discrepancy needed to be resolved in order to move forward with the planned lesson. In order to count wavelengths from crest to crest or trough to trough, students needed to understand what counted as a crest or trough. Ms. R noted this in an interview: "When I recognized that the students- because you're supposed to go crest to crest, and trough to trough. You can do either one. But when we couldn't say what's a crest, then we can't say the wavelength" [Interview, December 2012]. Ms. R's attention to students' ideas alerted her to the fact that there was disagreement, and the need to resolve this disagreement generally maintained her focus on students' ideas. So even though the original activity in the textbook was "supposed to be just like a quick discover activity" [Interview, December 2012], Ms. R was "willing to take the time for it because what's the purpose of moving on to count it if they don't believe what they're seeing" [Interview, December 2012]. In the next section, I provide evidence that Ms. R thought that the best way for students to "believe what they're seeing" was for them to reconcile the matter for themselves.

Yet there were times during the episode when Ms. R pressed students to see crests and troughs as distinct (i.e., pushing students to think about the opposite of a crest in lines 87-107, introducing the mirror analogy in lines 147-156). It is likely that her sense that students needed to come to a certain understanding in order to count wavelengths also supported these moments in which her attention was more on promoting her idea than listening to students' ideas.

Her Desire for Students to Reconcile the Matter for Themselves

In fact, Ms. R's desire for students to "believe what they're seeing" [Interview, December 2012] suggests that Ms. R not only wanted students to agree on *what* counts as a crest, but to understand and agree on *why* a given crest counts. This was particularly evident in the amount of prompting and time Ms. R gave students to reconcile the matter for themselves, both as a group and individually, which required students (and Ms. R!) to attend to and sense-make about others' ideas as well as their own. The clearest evidence from the episode came from Ms. R's meta-comments about who was responsible for the reconciliation and how much time she allowed for discussion. For instance, Ms. R's proclamation of "We gotta settle this" [line 46] tacitly communicated that she expected students to participate in doing so. Moreover, her next statement – "Why you all-whoever said four, why you think it's four?" [line 46] – suggested that settling the matter involved students sharing and considering others' ideas. This focus was also reflected when Ms. R asked students to weigh in on Rosie's idea about the number of crests depending on which side of the jumprope you were on (line 79, "What do you all think about that?") and indicated that it was up to students to figure out what to do next (line 81, "How do you solve that problem?"). She also later turned Rosie's idea into a specific question for the class to consider in real time (line 135, "Does it matter which side of the rope that you are on, when you counted your crests and your troughs?") and in their journaling (line 172, "Write the question, does it matter which side of the rope you are on?"). In the context of Ms. R giving students the entire class period to work toward reconciliation, these statements suggest that she actually wanted students to take the lead

in settling the matter, and her attention and responsiveness to their ideas supported them in doing so.

During an interview, Ms. R acknowledged that she was trying to get students to listen to others' ideas and clarify their own thinking. She wanted students to hear "other people's ideas and way of thinking" [Interview, December 2012], yet she also wanted to help students "tease out and make like a, a clear answer or clear rule for their reasoning" [Interview, December 2012]. Ms. R had students journal individually at the end of the episode because she was concerned that some students had not yet figured out what they thought:

> Some students are still trying to rationalize this in their mind. So without the distractions of other people, or trying to make sense of other people's rules without getting my own rule, I was like okay, write it down, what you think [Interview, December 2012].

Although I did not explicitly pursue the reasoning behind this emphasis, some of Ms. R's language provided hints. For instance, her statement in the previous section about whether students "believe what they're seeing" and her sense that without discussion, students "probably would have just memorized whatever you said, but not understood" [Interview, December 2012] suggest that for Ms. R, students truly *understand* content when they have made sense of it for themselves. Simply telling them what to count as a crest would not have resulted in deep understanding; grappling with their own and others' ideas (and Ms. R doing the same) was more beneficial in this regard.

Pushing Students Past Appeals to Authority

Closely tied to the section above, Ms. R seemed particularly sensitive to what could be considered students' appeals to authority. For example, consider the exchange from the episode:

> Rosie: Isn't the crest like the highest point, the highest point of the wave?
>
> Ms. R: Is the crest the highest point of the wave?
>
> Student: Yes.
>
> Ms. R: Okay. So what are you saying by that? What are you saying, what do you mean by that? I mean, why did you ask that? [lines 67-70]

During an interview, Ms. R stated that "in the book it said, the crest is the highest point… I'm like, what's that mean?" [Interview, December 2012]. Recognizing the language from the book in Rosie's statement, Ms. R might have taken extra care to press Rosie for *her* thinking and how that piece of information was relevant, asking three clarifying questions in close succession. Ms. R also noticed Gloria taking her book out while we were watching the video together, which was salient enough for her to spontaneously point out to me.

In addition to the book, Ms. R also recognized that students might treat other students as authorities. In an interview, Ms. R described how some students do not want to go against "the smart kid, or the cool kid" [Interview, December 2012]. Toward the end of the episode, this kind of awareness and sensitivity may have actually drawn her attention *back* to students' ideas. Ms. R had just proposed the mirror analogy in lines 147-156, and when Rolland responded that there would still be five in line 158, Ms. R pressed him specifically on the matter of crests or troughs (line 163). However, the tenor of the conversation changed after Marcelo joined:

> Marcelo: Look, does this count? ((points at #1))
>
> Rolland: Yes.
>
> Ms. R: Does it count for you?
>
> Rolland: Yes.
>
> Marcelo: No.
>
> Ms. R: This is what I want you to write in your journal right now. Write the question, does it matter which side of the rope you are on? And then tell me your response and why [lines 167-172].

My interpretation of the exchange above in part hinges on the particular students involved. During an interview in December of 2012, Ms. R indicated that she felt Marcelo was confused at this point in the conversation, and she identified Rolland as a student who liked and portrayed himself as knowing a lot about science. In this context, Ms. R may have interpreted Marcelo asking Rolland whether #1 counted as an appeal to Rolland's authority. Ms. R's attention quickly turned away from crests and troughs and to Marcelo's thinking, asking if it counted *for him*. In her next statement, she transitioned students to independent journal-writing.

In short, although Ms. R wanted students to consider each other's ideas, she wanted them to do so as part of their own sense-making. Her concern with appeals to authority cohered with and was perhaps a special case of the previous section on students reconciling the matter for themselves. However, her seeming sensitivity to possible appeals to authority, as evidenced by her rapid-fire questioning of Rosie, spontaneous mention of Gloria looking at the book, and attention to what Marcelo thought, suggests that this might serve as a particular trigger for Ms. R. Her response to both Rosie and Marcelo was to push them to articulate *their* thinking.

Summary

To recap, there are several plausible parts of the coherence(s) reinforcing Ms. R's attention and responsiveness to student thinking during this episode. When students provided a wide range of answers to how many crests there were in the wave, Ms. R explored their ideas to understand what they were counting as a crest and come to some consensus on the matter before moving on to counting wavelengths. Using the jumprope

itself as a common reference point and having students point to what they were talking about helped Ms. R make sense of their ideas. Moreover, Ms. R provided space and facilitative support for students to make sense of and reconcile their own and others' ideas about crests, asking questions in response to what students said that pressed them to take their ideas further and helped them consider others' ideas. Ms. R's desire for students to reconcile the matter for themselves became particularly apparent in the face of perceived appeals to authority, as she refocused attention on students' *own* ideas.

Episode 2: What Causes Something to Sink or Float?

Situating the Episode

The second episode from Ms. R's classroom occurred on September 23, 2010, at the beginning of Ms. R's second year in the project. Ms. R had just started a unit on sinking and floating with her students, and the episode occurred when she was eliciting ideas from students about what causes something to sink or float. (The video started partway into this discussion.) After the episode, she had students record a "rule" in their journals for what they thought made something sink or float, share some of their rules, and test out their rules by conducting an investigation with different liquids. For homework, students were to think about whether the investigation supported their individual rules – if so, how, and if not, how do they need to alter their rules? This flow was generally the same in other sections Ms. R taught that day as well.

Full Transcript and Coding

Table E-2 contains the full transcript and coding for the second episode from Ms. R's classroom. The transcript in the left column comes from approximately ten minutes of a whole-class discussion. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table E-2

Transcript and Coding for Second Ms. R Episode

Transcript	Coding
1. Ms. R: You said, you said when we were- *you said what about density because you remember last year anything that sinks has to do with what*?	Maintaining, pressing
2. Arielle: Density, volume, and mass.	
3. Ms. R: *Density, volume, and mass. So somewhere in there, that has to matter. And then Lamont said density is how thick or thin something is, and that has nothing to do really- that won't affect if it sinks or floats. Because*	Maintaining, identifying differences, pressing

	skinny things can sink or float, and big fat things can sink or float. ((students laugh)) For lack of better words. No, my last class, all they talked about was fat and this and that's what was in my mind. Sorry. *And you're* ((to Arielle)) *saying that what, in relation to what he said?* And then you can go next, and then you can go after her.	
4.	Arielle: That density doesn't have anything to do with if it was thick or skinny or fat or some of those words.	
5.	Ms. R: *So what are you saying density is then?*	Pressing
6.	Arielle: It was a measure of how much mass is contained in a volume, a given volume.	
7.	Ms. R: *So what does that mean?* ((students laugh)) So why don't we close the book and go about what you think. *Tell me what you think, in your mind, what density is*. Because clearly that's not working out for us. *So what's density? To you?*	Pressing
8.	Arielle: Mass times volume.	
9.	Ms. R: *When you think of density? What'd you say?*	Pressing, attempting to hear
10.	Arielle: Mass times volume is density.	
11.	Ms. R: *Mass- density is-*	Maintaining
12.	Arielle: Mass, mass times volume is density.	
13.	Ms. R: *Mass times volume is what density is, to you. And what does that look like?*	Maintaining, pressing
14.	Arielle: I do not know.	
15.	Ms. R: Okay, so I don't want to know a formula. This is not math class. You know, and, and- and that's not how we're gonna understand what it is, right? So we don't need that. Look, I'm not the teacher that- I'm not gonna get thrilled with vocabulary words. Do I want you to know 'em? Yes. But after you understand what they are. So, since you probably would have got a high five in your other class for doing what that was. But ((laughs)) it's not, if we don't know what it is, it's useless, right? If we don't understand what it means, who cares? Who cares what the book says? Because it didn't make sense to us. ((to Arielle)) Are you okay, need some water? I mean, drink. ((students, including Arielle, laugh)) All right, um, was it Twanda next?	

16.	Twanda: Yes.	
17.	Ms. R: What were you going to say, Twanda?	
18.	Twanda: I was going to say that, um, about the water? About the water? That you know, when you go to the pool, and you, um, play and stuff, and then you try to, um, lay back in the pool, it's like you're floating.	
19.	Ms. R: Okay.	
20.	Twanda: Water ().	
21.	Ms. R: *So what are you saying?*	Pressing
22.	Twanda: It could be the same thing, like, it could be the same thing with, like, wood, which would float.	
23.	Ms. R: Okay. *So what, what, what is your, your endpoint with that?*	Pressing
24.	Twanda: That-	
25.	Ms. R: *What are you connecting that to?*	Pressing
26.	Twanda: I probably think that the, um, the, the wood, which is not weight- or it would probably weigh, like, 25, instead of-	
27.	Ms. R: *So what if we made it 60? Remember, we made, cut out a 60 piece of- 60 pound piece of wood?* I'm gonna go with, um-	Countering
28.	Student: Bryan?	
29.	Ms. R: No, Donald. And then Isiah, and then Ray.	
30.	Donald: Um, I was gonna say that what Arielle said was right.	
31.	Ms. R: *What Arielle said density was was right?*	Confirming
32.	Donald: Yeah.	
33.	Ms. R: *Who says it's right?*	Pressing
34.	Donald: The book. ((students laugh))	
35.	Ms. R: *The book says it's right. So what does that mean?*	Maintaining, pressing
36.	Donald: That um, that um, that the, um, definition she said was right?	
37.	Ms. R: *The definition was right*. The definition probably is right. But if we don't know what it means, then it still doesn't matter. So *can you tell me what, can you tell me what that means?*	Maintaining, pressing
38.	Donald: No.	
39.	Ms. R: *No? You can't?* So who needs it? Let's close it, put it away. ((Donald closes book)) Go ahead, what was it, Isiah and then Ray?	Confirming
40.	Student: Yeah.	

41.	Ms. R: Go ahead, Is- put it down, you don't need that ((to student lifting white board, who puts it down)).	
42.	Isiah: I think, um, you know when Twanda said that you float in water?	
43.	Ms. R: Uh-huh?	
44.	Isiah: I think she means that, like, we got air in our bodies, so you float, like a soccer ball?	
45.	Ms. R: *Because in your- because in your mind, your, your, your idea, things that float there's air in it. What do you think about that* ((to Twanda))?	Maintaining, reflecting
46.	Twanda: He knows what I'm talking about.	
47.	Ms. R: *Oh, so you all are connected?* Okay. ((students laugh)) Ray? Hey, they both, they make sense to me. Ray, what were you gonna say?	Confirming, inserting
48.	Ray: I think some materials- some objects float from their material, like what they're made of? Or I kind of agree to Arielle about mass times volume because it can tell you something about the-	
49.	Ms. R: *What is mass times volume then?*	Pressing
50.	Ray: It's whether or not they float. It's, like…	
51.	Ms. R: Let me, let me correct something. I mean let me mention something. Am I saying that that definition of density is wrong? No, I'm not. But the definition doesn't explain what it is. And we want to know what it is so we can see if that's the reason things sink or float, right?	
52.	Heather: I thought density was ().	
53.	Ms. R: So (pause) I mean I like that you agree with her, that's fine, with that. And Donald because he said it as well. *So you said some materials sink or float? Give me an example of a material that would sink and an example of a material that would float*. ((to Twanda, who has her hand raised)) After him. ((to another student with his hand raised)) After her. Go ahead. Ray?	Confirming, pressing
54.	Ray: Scissors?	
55.	Ms. R: *Scissors? I can't hear you.*	Confirming, attempting to hear
56.	Ray: Scissors sink.	
57.	Ms. R: *Scissors sink, and scissors are made of?*	Maintaining, pressing

58.	Ray: Steel and plastic.	
59.	Ms. R: *Steel and plastic. So does the plastic sink because of the steel, or does the steel sink because of the plastic? Or are-*	Maintaining, pressing
60.	Ray: The plastic sinks because of the steel.	
61.	Ms. R: *So normally plastic would float?*	Confirming, inserting
62.	Thurman: Yeah, like a water bottle.	
63.	Isiah: Like this water bottle.	
64.	Thurman: It would float. But if it gets water in it, it will sink.	
65.	Ms. R: That makes sense. *So water will make it sink though?* ((to Twanda)) Go ahead.	Confirming
66.	Twanda: Yesterday I tried it, um, in my bathroom? ((students laugh)) I had like some water, and then after that I tried a ruler, then I tried just, um, metal thing, I tried this little, um, metal- it's like, it's kind of like a square, but it's metal. So I put both of them at the same time, and then at first the metal went straight down, and then the weight came- was floating. And I tried the bot- I tried the plastic bottle, and then I tried scissors, and then the plastic bottle was not sinking.	
67.	Ms. R: I'm glad that you're at home doing that. You just don't know how much- how happy you made me. Go ahead.	
68.	Antonio: Um, like a metal car, it will probably sink. And um, and um, a clipboard will prob- a clipboard will float?	
69.	Ms. R: *A what? A keyboard?*	Attempting to hear, confirming
70.	Antonio: A clipboard.	
71.	Ms. R: *A clipboard, like, like a plastic clipboard?*	Confirming, inserting
72.	Antonio: Yeah.	
73.	Twanda: But it's wood and metal. It's like the thing-	
74.	Ms. R: *Oh, no, the plastic one.*	Countering
75.	Twanda: Oh.	
76.	Ms. R: Oh, okay. *So you're saying- so you were giving me examples of something- materials that would sink or float?* ((Antonio nods, Ms. R gestures to other student to speak))	Confirming, inserting
77.	Raul: Oh. Um-	
78.	Ms. R: Paul. Raul! ((claps)) Paul's in the next class.	

79.	Raul: I think um, like, um, it floats because like there's no water in it. Like, um, what, um, he said about the weight? Um, and I think the more weight added to it, the more it will float. ((Ms. R touches student on shoulder to have her sit up))	
80.	Ms. R: *So, wait, wait, wait. You said the more weight is added to it, the more it'll float?*	Confirming
81.	Raul: Yeah.	
82.	Ms. R: *So more weight means it, it floats, and less weight means it sinks?*	Confirming, inserting
83.	Raul: No, I meant, um, like, it sinks when it has more weight, and, like, it floats when it has less weight.	
84.	Ms. R: *Okay, less weight floats, more weight sinks*. Okay. La-	Maintaining
85.	Raul: Because like with Titanic, like, it was like, um, huge and it weighed a lot. And then when it hit the iceberg, it filled with water.	
86.	Ms. R: Okay. *And then what happened?*	Pressing
87.	Raul: It went underwater.	
88.	Ray: It fell down.	
89.	Ms. R: *Because what?*	Pressing
90.	Ray: Water was-	
91.	Raul: Going in it.	
92.	Ms. R: *Because the water got in it.*	Maintaining
93.	Raul: And then, like, it caused more weight, and then it's underwater.	
94.	Ms. R: *So the water has weight itself, and then that made it go down?*	Confirming
95.	Raul: Yeah.	
96.	Ms. R: *And that's kind of like somebody just said with the water bottle over here, when you put the water in the water bottle, that'd make it-*	Identifying similarities
97.	Thurman: It'll sink.	
98.	Ms. R: *It'll sink*.	Maintaining
99.	Student: Float. ().	
100.	Ms. R: Okay. Lamont. And then Ray.	
101.	Lamont: Isiah said something about the body was oxygen. Actually, most of the body actually is water. ().	
102.	Ms. R: *Okay, most of the body- but Isiah said it had some air in it. He didn't say mostly air. So you're saying that air- the water would make us sink.*	Maintaining, countering, inserting

103.	Lamont: But the thing is bare- only, like, barely any of the body's actually air.	
104.	Ms. R: ((stifles yawn)) Sorry. What'd you say?	
105.	Lamont: I said barely, um, barely any of your body actually has air, actually has air.	
106.	Ms. R: *Does any of it actually- you're* ((shakes head, moves closer))- *one more time*.	Attempting to hear
107.	Lamont: I'm thinking the lungs are your on- the only part of your body that actually has air in them.	
108.	Ms. R: *The lungs are the only thing that has air in it.*	Maintaining
109.	Lamont: Mm-hmm.	
110.	Ms. R: *Actually your blood has air- oxygen in it. You need it*. Go ahead ((to Twanda)).	Countering
111.	Twanda: ((points to clock)) Instrumentals?	
112.	Ms. R: Okay. Um, before you go to instrumentals real quick-	
113.	Student: It's not 11:30.	
114.	Ms. R: You go at 11:30?	
115.	Student: Yeah.	
116.	Student: Mm-hmm.	
117.	Twanda: I go- I'm a string.	
118.	Ms. R: Okay, listen, listen up ((clicks to get attention)). I want you all to make a rule in your journal, make a rule- what causes something to sink or float? What's the rule? If I had to have a rule- if this happens, if this, like for example, if it's plastic, it's gonna float, if it's metal, it's gonna sink. That's my rule. I want you to make a rule that says that ev- in this situation, all the time, this will float, and this will sink.	
Note. Italicized sections of transcript reflect responsive utterances.		

Justifying Inclusion

The above episode met the criteria for inclusion in my dissertation. First, of Ms. R's 56 speech turns in the episode, 42 contained responsive utterances. This represents a percentage of 75%, meaning the majority of Ms. R's utterances during the episode were responsive to students' ideas. Second, Ms. R's attention and responsiveness to student thinking exhibited resilience in the face of multiple appeals to the textbook definition of "density," which I unpack in my analysis. Third, Ms. R reflected on video of this episode at a teacher meeting in March of 2011.

Plausible Parts of the Coherence(s)

In what follows, I provide evidence for what might be part of the coherence(s) supporting Ms. R's attention and responsiveness to student thinking during this episode:

- The plan for the day
- Focusing students on voicing what makes sense to them

The Plan for the Day

I do not have access to Ms. R's lesson plan, but the flow of the lesson was the same in several class sections, leading me to believe it was her intended flow for the day. She began by opening up space for this more general kind of discussion about what causes something to sink or float, then had students devise their own independent rules on the matter. Students shared their rules briefly before conducting an investigation with different liquids to test their rules. If the investigation supported their rules, students were to explain how; if the investigation did not support their rules, students were to alter their rules.

Thus, the activity in the selected episode was likely part of the plan for the day, a preplanned space in which students and Ms. R were to focus on students' preliminary ideas about what makes something sink or float. Planning a space in advance to listen to students' ideas likely contributed to Ms. R's attention and responsiveness to student thinking during the episode. Moreover, the remainder of the plan hinged on students articulating their ideas for themselves, so attending to students' ideas during the episode also supported Ms. R's later aims.

Focusing Students on Voicing What Makes Sense to Them

During the episode, something that seemed particularly salient to Ms. R was that students voice ideas that make sense to them. This salient aspect was most apparent when Arielle described density as "how much mass is contained in a volume" [line 6], which Ms. R quickly identified as a book-like response (line 7). Ms. R continued to press Arielle in the exchange that follows:

Ms. R: So what's density? To you?

Arielle: Mass times volume.

Ms. R: When you think of density? What'd you say?

Arielle: Mass times volume is density.

Ms. R: Mass- density is-

Arielle: Mass, mass times volume is density.

> Ms. R: Mass times volume is what density is, to you. And what does that look like?
>
> Arielle: I do not know [lines 7-14].

Here, Ms. R reframed the question as being about Arielle's thinking, asking, "So what's density? To you?" When Arielle persisted with talking about mass and volume, Ms. R repeated what she said and took a different tack to see if Arielle was making sense of what she was saying: "And what does that look like?" After Arielle replied that she did not know, Ms. R tried to explain what she was looking for:

> Okay, so I don't want to know a formula. This is not math class. You know, and, and- and that's not how we're gonna understand what it is, right? So we don't need that… If we don't know what it is, it's useless, right? If we don't understand what it means, who cares? Who cares what the book says? Because it didn't make sense to us [line 15].

Ms. R directly emphasized the importance of talking about what we understand, what makes sense to us.

At a teacher meeting, Ms. R commented extensively on this exchange with Arielle:

> It's the beginning of the uh, the year, and it's definitely the, the switch. Because if Arielle definitely- she's an A student, she knows how to play school. So it was hard for her to break away from what the book is saying, or giving me the form- formula. So she's just – what do you mean, what do I think about what it means to me? This is – it's mass times volume ((laughs)), you know [Meeting, March 2011].

Ms. R indicated that there is a "switch" that needs to happen when students come into her class. In many of their classes, they "play school" and are rewarded for giving the correct answer. In her class, however, Ms. R wants students to focus on sense-making, or "what it means to me" – a "switch" from their other classes. Ms. R also noted how engrained playing school is for students by sixth grade:

> And this is sixth grade, so for six years you just were coming in, and you play school, and just do exactly what the teacher says, and then you'll get an A. And you can tell me a vocabulary, or a formula for density, but no real idea of what density is ((shrugs)), you'll have a hard time [Meeting, March 2011].

Ms. R expressed a similar sentiment during an interview when we discussed what she was trying to get Arielle to think about:

> Jen: And what are you hoping that gets them to do?

> Ms. R: To, um, stop looking for definitions. ((laughs)) And try to think about, think about the scenario because you don't understand the definition… What does that mean, in real life? So I just want them to think about it in real life. What are we seeing right now?
>
> Jen: Okay. Rather than trying to appeal to – whatever they've heard before?
>
> Ms. R: Whatever they heard, or a definition, or, you know, what sounds right, sounds good. Because you know, like, they've all played school before, they know, get the right answer, the teacher gets excited, we move on [Interview, December 2012].

To summarize, something salient to Ms. R – evident in both her classroom practice and later reflections – is that she does not want to hear what "sounds right" or "sounds good." She wants to hear what students actually think, what makes sense to them. Thus, in listening to students' ideas, she is particularly alert to the presence of book-like language; if she hears it, she responds by redirecting students to their *own* ideas.

This desire for students to voice what makes sense to them generally supported Ms. R's attention and responsiveness to the substance of students' ideas. For instance, as evidenced with Arielle above, Ms. R tried several times to get Arielle to share more of her thinking about what density is and how she understands the ideas she put forth about mass and volume. Later, Donald reiterated that what Arielle said was right (line 30), and Ms. R pressed him for his sense of what the definition means: "So what does that mean?" [line 35], "Can you tell me what that means?" [line 37]. When Donald indicated that he could not, Ms. R again made a bid to move away from book-like statements (line 39).

However, Ms. R was less patient when Ray brought Arielle's idea up again, as seen in the following exchange:

> Ray: I think some materials- some objects float from their material, like what they're made of? Or I kind of agree to Arielle about mass times volume because it can tell you something about the-
>
> Ms. R: What is mass times volume then?
>
> Ray: It's whether or not they float. It's, like… [lines 48-50]

Here, it sounded like Ray was beginning to articulate why mass times volume mattered, but Ms. R cut in with, "What is mass times volume then?" After Ray drifted off in line 50, Ms. R reiterated that "the definition doesn't explain what it is" [line 51] and pursued Ray's idea about materials instead (line 53). In this case, the reference to Arielle's idea was only followed by a bit of space for Ray to articulate what he thought it meant, perhaps because earlier attempts with Arielle and Donald had not met with success.

Summary

To summarize, Ms. R's attention and responsiveness to student thinking was likely stabilized by her plan for the day, which centered on students articulating their own

ideas about what causes something to sink or float. She was also particularly attentive to instances in which she felt that students were providing book-like responses rather than their own ideas, and she used those opportunities to probe students about their thinking and to communicate that the most useful ideas are those that make sense to us. This latter aspect can also be seen in the first episode from Ms. R's classroom, when she pressed for students' own ideas in the face of perceived appeals to authority.

Episode 3: What is Energy?

Situating the Episode

The third episode from Ms. R's classroom occurred on April 13, 2011, toward the end of Ms. R's second year in the project. Ms. R had just started a unit on energy with her students, and she started class by asking students, "What is energy?" [Episode, April 2011] as a warm-up. After sharing some ideas, she had students fill out an alphabet sheet about energy – they had to provide an example of energy for each letter of the alphabet (e.g., N = nuclear). Students shared some examples, such as car for C because it requires a motor to run, or mitochondria for M because it's the part of the cell that creates energy. Then Ms. R set them the task of coming up with group rules at their tables for energy that would apply to all of the examples on their sheets. The selected episode occurred at the end of class as groups shared their rules, and Ms. R recorded the rules on a Word document projected at the front of the classroom. Students were also to note comments or questions they had about other tables' rules.

Full Transcript and Coding

Table E-3 contains the full transcript and coding for the third episode from Ms. R's classroom. The transcript in the left column comes from approximately eight minutes of a whole-class discussion. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table E-3

Transcript and Coding for Third Ms. R Episode

Transcript	Coding
1. Ms. R: Read what you have. ((Keven stands and holds board)) Uh, Raul. Get your paper so you can write a question about the purple group's idea. ((turns to computer)) Go ahead.	
2. Keven: Uh, we wrote-	
3. Ms. R: Wait a second. Excuse me. It's over ((to another group)). You need to pay attention to (). And we need to hear everybody's idea. Go ahead. Keven.	

4.	Keven: Huh? Okay. Uh, we wrote wildfire – we wrote wildfire, (), videos, rubber band, car battery, computer, phones, walk and talk and run. Wave, tsunami, water-	
5.	Student: She can't hear you.	
6.	Keven: Tsunami, bike, uh, rain, sleet, and tornado and hurricane. ((student sneezes))	
7.	Wyatt: God bless you, ma'am. ((Keven playing with white board, it falls over))	
8.	Cristobal: Can you repeat that, I didn't hear.	
9.	Ms. R: So, purple group-	
10.	Keven: Wildfire-	
11.	Ms. R: *No, no, no, no, I don't want you to read your whole list. What did you all come up with as to what energy is then?*	Clarifying scenario, pressing
12.	Brandon: Uh, energy is power. Power makes things work.	
13.	Keven: Force.	
14.	Ms. R: ((typing)) *So energy is power and force?* ((Keven playing with white board, it falls over)) *Is that what you said?*	Confirming
15.	Brandon: No, I said power makes things work.	
16.	Ms. R: Okay. Thank you. Yellow table, what did you all have? This, this table right here. Olivia, what did you all have? (pause) I'm sorry? You all had something on your paper. So what did you all dis- excuse me ((to purple group)). Gentlemen!	
17.	Wyatt: Yes ma'am.	
18.	Ms. R: Sit down.	
19.	Wyatt: Yes ma'am.	
20.	Ms. R: ((to yellow group)) What did you all discuss?	
21.	Violet: Um, that- we just said that, we just said-	
22.	Ms. R: Wait a second because they're not, I don't know what they're doing over there. ((to purple group)) ().	
23.	Violet: We discussed dance, like if you use it, you could win ().	
24.	Ms. R: *So you need energy to dance, that's what the definition of energy is?*	Pressing
25.	Anna: No. Energy is, like, if you move or something, () – if you move or something.	
26.	Ms. R: ((typing)) *So energy is if you move or something.*	Maintaining

27.	Anna: Yeah.	
28.	Ms. R: Okay. Green table. Go ahead.	
29.	Cristobal: I say that when a bomb, a bomb somebody set off, it stores up energy, and then when the time runs out, it, it re- it releases a massive amount of energy that causes an explosion.	
30.	Franklyn: I say ridin and blitz is electricity, and electricity is energy.	
31.	Ms. R: *You think what?*	Attempting to hear
32.	Franklyn: Ridin and blitz is energy, and elect- is electricity, and electricity is energy.	
33.	Russel: I say that-	
34.	Ms. R: *Un momento, un momento. What did you say? Writing and what?*	Attempting to hear
35.	Franklyn: Ridin. R I D I N. And blitz is electricity, and electricity is energy.	
36.	Keven: And the gang?	
37.	Student: What?	
38.	Keven: Ridin ().	
39.	Russel: I said, um, I say, um, energy is basically-	
40.	Ms. R: Stop. ((to purple group))	
41.	Russel: I say energy is basically movement.	
42.	Ms. R: And then, um, Waldo, did you have something else yourself? ((snaps)) Yellow.	
43.	Waldo: No, I, I was with Cristobal.	
44.	Cristobal: He didn't even do anything!	
45.	Ms. R: *You was with Cristobal, that energy is* ((looks at computer)), *um, a stored, stored things in a bomb that blows up?* All right, cap ((to yellow group)). Put the top on that. You're not writing, you're listening. Uh, blue group. Thank you. Gentlemen at the green group, we already discussed. We're listening. Go ahead. (pause) ((to blue group)) It's your group's turn to share, I don't know if you were ((laughs, looks at Luke, a member of the research team)).	Confirming
46.	Nathaniel: All of ours didn't have to do with X-rays. So our definition is that energy is the ability to do any action.	
47.	Ms. R: ((typing)) *So you're saying energy is what?*	Attempting to hear
48.	Nathaniel: The ability to do any action.	
49.	Ms. R: Okay. *So energy is the ability to do any*	Maintaining

	action. Stop doing that. ((to yellow group)) Wyatt, and Keven, step outside so I can pay attention. Push in your chairs. ((Wyatt and Keven leave)) Is that everything? Is that everything? Okay. All right, orange table.	
50.	Raul: Energy is the movement or-	
51.	Chris: Ability to move an object from one place to another, or to create an energy source to make an object power up.	
52.	Ms. R: ((typing)) *Energy is the ability to move an object from one place to another, or what?*	Maintaining
53.	Chris: To create an energy source to make an object power up.	
54.	Lindsay: And we've got a picture, a drawing, or whatever it was.	
55.	Dylan: That's the energy source for sunlight, and it's affecting all ().	
56.	Ms. R: Felicia.	
57.	Felicia: What?	
58.	Ms. R: *Um, so how, what is moving? What is moving something on there? Because you said the ability to move an object. The sun is moving something?*	Pressing, maintaining
59.	Dylan: That, the sun-	
60.	Raul: It's the power source, and it's giving energy to the, um, what do you call it? Sun, sun-	
61.	Chris: No.	
62.	Raul: The, the thing. The – I don't know.	
63.	Dylan: You know, the thing that reflects the light?	
64.	Raul: You know that-	
65.	Ms. R: *A mirror?*	Inserting
66.	Students: No!	
67.	Ms. R: *You said the thing*.	Maintaining
68.	Lindsay: The thing that makes energy.	
69.	Students: ((overlapping talk)) You know the sun, solar power, solar stuff…	
70.	Ms. R: *Solar panels?*	Inserting
71.	Students: Yeah!	
72.	Dylan: That thingie.	
73.	Raul: So that the sun gets () and we use the solar panels that, so the-	
74.	Chris: Panels.	
75.	Raul: This absorbs the energy, and we use the	

	energy from that.	
76.	Dylan: And it's reflected. And the sun is the core-	
77.	Raul: The sun is the core, um-	
78.	Chris: Energy, or the power source.	
79.	Ms. R: *Okay, so what's moving? Because your definition said-*	Pressing
80.	Chris: The sun rays!	
81.	Dylan: Sun rays, it's moving. Sway back and forth.	
82.	Ms. R: Leonard does not agree.	
83.	Chris: All right, Leonard, what's your idea?	
84.	Ms. R: ((to blue group)) Ladies, I don't understand why you're making decibels of sound. *All right, we're gonna come back with that. That's a question I have for your diagram. So what is moving, that's the question*. Last group, uh, red group.	Pressing
85.	Cynthia: Uh, we all think that energy is if someone moves because of something or moves something.	
86.	Ms. R: That was it?	
87.	Cynthia: Yep.	
88.	Ms. R: Plain and simple?	
89.	Cynthia: Yep.	
90.	Ms. R: Okay, so tomorrow we're gonna come in and try to see if our definitions apply to every situation. You need to write down questions, that's your homework, for each person's idea. I'm gonna print all- everybody's ideas for you.	
Note. Italicized sections of transcript reflect responsive utterances.		

Justifying Inclusion

The above episode just met the criteria for inclusion in my dissertation. First, of Ms. R's 31 speech turns in the episode, 16 contained responsive utterances. This represents a percentage of 51.6%, meaning the majority of Ms. R's utterances during the episode were responsive to students' ideas. Second, Ms. R's attention and responsiveness to student thinking exhibited resilience in the face of fairly continuous behavioral issues; she even asked two students, Wyatt and Keven, to leave the classroom "so I can pay attention" [line 49]. Third, Ms. R reflected on this episode later the same day in conversation with Luke Conlin, a visiting member of the research team, and at a teacher meeting.

I also selected this episode as an example of two common classroom practices of Ms. R's – 1) having students come up with and share "rules" or definitions for various

scientific phenomena, and 2) recording students' ideas on a Word document projected in the front of the classroom. I explore how both of these practices intersected with her attention and responsiveness to students' ideas in what follows.

Plausible Parts of the Coherence(s)

In what follows, I provide evidence for what might be part of the coherence(s) supporting Ms. R's attention and responsiveness to student thinking during this episode:

- The plan for the day, especially having students come up with rules for energy
- Recording students' ideas on a projected Word document
- Holding students accountable to their own ideas
- Pressing on an idea from the book

The Plan for the Day, Especially Having Students Come Up with Rules for Energy

Similar to the previous episode, the plan for the day included this discussion in which students shared their group rules for energy. Preplanning this space likely supported Ms. R's attention and responsiveness to students' ideas in the moment. Additionally, Ms. R intended for these rules to span the rest of the energy unit, so it was important to make sure that the rules were clearly articulated and understood. As she described at a teacher meeting later the same day, "If this is their rule, right, for the rest of the time, they're gonna try to apply this to all they're exposed to" [Meeting, April 2011]. Ms. R saw these initial rules as students' starting points and imagined that they would change over time as students tried to apply them in various situations: "So this is where they are, and this is what I think it is now. Is this gonna change by the time I get to the end? How so? Why did I change it?" [Meeting, April 2011].

In an interview, I asked Ms. R more about her use of rules in the classroom:

> When they created a rule of at least what do I think, and made a rule for it, they would- it was easier for them to – discuss things based on their rule. Even if they were discussing between each other, or moving on to try to apply something, to design an investigation, like if this is my rule, then this should happen, so I need to test this in this way. To see if my rule still holds up. So then it becomes like testing your rule because that's what you do in science, if I think something, then I need to do some tests to see if, if this – is there some evidence to support what I think. If not, I also find that after they do an investigation, it's easier to let go of- let that rule go, because the evidence doesn't support it. And then they take in other people's ideas more because then they have evidence to support it. So I think that's why I consistently have done the rule thing, overall [Interview, December 2012].

For Ms. R, there are many facets to "the rule thing." Articulating a rule helps students discuss their ideas with each other and devise ways to test their ideas. Ms. R also noted in the interview how having students keep track of their rules helps her "to see like where they started and how they're flowing. So I always have them when they have to change their rule say why they have to change it" [Interview, December 2012]. Given how

deeply these rules influence what happens in the rest of the unit, it was likely all the more critical for Ms. R to listen to them carefully in the episode.

Recording Students' Ideas on a Projected Word Document

While listening to students' rules for energy, Ms. R typed them on a Word document projected at the front of the classroom for all students to see. In an interview in December of 2012, Ms. R indicated that doing so allows students to *see* their ideas in addition to hearing them, and that she often uses the documents as the basis for future planning and homework assignments (as in the present episode in which students were to write questions for each group's idea, line 90). Importantly, though, Ms. R also indicated that typing students' responses enhances her understanding of their ideas – she uses the process as a way "to make sure that I'm getting what they're saying" [Interview, December 2012].

In the selected episode, Ms. R's typing was often intertwined with confirming her understanding of students' ideas. For instance, this kind of intertwining was evident during Ms. R's interactions with the purple group:

> Brandon: Uh, energy is power. Power makes things work.
>
> Keven: Force.
>
> Ms. R: ((typing)) So energy is power and force? ((Keven playing with white board, it falls over)) Is that what you said?
>
> Brandon: No, I said power makes things work.
>
> Ms. R: Okay. Thank you [lines 12-16].

Here, as Ms. R was typing the group's rule, she articulated what she was typing and asked if it was what the group said, giving Brandon an opportunity to correct her. Similar exchanges happened in which Ms. R simultaneously typed and confirmed or restated her understanding of groups' rules in lines 25-27, 46-49, and 51-53. In other words, recording groups' rules served as an opportunity to ensure that Ms. R understood their ideas correctly.

Holding Students Accountable to Their Own Ideas

Ms. R's interactions with the orange group in lines 50-84 highlighted two other plausible aspects that came into play during the episode. As a matter of general practice, Ms. R noted that "I try not to judge what they say, or ask questions about what they're saying when we're just getting everybody's ideas in" [Interview, December 2012]. However, there was an exception with the orange group's idea. In line 51, Chris presented a two-part rule for energy: "Ability to move an object from one place to another, or to create an energy source to make an object power up." Lindsay then indicated that the group had drawn a picture (line 54), and Dylan pointed out the energy source (the sun) in the picture (line 55).

In response, Ms. R asked the following question: "Um, so how, what is moving? What is moving something on there? Because you said the ability to move an object. The sun is moving something?" [line 58]. The group's focus on just one part of their rule in the picture was salient enough for Ms. R to ask a question about the other part of their rule. Moreover, Ms. R asked this question several times – as the conversation continued, she reiterated, "Okay, so what's moving? Because your definition said-" [line 79] and indicated that "we're gonna come back with that. That's a question I have for your diagram. So what is moving, that's the question" [line 84]. Ms. R's repeated appeals to what the group had included as part of their definition suggest that part of what sustained her probing of their diagram was the group should be held accountable to *everything* they said. This may have been particularly important in the context of setting rules, in which the expectation was that the rule or definition apply widely.

Pressing on an Idea From the Book

Another aspect that may have sustained Ms. R's probing of the orange group's diagram was that she recognized the "ability to move an object from one place to another" [line 51] as a definition from the book. At the end of the period, Ms. R shared this with Luke:

> Ms. R: Some people looked up, looked up something in their books.
>
> Luke: Oh, really?
>
> Ms. R: The ability to move an object from one place to another [Conversation, April 2011].

At that point, it became difficult to hear the conversation since the next group of students was entering, but Ms. R noted this again at a teacher meeting later the same day:

> Some people looked in a book and found the ability to move something from one place is energy, right? So it's like trying to grapple with- they still couldn't apply that book definition to, to their, their examples of what they saw energy was [Meeting, April 2011].

This awareness on Ms. R's part suggests that part of why she probed the orange group might have been to see if they could make sense of or apply the book definition they cited.

Summary

In the third episode from Ms. R's classroom, some of the posited parts of the coherence(s) reinforcing her attention and responsiveness to student thinking were part of the plan for the day, which involved understanding and recording students' initial rules for energy. Other parts arose from an inconsistency she noticed in the moment, in which a group of students gave an example that accounted for one part of their stated definition but not the other. Ms. R pushed them to connect their example to the other part of their

definition, in part because a rule or definition should apply in all instances and in part because the left-out piece of the definition was from the book. She may have wanted to see if students were able to apply what they had read.

Synthesizing Across Episodes

Looking across episodes from Ms. R's classroom, the second and third episodes were essentially parts of the plan for the day, whereas the first episode was more emergent in nature. Interestingly, though, all three episodes reflected a forward-looking stance on Ms. R's part – a sense of how the discussions (both emergent and preplanned) fit in to where she saw the class heading. In the first episode, reconciling what counts as a crest needed to occur before counting wavelengths. In the second and third episodes, having students articulate their ideas and ultimately rules at the beginning of a unit set them up to refine those rules throughout the course of the unit. In other words, discussions in Ms. R's classroom were largely part of the flow of instruction.

Another notable commonality across episodes was Ms. R's sensitivity to students providing book-like responses. This was most prominent in the second episode, when Arielle and several other students provided a formula for density and Ms. R pressed them on what density meant to them. It also occurred in the first episode with Rosie and in the third episode with the orange group, in each case sustaining Ms. R's attention to the student or group of students and the sense they were making of the book-like response. This sensitivity to appeals to the book or other perceived sources of authority likely connects to Ms. R's articulated goal for her students to be critical thinkers and to work to make sense of ideas for themselves.

Appendix F: Episodes from Mr. S's Classroom

This appendix includes analyses of three episodes from Mr. S's classroom, focusing on identifying parts of the local coherences supporting his attention and responsiveness to the substance of students' scientific thinking. Each analysis includes a description of the context in which the episode is situated, full transcript of the episode with coded responsive utterances, justification of why the episode was selected for inclusion, and candidates for what may have stabilized Mr. S's attention during the episode. At the end I also synthesize a bit across the three episodes.

Episode 1: Where Would You Drop the Keys? (Take 1)

Situating the Episode

The first episode from Mr. S's classroom occurred on April 7, 2010, during Mr. S's first year in the project. The primary question Mr. S posed to students was as follows: If you're walking with keys, and you want to drop the keys into a container sitting on the floor, should you release the keys before the container, over the container, or after the container? Students had discussed where they would drop the keys in small groups the previous day, and the discussion below ensued at the beginning of class. According to field notes from Ayush Gupta (a member of the research team who worked closely with Mr. S), the plan for the day was to 1) draw three trajectories of the falling keys (before, over, and after) and take students' reasoning on each, 2) have students come up with counterarguments in groups, and 3) have students think about how to test their ideas.

Full Transcript and Coding

Table F-1 contains the full transcript and coding for the first episode from Mr. S's classroom. The first section of transcript in the left column comes from approximately eight minutes of a whole-class discussion, and the second section represents a continuation of approximately ten minutes. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table F-1

Transcript and Coding for First Mr. S Episode

Transcript	Coding
1. Mr. S: Anybody have an argument for dropping the keys over? So I take the keys, I have some keys ((gets out keys)), and I'm walking with the keys ((walks with keys)), and I, and I drop it over the, the container. Why should I drop it over? Can somebody give us a reason for dropping the keys over? (pause)	

	((Martin raises hand)) Martin?	
2.	Martin: Because if you're walking slowly? Like you could just drop it in there.	
3.	Student: Walking or running?	
4.	Mr. S: *So, in other words, if you're going slow-* ((faces board, writes))	Maintaining
5.	Martin: Yeah.	
6.	Mr. S: *What would the keys do?*	Pressing
7.	Martin: It would just stop, like, if you were just walking, and then you dropped it over, it- it will most likely go in.	
8.	Mr. S: *It will just fall?*	Confirming
9.	Martin: Yeah.	
10.	Mr. S: *It will fall directly down?*	Confirming
11.	Martin: Yeah.	
12.	Mr. S: ((finishes writing)) Okay. Any other arguments for dropping it over the container? *I know we had some yesterday*. Anybody else want to add to? ((Jack raises hand)) Uh, Jack?	Returning to idea later
13.	Jack: The weight of the keys.	
14.	Mr. S: ((faces board, writes)) *The weight. What's, say a little bit more about the weight. What is it about the weight?*	Pressing
15.	Jack: The weight – the weight weighs ().	
16.	Mr. S: Hold on, not everybody's listening to your, to, to Jack right now. (pause) *The weight of the keys will do what?*	Pressing
17.	Jack: Wouldn't it make it go down because it's heavier?	
18.	Mr. S: *So, so something having to do with the, the weight of the keys because it's heavy. What force will cause it to go straight down? What force will cause it to go straight down?* ((Suri raises hand)) Suri?	Maintaining, eliciting
19.	Suri: Gravity.	
20.	Mr. S: ((faces board, writes)) *Maybe GRA::vity. GRA::vity.*	Maintaining
21.	Ayush: So Jack, are you thinking, like, the keys are heavy and so they just get pulled down?	
22.	Jack: Yeah, they're heavy, and then gravity just pulls them down.	
23.	Ayush: Just pulls them down, straight down. Okay.	
24.	Mr. S: Okay ((Diane raises hand)), uh, Diane?	
25.	Diane: No, no, I'm not for that one, I feel like I	

	would go before.	
26.	Mr. S: *Before. Why before? You're for the first option.*	Pressing
27.	Diane: Yeah.	
28.	Mr. S: *Why before, Diane?*	Pressing
29.	Diane: Because I thi:::nk that – well, let me try to give you an example, li:::::ke ((loudspeaker interruption)) I think, like, when you're racing? Like, you're in a racecar? And then, you know, let's say you have to () on fire or something? So when you're trying to land on the grass – because you're not going to get there right when you're at the grass or else you're gonna- because the car's fast, and you're going fast too. You gonna, like, get on the mud or something, so you're going to have to go before, so you know, you could, you know what I mean?	
30.	Mr. S: *So what do you mean is that there's some kind of forward motion?*	Confirming, inserting
31.	Diane: Yeah.	
32.	Mr. S: ((faces board, writes)) Okay. *So you're saying some kind of forward motion based on what?*	Pressing
33.	Diane: On the speed of the person who ().	
34.	Mr. S: *So based on speed, right?*	Maintaining
35.	Ayush: = Folks, did you hear that reasoning?	
36.	Students: Yes.	
37.	Student: Yes, it's based on speed.	
38.	Ayush: Based on speed.	
39.	Mr. S: Okay, anything, any other reasons for dropping it before? *Diane said she liked the first reason.*	Maintaining
40.	Student: It's, it's just because it depends how fast you're going. It just depends how fast you're going.	
41.	Mr. S: *So this one's gonna depend on the-*	Maintaining
42.	Student: Speed.	
43.	Mr. S: ((faces board, writes)) *So this one depends on – how quickly.*	Maintaining
44.	Ayush: And the specific example I heard was somebody jumping off a car or something? Is that what you were saying?	
45.	Diane: That was me. ((raises hand))	
46.	Ayush: Great. And so if you're jumping off the car, it's like you're thinking about, like, you	

	just have to jump off a little bit before – if you want to reach that stop, you're thinking that you will jump off a little bit before kind of thing. Okay.	
47.	Mr. S: Okay, any other, any other, any other reasons for going, uh, releasing the keys before? Any other reasons? (pause) *Now somebody said yesterday, after would be better. Why after? There are a couple- I remember Katherine said after.*	Returning to idea later
48.	Katherine: I'm giving up after.	
49.	Mr. S: *Why give up on it?*	Pressing
50.	Katherine: Because I'm confusing myself.	
51.	Mr. S: *You're confusing yourself, okay.*	Maintaining
52.	Katherine: Because people are talking about walking, a couple people were talking about running slowly, but I'm talking about running fast ().	
53.	Mr. S: *Okay, so how would- so if you're running fast-* ((faces board, writes))	Maintaining
54.	Student: () what does running fast mean?	
55.	Mr. S: *So, fast-*	Maintaining
56.	Student: Just ((points at Katherine)) stay over there!	
57.	Mr. S: *A fast run – so what would a fast run do, Katherine?*	Pressing
58.	Katherine: It would make the keys go ((points back over shoulder)) this way?	
59.	Mr. S: *Go back – keys would go back.*	Maintaining
60.	Katherine: Yeah, but I don't ().	
61.	Mr. S: Okay, now, Katherine – again, we're talking one at a time, not two at a time, or three at a time. *Katherine, why walking back- why going fast, if I'm going fast* ((walks fast)), *why would that cause the keys to go backwards? What, what force* ((Bill raises hand)), *what would cause the keys to go back?*	Pressing, eliciting
62.	Katherine: (pause) The speed, like – when you're, when you're running, like, the speed of the wind is hitting you, the keys, and causing them to go back.	
63.	Mr. S: ((faces board, writes)) *So you said something about the wind.* (pause) Bill, did you want to add to or, or say something else?	Maintaining
64.	Bill: I've got an example?	
65.	Student: You can put a ().	

66.	Mr. S: Hold on, hold on.	
67.	Bill: If you're in a car, and like, you're in a car that's going fast, then you can like, I know it's illegal, but if you take a piece of paper and throw it out the window, you know, it never hurts nobody. So you can throw it out the window, and it's gonna, and it's gonna go back because the wind is hitting it, it's going like this ((passes one hand over the other)) on the car, and when you drop it, it goes back.	
68.	Mr. S: *So you're saying that the wind would cause the object to fall back. So we're dealing with option number three, we're dealing with option number three*. ((faces board, writes)) *So the wind* (pause) *will cause object* (pause), *in this case keys* (pause) *to fall back*.	Maintaining

At this point in the discussion, Mr. S started talking about designing an experiment to test out what would happen with the keys, and Ayush made a counterbid to discuss what students thought would happen if you were going fast. Students discussed in small groups for a few minutes before coming back to the discussion below.

69.	Mr. S: All right, so we're going really fast, what option should we choose? Should we choose option 2, option 1, option 3? Let's say we're going, like, we're, we're, we're in a vehicle, we're driving like a hundred miles an hour. Should we go- or we're on a motorcycle, we're doing 80 miles an hour, going over the speed limit. When should we drop it? Before, after, or during?	
70.	Edwin: Before.	
71.	Mr. S: Option 1 – before, over, or after? Uh, first group, um, Katherine's group. Okay, go ahead.	
72.	Edwin: I say, I say before because it's like Diane said-	
73.	Nat: See? ((laughter))	
74.	Mr. S: Come on, let's stay focused.	
75.	Edwin: So, it would be like Diane said, if you were trying to jump out a car, you would want to, you're gonna want to jump before it gets to you, because if you try to as soon as it's right there, () keep driving and it'll fall on the side of the road.	
76.	Mr. S: *Where's it gonna fall at if you drop it*	Pressing, inserting

	before? Is it gonna fall over here, over here, over here, or in there? ((indicates locations on, presumably, a drawing on the board))	
77.	Edwin: ((stands up to look)) Okay, it's gonna fall () ((points to board)).	
78.	Mr. S: *Over here?* ((points to board))	Confirming
79.	Student: No.	
80.	Mr. S: *So if you do it before, it's gonna fall, it's gonna come over here?*	Confirming
81.	Edwin: Oh wait no, it's gonna fall ().	
82.	Mr. S: *It's gonna fall over here* ((points to board)). *So it's gonna go straight down on an angle* ((writes on board)).	Maintaining, inserting
83.	Ayush: So you are, you're sticking with the earlier reasoning that look, if you're- if I'm going to jump off the bus and I want to reach that spot, however fast the bus is going, I'm going to jump before that spot.	
84.	Edwin: Yeah.	
85.	Ayush: Okay.	
86.	Mr. S: Okay, uh, Katherine, your group, what did you all come up with?	
87.	Katherine: I think that going before doesn't make sense because if you're going really fast, if you're going really fast then the wind, the speed of the wind is just going to push it farther back and it's not going to- because he said fly like that () ((Edwin and Bill raise hands)).	
88.	Mr. S: So you want to respond to that, uh, Ed-Edwin?	
89.	Edwin: Yes because ke:::::ys are not like paper. They're made out of metal.	
90.	Katherine: Exactly, ()-	
91.	Edwin: So how are they, how are the wind going to push it?	
92.	Katherine: Exactly, ()-	
93.	Mr. S: Hold on, let's listen, okay? Uh, uh, Bill, you want to respond to, to them?	
94.	Bill: It's, it's because, no, Edwin kind of has a point. If, if you dropped, if you were running really fast and you dropped a key, it's not, it's not going to go back. I mean, you might think it's going back because you're still running, but it's just going to drop in the same place.	
95.	Mr. S: Okay, Derek, then Diane.	

96.	Derek: All right, I'm feeling like if you're going really, really fast, so then the keys, then you're running, so then, like, when you drop it, the air would, like, push it that way because you're going this way. ((Mr. S writes on board)) And that's air pressure.	
97.	Mr. S: *What, what about the air? You said air pressure? What about the air?*	Pressing
98.	Derek: Like, it would be going, uh, if you're going this way ((stands and moves forward)), then when you drop it, the air flowed that way ((points behind him)).	
99.	Mr. S: *So air's gonna push it back?*	Pressing
100.	Derek: Yeah.	
101.	Student: No comprendo.	
102.	Mr. S: Okay, Diane?	
103.	Diane: Have you ever played those games where it says you have to flick on the thing, right? Have you ever played those games in, those are the kind of games where you have to flick on the thing as soon as you get there-	
104.	Student: I know about, I know about those.	
105.	Diane: So you gotta do- have you noticed that when you try to do it at that time when it's there, it doesn't work out if you do it after? But then when you do it before, it gets to the little thingie () get it. So it's related to this.	
106.	Mr. S: *So yours is similar to what Jack said a little while ago about timing.*	Identifying similarities, returning to idea later, inserting
107.	Diane: Yeah.	
108.	Mr. S: *Timing has to be, what, over here* ((points at board))? *Are you saying it, it has to go first?*	Confirming
109.	Diane: Yeah.	
110.	Mr. S: *Opt- option one?* Okay, any other, any other groups want to weigh in? Um, Brittany?	Confirming
111.	Brittany: Can I go ()?	
112.	Mr. S: That's not related to the discussion. Um, Martin?	
113.	Martin: I think I agree- I agree with Derek because if you go, if you run it before- wait, no, I don't agree with Derek. If you go before, and then you drop the key a little bit before it, it goes on top of it. Then it's gonna go.	
114.	Mr. S: *So you- Derek's argument about the air pushing back* ((points to board)), *you don't*	Returning to idea later, maintaining

	agree with? You think if you're going really really fast, you still need to drop it right before the, uh-	
115.	Martin: Yeah.	
116.	Mr. S: *The tarp.* Okay, um ((Katherine raises hand)) Katherine?	Maintaining
117.	Katherine: But it's the same thing, just how they're saying that if you do it before, the keys aren't gonna go- they're supposedly pushed to the container, it's the same thing as saying that the wind is going to push it ((Suri raises hand)) back to the thing.	
118.	Mr. S: Okay, Suri, you want to respond to that or add something to the discussion?	
119.	Suri: Yeah, I'm like, if you're running, you feel like the wind is pushing you back.	
120.	Mr. S: *So you're saying as you're going fast, faster, you're also feeling some pressure, some air, pushing back against you.*	Maintaining, inserting
121.	Suri: So my drop, um, is from above or after.	
122.	Mr. S: *Above or after because of what?*	Pressing
123.	Suri: Because if the wind is working in a different direction than you, you're running and () ((moves one hand forward and the other in the opposite direction on top)).	
124.	Mr. S: *So when you, when you're saying, when you're running fast, there's some pressure coming up against you, coming against you?*	Confirming
125.	Suri: Mm-hmm.	
126.	Mr. S: *What is that?* (pause) *What do you think that is?* (pause) *So you're saying there's a pressure, there's something pushing back against you.* ((faces board, writes)) *There's a push back. And, so that push back, when you release the keys, what is it going to do to the keys?*	Eliciting, maintaining, pressing
127.	Suri: They're gonna drop backward.	
128.	Mr. S: *They're going to drop back.* Okay, okay. Um, now, what are some- Traci, did you want to respond? ((Traci shakes head)) *What are some arguments against this* ((points to board)), *this idea that there's air pushing back or there's something pushing back? What are some arguments against that? Why is that possibly not a good* ((Diane raises hand*)), a good, um, predict- a good rat* ((Katherine	Maintaining, asking for counterclaims

	raises hand))- *uh, reasoning?* Um ((points at Katherine)).	
129.	Katherine: Just because of the weight of the keys.	
130.	Mr. S: *So what you're saying is the weight of the keys might nullify this.* ((faces board, writes)) *In other words, the weight of the keys means that what? What about the weight of the keys – would nullify that or would cause that not to be a good argument?*	Maintaining, pressing
131.	Katherine: The weight might cause them to just fall down, but like a piece of paper would fly back.	
132.	Mr. S: So- (pause)	
133.	Ayush: So you're thinking-	
134.	Mr. S: *So you're saying the weight is gonna overcome this push back?*	Confirming, inserting
135.	Ayush: So you're thinking that, suppose I had these light single keys versus this big heavy dictionary, and I was in this car, I'm going, and I kind of drop them simultaneously, then the air might be able to push this thing back, but it won't be able to push this really heavy book back. Is that-	
136.	Katherine: That's it.	
137.	Ayush: Is that the kind of thing? Okay.	
138.	Mr. S: Okay, any other arguments against this, this last option of, of releasing after? Yes?	
139.	Diane: I think that air doesn't have to do with the keys because the, the, what's it called, the speed of somebody running is the kind of variable that actually pushes it. So I think it has to do with the motion and how you- the angle you're going, so like if you go like that ((overhand pitch)) it's gonna go high up.	
140.	Mr. S: *So you're, so you're saying, Diane, that the angle is the key* ((faces board, writes)), *not the air push back. The angle of the drop, right?*	Confirming
141.	Diane: Yeah.	
142.	Mr. S: *Of the drop, okay. Any other arguments against the air pushing back?* (pause) *Okay, now what about the- this idea* ((points to board)) *that, that it will be better to drop it before because it's gonna go at an angle? Any arguments against that?*	Maintaining, asking for counterclaims
143.	Student: No.	

144.	Student: No, sir.	
145.	Mr. S: Now, if you know- well, if you don't have a reason, then you would, you would just wait and let's see who does. Not say no because you think- you can't speak for the rest of the class, right? So, *who thinks that this* ((points to board)) *is not a good idea?* ((Katherine raises hand)) Katherine?	Attempting to elicit when little evidenced
146.	Edwin: Oh, oh ().	
147.	Katherine: ((laughs)) I don't because if () if you think that the keys are gonna go straight to the (), you might as well just drop it on- above so that they could go straight in. So that's what, that's what they're trying to say that if you drop it, it's gonna make an angle and just fly into the container.	
148.	Edwin: Oh, so hold on, hold on, she thinks that if she's running after, she's gonna drop it where it isn't- where the cup is not even at, and it's just going to fly into it.	
149.	Katherine: No, that's what you said.	
150.	Edwin: That's what YOU said.	
151.	Katherine: You're gonna drop it here-	
152.	Edwin: ().	
153.	Mr. S: Hold on, speak loudly, speak loudly so everybody can hear you.	
154.	Edwin: Because, because she thinks if she runs after it, and she drops it, the wind is going to pull it back behind.	
155.	Mr. S: *That's not what she said, she said it's gonna go straight down. The option ().*	Maintaining
156.	Edwin: If it, if it goes above, that's what she said. But she's saying, um, she's for after, number three?	
157.	Katherine: I'm saying for before. You're saying that if you dropped it-	
158.	Edwin: () before ().	
159.	Katherine: That's why () say, this is an example, but if you drop it like where the, where the word "angle" is ((points to board, Sam looks over at Nat who is talking to another student)), that's what you're trying to say, that it- it's just going to fly straight to the thing. It's just saying that.	
160.	Mr. S: Okay, Nat? Nat, what do you think?	
161.	Nat: I think before.	

162.	Mr. S: *Why?*	Pressing
163.	Nat: Because like, when you're running, right, like, it wouldn't go back-	
164.	Mr. S: ((to student who has head down)) Oliver, go get some water, you can't do that. ((Oliver stands up and leaves))	
165.	Nat: Because that's just like unrealistic.	
166.	Ayush: What if you were in a car?	
167.	Student: What if you were moving forward, yeah?	
168.	Nat: If you were in a car, it depends on the object.	
169.	Ayush: If you were in the car, it depends on the object, tell me more about that? What do you mean by depends on the object?	
170.	Nat: It depends on the object, a giant key. The keys would most likely-	
171.	Mr. S: Now right now, now hold on, hold on, Nat, hold on, hold on, Nat. Hold on, Nat. Right now, Nat is speaking, no one else.	
172.	Nat: The keys would most likely go backward, depending on the object, say like a brick? It would most likely just fall in place, like where you dropped it out of the car.	
173.	Ayush: So if I had a brick versus a, a key, the keys might go back, but the brick would flo- would fall. So- ((Nat nods)) okay.	
174.	Mr. S: Okay. So now, let's look at how we're gonna test this out.	
Note. Italicized sections of transcript reflect responsive utterances.		

The remainder of the class period was spent designing an experiment to test students' predictions about the key drop scenario.

Justifying Inclusion

The above episode met the criteria for inclusion in my dissertation. First, of Mr. S's 70 speech turns in the episode, 50 contained responsive utterances. This represents a percentage of 71.4%, meaning the majority of Mr. S's utterances during the episode were responsive to students' ideas. Second, although the episode was not continuous and experienced a large perturbation when Mr. S began to shift gears (which I discuss more below), his attention throughout was otherwise relatively resilient in the face of other perturbations, such as when a student asked an unrelated question in line 111 or when students indicated that they did not have anything to say in response to Mr. S's question in lines 143-144. In fact, Mr. S actually used these moments to communicate metamessages to students about what they were to be doing, brushing past the student's

unrelated question in line 112 ("That's not related to the discussion") and telling the other students that they should not presume to speak for the whole class in line 145 ("if you don't have a reason, then you would, you would just wait and let's see who does"). Third, Mr. S reflected on the discussion in several forums, namely a debriefing conversation with Ayush immediately after class and at two teacher meetings in April and May of 2010.

Plausible Parts of the Coherence(s)

In what follows, I provide evidence for what might be part of the coherence(s) supporting Mr. S's attention and responsiveness to student thinking during this episode:

- Modeling the discussion after his own inquiry experience
- His familiarity with ideas likely to come up
- Use of the board to organize ideas
- Eliciting a particular kind of explanation from students
- Ayush's involvement with the discussion
- Participation of students who did not typically participate

Modeling the Discussion After His Own Inquiry Experience

One point that Mr. S returned to in discussion about the episode in a teacher meeting was its similarity to a fruitful inquiry on the same topic that he participated in the previous summer. At a teacher meeting, Mr. S noted the following:

> The question had the options in it, the question was do you want to release- similar to what we- almost identical to what we dealt, dealt with in the summer? The question was should we release the, the, uh – the keys before we get to the container, above the container, or after the container, and – so I just turned it into option one, two, and three [Meeting, April 2010].

Here, Mr. S indicated that he kept the question largely the same as the question he and other teachers discussed for an extended period of time in the summer. Looking back at how Andy Elby (lead member of the research team) introduced the question during the 2009 summer workshop, the parallels are clear:

> The question is deceptively simple. I got my keys, I got that cup on the floor, I'm just gonna hold my hand – still, compared to me, and I'm gonna run towards and past that cup ((physically demonstrates scenario)). And I say hey, I want to drop my keys so that they fall in the cup. And my question is, should I drop them before I reach the cup, when I'm right over the cup, or when I'm a little past the cup? ((illustrates the location of each drop relative to the cup)) [Workshop, July 2009]

Mr. S also acknowledged in an interview in October of 2012 that the whole-group nature of the discussion in his classroom was similar to what he had experienced over the

summer. His own experience with the question and ensuing discussion seemed to serve as a model for how he approached and facilitated the discussion.

His Familiarity with Ideas Likely to Come Up

From this previous experience and others, Mr. S was also familiar with some of the ideas likely to come up in discussion. In an earlier conversation with Ayush, Mr. S expressed a desire to be at ease with the content when facilitating inquiry discussions: "I'm not there yet. I think it has to do with a lot of planning – and/or being very, very comfortable with the – with the material – being covered. At least I think it helps if you are, you know?" [Conversation, December 2009]. The key drop inquiry afforded some comfort along these lines, as Mr. S was familiar with ideas that came up from participating in the inquiry himself, watching classroom video of another teacher's class tackling a similar question, and listening to his students discuss the question in small groups the day before.

This familiarity may have helped Mr. S process some of the ideas that students put forth, particularly the ideas that were lengthier in nature. For instance, in line 67, Bill provided an example of throwing a piece of paper out of a car and it flying backward because of the wind hitting it. Mr. S summarized this idea as the wind causing the object to fall back (line 68), but he recalled the idea in greater detail in conversation with Ayush after class:

> Ayush: The kids were coming up with reasonings that we all came up with in summer.
>
> Mr. S: Right, right. Oh yeah, I, I did notice that, I, I was like (pause) that was ((looks to where Bill sat in class)) perplexing me, even like Bill ((points at where Bill sat)), he said, he even mentioned the- we didn't- I didn't say anything about an automobile, he said well, like, if you had an automobile, and you take the napkin, and you let it go hanging out the door, it's gonna fly backwards. You know? That was very similar to what we did with the bottle [Conversation, April 2010].

When Ayush stated that the students were coming up with similar ideas as the teachers did in the summer, Mr. S highlighted Bill's idea as being similar to his own experience of dropping an empty bottle out of a moving car. What is notable is that he recalled more of the details of Bill's idea – dropping paper from a car – than he indicated in his summary of Bill's idea in class.

Diane expressed a similar lengthy idea in line 29 about needing to jump out of a moving car before it reaches the place you want to land. Mr. S recapped Diane's idea as there being forward motion based on speed (lines 30, 32, 34), but he remained unclear about the specifics of her idea until a teacher meeting when Ayush explained the sense he made of it:

> Ayush: Diane was saying that if you jump off a, a car and you want to, you know, land somewhere – on grass or something, you have to jump off the bus or the car

> before – uh, because if you jump when the grass patch is right here, you will end up in the mud or something like that.
>
> Mr. S: I, you know, it kind of threw me too, um, when she said that, I wasn't quite sure even till your point exactly what she was talking about… when she initially talked about it, I wasn't quite sure – where she was going with it, but I think, I think, uh, Ayush is right, she's talking about – if you're going to jump out the vehicle – you know, you need to jump out, if you want to get to that spot, you need to jump out before you get there [Meeting, April 2010].

These examples suggest that not only did familiarity with ideas likely help Mr. S feel more secure facilitating the discussion, especially as recognizable ideas came up in the moment, but it also helped him to attend to more complicated ideas. He recalled Bill's idea in detail, relating it to something from the summer workshop, but he had more trouble with Diane's idea, which was likely new to him in the moment.

Use of the Board to Organize Ideas

Another feature that was salient in the episode was Mr. S's repeated orienting to the board, at times writing on the board and at other times using it as a common reference point when revisiting and clarifying students' ideas. For instance, Mr. S often faced the board and wrote after a student contributed (e.g., line 4 following Martin's statement, line 14 following Jack's statement, line 20 following Suri's statement, etc.). At a teacher meeting later the same day when a group watched video of the episode, Mr. S and Ayush both mentioned this use of the board:

> Mr. S: Now what you can't see here is there's a white board we were using- Ayush suggested we use the white board, so we had the white board hooked up and we were using it-
>
> Ayush: Yeah, so some of this was getting written down on the board [Meeting, April 2010].

Here, Mr. S drew participants' attention to his use of the board, which was not visible on the video. Mr. S indicated that it was Ayush's suggestion to use the white board, and Ayush reiterated that one use of the board was to record some of what was going on during the discussion.

Mr. S also referred to what he had recorded on the board during the episode, like when he asked students for counterarguments to specific ideas (lines 128 and 142). Furthermore, he used "a little sketch" [Interview, September 2012] that he had drawn on the board with a container and arrows representing the different options to clarify his understanding of students' ideas. For instance, consider the following exchange between Mr. S and Edwin:

> Mr. S: Where's it gonna fall at if you drop it before? Is it gonna fall over here, over here, over here, or in there? ((indicates locations on, presumably, a drawing on the board))

Edwin: ((stands up to look)) Okay, it's gonna fall () ((points to board)).

Mr. S: Over here? ((point to board))

Student: No.

Mr. S: So if you do it before, it's gonna fall, it's gonna come over here?

Edwin: Oh wait no, it's gonna fall ().

Mr. S: It's gonna fall over here ((points to board)). So it's gonna go straight down on an angle ((writes on board)) [lines 76-82].

Something notable about this exchange is that, without access to the representation on the board, it makes very little sense. Due to the ambiguous speech referents (i.e., repeated use of the term "here"), I cannot parse the substance of Edwin's idea about the motion of the keys. Yet Mr. S and Edwin, having access to the common representation, seemed to understand each other, and Mr. S was able to make an interpretation of how Edwin thought the object would move. Thus, Mr. S's use of the board was intertwined with making sense of Edwin's idea.

Eliciting a Particular Kind of Explanation from Students

Another plausible element supporting Mr. S's attention and responsiveness to student thinking during the episode was his focus on eliciting a particular kind of explanation from students – namely, an explanation involving causal factors. Throughout the episode, Mr. S tended to organize students' ideas into the following explanatory structure:

<*Causal factor* causes *kind of motion,* which supports *specific option*>

Explanations of this form would be *speed* causes *forward motion*, meaning you should drop the keys *before* the container, or "the *wind* would cause the object to *fall back*" [line 68], meaning you should drop the keys *after* the container.

Many of Mr. S's follow-ups solicited these different explanation components. For instance, early in the discussion, Jack supported dropping the keys over the container, as their weight would cause them to fall straight down (lines 13, 15, 17). Mr. S responded in part by asking, "What force will cause it to go straight down?" [line 18] and excitedly accepting the response of gravity (line 20). In an interview, Mr. S reflected on this exchange as having to do with internal and external factors:

Mr. S: So that, that, that was part of what I was trying to get to, is that you have an internal, uh, possible factor that would, that would explain the drop, but is there anything external in the environment that would explain it? If so, what, what would that be?

> Jen: Okay. So like, the weight would be the internal factor, and the gravity would be the external factor.
>
> Mr. S: Right [Interview, September 2012].

A similar pattern occurred with other ideas that students raised throughout the episode. When Diane talked about jumping out of a car before you reach the spot you want to land (line 29), Mr. S abstracted the idea of forward motion from what she was saying (line 30) and pressed her to explain on what the forward motion would be based (line 32). He then acknowledged her idea of "speed" [line 34] – the relevant causal factor – and moved on to another student[35]. When Katherine talked about the keys going backward if you're going fast (lines 52, 58), Mr. S asked, "If I'm going fast, why would that cause the keys to go backwards? What, what force, what would cause the keys to go back?" [line 61] His reframing of the question from *why* the keys would go backward to *what* would cause them to go backward, and his subsequent summary that Katherine "said something about the wind" [line 63], reflected his foregrounding of the causal factors underlying students' ideas. This focus on factors can also be seen in his summary of Bill's idea (idea in line 67, summary in line 68) and his pressing of Suri for what the factor is in his explanation (line 126).

It is likely that Mr. S's focus on causal factors was partly mediated by the plan for the class period, which involved designing experiments to test students' ideas. In fact, as Mr. S made a bid to transition to the experimental design part of class, he explicitly asked students about relevant factors: "So what's a common theme- what's a common factor we need to look at?" [Class, April 2010]. Another potential influence on Mr. S's focus on causal factors was that he tended to foreground them in his own scientific explanations. Looking at Mr. S's participation in the key drop inquiry the previous summer, he often highlighted relevant factors and their implications for the motion of the object. For instance, on the first day of the inquiry, a small group of teachers were discussing how water would fall from a crop plane on a windless day, and Mr. S offered that the momentum of the plane, temperature, and air pressure would all matter in determining what happened to the water. A bit later, the same group was discussing a similar scenario in which there was now not only no water, but no air, and Mr. S highlighted that "two of the main factors" [Workshop, July 2009] would be the altitude and speed of the plane. During a whole-group discussion several days later, Mr. S stated, "I think there are many factors," and offered the following comparison:

> … if we increase the speed, or keep the speed constant at a certain level and increase the weight, at some point the impact of gravity on the weight of the object's going to be greater than the momentum causing the object to go forward [Workshop, July 2009].

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[35] Some of these examples are examined in more detail in Chapter 5, which focuses specifically on distinctive forms of scientific knowledge Mr. S foregrounded in the first and third episodes from his classroom.

Here, Mr. S identified two relevant factors with respect to the motion of the keys – speed and weight. He seemed to be specifically considering a situation in which speed was kept constant and weight was constantly increasing, and he thought there was a point at which gravity (causing the object to move down) would overcome momentum (causing the object to go forward). It is likely that his own use of factors-based explanations played into his focus on causal factors in his students' explanations.

In terms of the interaction between Mr. S's foregrounding of causal factors and his attention and responsiveness to student thinking, there is evidence that reorganizing students' explanations may have helped him make meaning of what they were saying. For instance, with Diane's idea about jumping out of a car (which Mr. S acknowledged he did not fully understand in the moment), Mr. S's distillation of the ideas of speed and forward motion allowed him to connect to the gist of what she was saying. However, that very distillation also meant he only attended to certain *pieces* of students' ideas, namely the pieces italicized in the explanatory structure above (causal factors, kinds of motion, and specific options).

Ayush's Involvement with the Discussion

An additional salient feature was the role that Ayush played during the episode and in the planning stages. Ayush's most obvious influence was when Mr. S moved to designing the experiment, and Ayush made a bid to continue the conversation instead:

> Ayush: I wanted to ask a question before we go on to design the experiment-
>
> Mr. S: Okay.
>
> Ayush: = Is that okay?
>
> Mr. S: Sure [Class, April 2010].

Ayush then asked the question about what would happen if you were going fast, which formed the basis of the second part of the episode. Thus, Mr. S's continuing attention and responsiveness to the substance of students' thinking about the key drop question was made possible in part by Ayush's contribution and may have been stabilized by Ayush's active presence in the classroom. Additionally, Ayush was an integral part of the planning process for class, as evidenced earlier by Ayush's field notes outlining the plan and Mr. S's acknowledgment that Ayush suggested using the board.

I looked more closely at interactions between Mr. S and Ayush prior to this class period to explore their interpersonal dynamics and, especially, how Ayush was positioned in Mr. S's classroom. In late 2009, Ayush facilitated a discussion with one of Mr. S's classes about questions they might be interested in researching for their science fair projects. Mr. S stated that he would like Ayush to continue to come in and co-teach in a conversation after this class:

> I think we should, you know – try to – plan another, another – co-teaching round for whatever I'm teaching that day? Or that week?... I think we'll get the most out of it- most value out of your being here because, you know, you have a wealth of

> – knowledge and insight and – curiosity to, to share with the kids, and I can see them really like, they're into, like ((laughs)), today, I could tell – they were really struggling with some of the questions you posed, you know? It made them think [Conversation, December 2009].

Here, Mr. S indicated that he thought co-teaching was the way to get the most value out of Ayush's classroom visits. He highlighted that Ayush had a lot to offer the students and that Ayush's questions made students think.

Classroom audio from the day before the selected episode shows that Mr. S told students, "When Mr. Gupta comes- we're gonna be co-teaching, we're gonna be teaching together" [Class, April 2010]. Mr. S's openness to Ayush's contributions was also evident in an interview when Mr. S talked about Ayush's role in the classroom: "Basically what I said to him was, you know, feel free to chime in anytime" [Interview, September 2012]. Mr. S indicated that he and the students both appreciated Ayush's contributions: "I think they appreciated him, and I know I did. Anytime he spoke and he asked questions. Usually, they were questions for clarification" [Interview, September 2012]. From this data, it is evident that Mr. S positioned Ayush as a co-teacher in his classes, which he communicated to the students and which seemed to include Ayush jumping in at will.

Participation of Students Who Did Not Typically Participate

Finally, something that was salient to Mr. S upon reflection on the key drop inquiry was the increased participation of students who typically did not participate. Mr. S noted this in conversation with Ayush right after class:

> I thought there were some kids who normally don't speak who – started to talk, like Martin over here ((looks over to where Martin sits in class))… I thought that – the format (pause) um – allows some kids to, to, um, demonstrate their strengths that normally wouldn't be able to [Conversation, April 2010].

Mr. S expressed a similar sentiment about Jack in an interview as well:

> And Jack was, uh – yeah, as I recall, Jack was a kid who – he was always observing. He didn't participate very much. But when it came to the, um, inquiry discussions we had, um, he was one of the kids who got really involved with it [Interview, September 2012].

These statements suggest that part of what likely supported Mr. S's attention and responsiveness to student thinking was the students who participated when he did so. He noted that Martin and Jack, the first two students to raise their hands and speak in the discussion, did not usually speak. Seeing them do so might have piqued his interest in continuing the conversation and seeing who else contributed.

Mr. S also reflected several times on the unexpected participation of Nat, a student who contributed his ideas at the end of the discussion. Mr. S indicated at a teacher meeting later the same day that he called on Nat "because he was talking to another kid, he was having a side conversation" [Meeting, April 2010]. Yet Nat quickly replied and

elaborated on his ideas in interaction with both Mr. S and Ayush, standing up and gesturing while making his points. Both Nat's ability to jump right into the conversation and his animation in doing so seemed to make an impression on Mr. S. He commented on how Nat was much more animated than usual in a conversation with Ayush after class and talked about Nat at length at the teacher meeting that night:

> What's interesting about this scene is that that kid there? Very rarely does he participate… the fact that he got out of his seat too? ((laughs)) He does- that's more animated than I've seen him almost the whole year… That's the most that he has participated… he kind of was following things, and then he got up and actually gave some rationale for his, his thought. I was really kind of impressed with that [Meeting, April 2010].

Moreover, Nat's participation had a lasting effect on Mr. S. At a teacher meeting more than a month later, Mr. S again described Nat's participation and suggested that "he wasn't challenged with the other traditional approach. He wasn't challenged" [Meeting, May 2010]. While viewing video of the episode during an interview two and a half years later, Mr. S picked Nat out of the crowd prior to seeing Nat's contributions:

> Mr. S: I do remember that kid over there, Nat?... He didn't really say much in other activities, but I noticed at a certain point, he became very animated during discussion on the key drop.
>
> Jen: Yeah, yeah, yeah. I think we're gonna get to that point actually.
>
> Mr. S: That was uncharacteristic of him. He was, he was really, for the most part, he was more listening and sort of observing. You know, and I would see that every year that I was using inquiry in the classroom, that the kids who initially seemed to be a little more laidback or less participatory are sometimes the best, uh, inquirers [Interview, September 2012].

The participation of students who did not typically participate – particularly students who were not successful in other school activities – was a potent force for Mr. S. He saw inquiry discussions as a new way for students to demonstrate their strengths, or to be challenged. For instance, Mr. S reflected more generally on this matter at a teacher meeting about a month after the episode:

> Mr. S: One thing I've noticed with kids, um (pause) juxtaposing the (pause) more book-based out of the text or whatever versus discussion and careful ()- what I've noticed is that (pause) with more discussion, I see kids who normally (pause) sit back and don't engage are engaged… now we're all- I don't want to say equal, but we all have an equal chance to, to, you know, engage in a way that's not related to (pause)-
>
> Ms. R: A's and B's.

> Mr. S: A's and B's or, um, to a certain extent, um (pause) just as kind of a what happens in school [Meeting, May 2010].

Here, Mr. S indicated that during inquiry discussions, students have more of "an equal chance" to engage in a way unlike what traditionally "happens in school." In other words, Mr. S saw the power of inquiry discussions – centered on student thinking – to level the playing field. He repeated this sentiment recently in an interview:

> You don't need to, you don't need to access it from the academy only. And that's part of what I got from those kids because some of those kids that were, to me, the most, had some of the greatest ideas of all, some of them, some of the kids were also the kids who didn't have ac- a lot of academic skills [Interview, September 2012].

He also highlighted the power of students feeling like their ideas are important and "worth not only discussing, but… testing, putting to, um, another level of… exploration" [Interview, September 2012].

For Mr. S, then, a feedback loop is likely in play between inquiry discussions and matters of social justice more broadly. Recall from Chapter 3 that his primary purpose in teaching is to impact the lives of at-risk and traditionally marginalized youth. When he began facilitating inquiry discussions, he noticed students like Martin, Jack, and Nat begin to participate in ways they had not previously. Their unexpected participation likely stabilized his focus on students' ideas during the present episode and possibly more generally, as he saw that inquiry discussions in which students' ideas were respected and validated created space for these students to contribute in ways that traditional schooling had not. Continued participation from these students would further reinforce this dynamic.

Interestingly, interactions between Mr. S and Ayush commonly included discussion of how inquiry connected to social justice. According to Ayush's field notes from an early visit, he and Mr. S discussed how inquiry connects to issues of justice in a conversation after class – "how developing the sense of agency in constructing their own knowledge can lead students to be better learners and more authentically capture the process of science" [Conversation, October 2009]. In the conversation immediately after the episode, Ayush also validated Mr. S's sense that inquiry allows students to demonstrate previously unseen strengths: "And that's – part of the thing, right? The kids who feel like that feel marginalized by the normal educational system and now suddenly they feel, oh, I can say something, I have something valuable to say" [Conversation, April 2010]. Thus, the working relationship between Mr. S and Ayush was buttressed by their common interest in promoting social justice for students.

Summary

To recap, there are numerous plausible parts of the coherence(s) reinforcing Mr. S's attention and responsiveness to the substance of student thinking during the first episode from his classroom, many of which intersect with each other. Mr. S's previous experience as a participant in a similar inquiry served as a model for his facilitation in the episode, and his familiarity with likely responses enhanced his comfort with opening up

the space for students and aided his understanding of some of their lengthier responses. His use of the board allowed him to record students' ideas externally and provided a common point of reference for revisiting and clarifying ideas. Reorganizing students' explanations into a causal factor-centric explanatory structure may have helped him make meaning of what they were saying and probe them further (to elicit all of the explanatory pieces), albeit in a selective manner. Additionally, Mr. S's co-planning and co-teaching relationship with Ayush likely stabilized Mr. S's attention and responsiveness to student thinking, as Ayush suggested Mr. S's use of the board and took an active role in reorienting focus to students' ideas about the key drop question during the discussion. Finally, Mr. S valued the participation of students who typically did not participate, particularly if they were otherwise marginalized by traditional schooling experiences. Seeing their participation may have helped to maintain his focus on students' ideas. Moreover, he and Ayush commonly discussed connections between inquiry and social justice, which likely strengthened their relationship and Mr. S's valuing of what Ayush brought to the table. Such intersections between elements suggest that, in addition to reinforcing Mr. S's attention and responsiveness to student thinking individually, they may also reinforce each other and enhance the stability further.

Episode 2: How Did the Dinosaurs Become Extinct?

Situating the Episode

The second episode from Mr. S's classroom occurred on January 3, 2011, halfway through Mr. S's second year in the project. Structurally, this class was distinct from the first episode in that Mr. S had set aside the entire class period for discussion (what he called "inquiry Monday"). The general topic of inquiry Monday was typically connected to the content he was addressing the rest of the week. He also engaged students in a fishbowl discussion, in which a small group of students sit in an inner circle and discuss a topic, and a larger group of students sit in an outer circle and observe the discussion. After a period of time, outer circle students may also contribute to the discussion and eventually rotate to the inner circle as iterations of the structure continue.

Here, Mr. S specifically asked the first group of inner circle students to discuss the following question: "How did the dinosaurs become extinct?" [Class, January 2011]. Outer circle students were to take notes on what the inner circle students were saying, noting points they found important or questions they had; Mr. S also took notes while inner circle students were talking.

Full Transcript and Coding

Table F-2 contains the full transcript and coding for the second episode from Mr. S's classroom. The transcript in the left column comes from approximately ten minutes of discussion among the first group of inner circle students. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table F-2

Transcript and Coding for Second Mr. S Episode	
Transcript	Coding
1. Mr. S: Okay, Evan? ((prepares to write))	
2. Evan: It was a meteor shower.	
3. Mr. S: *A meteor shower, okay. And explain, explain a little bit more in terms of the meteor shower, what actually happened in terms of the extinction of the dinosaurs*.	Maintaining, pressing
4. Jake: Because he copied.	
5. Mr. S: Evan's- Evan's speaking now. Again, I said, it's gonna be important that you listen to each other, and only one person speak at a time so we can hear what each person's saying. You gotta speak up a little bit too, Evan.	
6. Evan: ((Mr. S writes while Evan talks)) Um, a meteor shower killed the dinosaurs, and um, they just became extinct because all the females died, and the males couldn't mate, and they just died.	
7. Mr. S: *So you're saying that the meteor shower, um* (pause) *basically killed all of the females and left the males alive*?	Confirming
8. Evan: Yeah.	
9. Mr. S: Okay, okay. And, and how, okay, um, before you- *how did the, how did the meteor know that it was the female and not the male? How did it, how'd it differentiate*?	Pressing
10. Student: There were-	
11. Mr. S: Uh uh uh uh, he's answering. What? (pause) *What do you think? How did the meteor ((smiles)) decide that just the females, how did- why did the females die and not the males? That's the point I'm raising if you said a meteor shower*. (pause)	Pressing
12. Jenny: I have a question. (pause)	
13. Mr. S: Okay, *you have a question for him*? Go ahead, Jenny.	Confirming
14. Jenny: Why did the, the meteor shower only hit the females and not the males?	
15. Evan: It only hit, it hit both of them, but, um, some of them stayed, some of them were still there.	
16. Terell: I have a question.	
17. Mr. S: Those on the outside, you're going to	

	have your questions after about ((checks timer)) eight minutes. Okay, Cooper?	
18.	Cooper: Oh, I want to ask Evan, um, why did they like, um, how come they only killed all the females, not all the males?	
19.	Jenny: I just said that!	
20.	Cooper: Yeah, that.	
21.	Mr. S: Okay, *he just tried to answer that question*, but I have a question for you, Cooper. What's another possible causal story for the dinosaurs becoming extinct? Cooper? ((prepares to write))	Acknowledging attempts to answer
22.	Cooper: Um, like, because um, because, um, they lived so long that like, um, probably some of them were getting extinct because of the other hunters, the T. rex, and the meat-eaters. Yeah. ((Mr. S writes))	
23.	Student: The predators.	
24.	Cooper: Yeah. And they ate like almost all of them, and then they started starving, then they killed each other off.	
25.	Mr. S: *So you- you're saying that the carnivores ate the herbivores- the ones that ate the, the, the, the plants*?	Confirming
26.	Cooper: Yeah.	
27.	Mr. S: Okay.	
28.	Cooper: No, they, they killed everybody. Like, they killed each other because like, they killed the plant-eaters ((Mr. S writes)), and then like there weren't any more, um, stuff to eat, so they were going against each other, and they died.	
29.	Mr. S: *Okay, so they ate all the- the plant-eaters, and then once they ate all the plant-eaters, then they killed each other, and they, they killed each other so that there were no more dinosaurs*. Okay. ((Jose, in outer circle, raises hand)) Um, anyone else in our inner circle? Again, those in the outer circle, you're, you're sitting quietly, and you're waiting for the, the time to elapse, Blaine, before we move on. Okay? Um, um, anyone else in our circle? What do you think happened? (pause) Any ideas? Kendra, what do you think happened? ((prepares to write))	Maintaining
30.	Kendra: Um, a meteor shower?	

31.	Mr. S: Okay, any other possible, um, um, possibilities for causal stories as to how the dinosaurs became extinct?	
32.	Jenny: ((points at Jake)) He just said something.	
33.	Mr. S: I'm wait- waiting for Kendra to speak first.	
34.	Kendra: I don't- I said a meteor.	
35.	Mr. S: *A meteor shower? So you agree with Evan, it was a meteor shower*.	Confirming, identifying similarities, returning to idea later
36.	Kendra: Yeah.	
37.	Mr. S: Okay, I'm gonna ask again, those on the out-	
38.	Jenny: A volcano?	
39.	Mr. S: Outside the circle, to sit quietly please. Jake, go ahead. Speak loudly so everybody can hear you.	
40.	Jake: I thought maybe the volcanoes and stuff, if they blow? Or the big bang ().	
41.	Mr. S: ((writes)) *The volcano, so you said a volcanic, um, eruption*?	Confirming
42.	Jake: Yeah.	
43.	Mr. S: *And tell us what happened after the volcanic eruption? Tell us a little bit more? Can you say a little more about that*?	Pressing
44.	Jake: Um (pause) I don't know.	
45.	Mr. S: *I mean what, how did they actually become extinct? You said a volcanic eruption, so tell us what happened. Can you maybe potentially give us some ideas as to how it happened*? (pause) ((Cooper raises hand)) Cooper?	Pressing
46.	Cooper: Um, I think, like, maybe a flood, or like a tsunami came ((Mr. S writes)) and like destroyed them all?	
47.	Mr. S: *So you said a flood or a giant tsunami*?	Confirming
48.	Cooper: Yeah.	
49.	Mr. S: *And what did the tsunami do*?	Pressing
50.	Cooper: It- it's like a super-giant wave, it's like a hurricane, it's like, it's like super-heavy water that just (). ((phone rings))	
51.	Mr. S: Okay, Evan? ((gets up to get phone))	
52.	Evan: ()	
53.	Jose: How could a tsunami be in a desert?	
54.	Cooper: Who said they were in a desert?	

55.	Jose: Most dinosaurs are.	
56.	Student: So ().	
57.	Blaine: Hey, hey, hey, but that's the, the dinosaurs that live in the water. ((Mr. S hangs up phone, returns))	
58.	Student: There's desert- there's water in the desert.	
59.	Mr. S: Okay, now again, the people on the outside have to wait, wait until we, we get to the questions from the outside. Now Evan, state, state it one more time, what did you, what you were going to say.	
60.	Evan: Um, I had another idea about it.	
61.	Mr. S: Okay, let's hear it, and speak loudly-loud, loud enough for them to hear you outside.	
62.	Evan: Maybe the ice age made it too cold ((Mr. S writes)), and the dinosaurs froze up and died.	
63.	Jake: Yeah, that's why they made the movie.	
64.	Mr. S: *So you said the ice age, um, ice age made it too cold*? ((Evan nods))	Confirming
65.	Jake: They put the nuts, and then they-	
66.	Mr. S: ((holds hand up toward Jake)) Hold hold hold hold hold hold, hold on, hold on. Um, you know what, um, we're not laughing and we're not making jokes about it either-	
67.	Jake: ()	
68.	Mr. S: Uh uh uh. Go ahead, go ahead, Evan.	
69.	Evan: Uh, the tree, the trees, um, got frozen up ((Mr. S writes)), and the veggie-eaters, they all died, 'cause of no food.	
70.	Mr. S: *So you said the ice age froze the trees, so the, the, the plant-eaters died first. Then how did the, how did the, um, the carnivores die*?	Maintaining, pressing
71.	Evan: It got too cold for them. And since the other ones died, they couldn't eat anymore.	
72.	Jake: Like the same thing-	
73.	Mr. S: *So the other ones couldn't, couldn't*- you gotta wait, you gotta wait, Jake.	Maintaining
74.	Evan: They couldn't find food?	
75.	Mr. S: ((writes)) *So then you're saying that the carnivores could not find any meat to eat*. ((Evan nods)) *No food. And so what happened to them*?	Maintaining, pressing

76.	Evan: They died.	
77.	Mr. S: *They died*. Okay, um, Jake?	Maintaining
78.	Jake: Um, I think that, like, um, maybe like, like, um, in the ice age times, like, um, sabertooth, they died because their teeth were too big. They couldn't eat. They died of starvation.	
79.	Mr. S: *What did, what did their, what did their teeth size have to do with their extinction again? Say a little bit more about that*.	Pressing
80.	Jake: Because they couldn't bite, and stuff. They, they couldn't, um (pause) they, uh, they couldn't eat 'cause the teeth were like chuuuu ((moves hands from mouth to mimic size of teeth)).	
81.	Mr. S: Okay, okay. Um, anyone else, uh, Tatiana? Do you have any thoughts about possible causes for the extinction of the dinosaur?	
82.	Tatiana: No. ((laughter))	
83.	Mr. S: *Which one out of the, out of the stories you've heard so far, which one do you most agree with*?	Attempting to elicit when little evidenced
84.	Jake: Ice age.	
85.	Tatiana: (pause) Cooper.	
86.	Mr. S: *And why, why Cooper? Why his story*?	Pressing
87.	Tatiana: Because, I like it. ((laughter))	
88.	Jake: What'd he say?	
89.	Mr. S: *Why, why Cooper's story*?	Pressing
90.	Tatiana: Because of the carnivores, maybe they didn't have enough to eat, and then they died. Then they (pause)-	
91.	Mr. S: ((to kid outside circle)) Terell. ((shakes head)) So, okay, so now ((Kendra raises hand)), uh, Kendra?	
92.	Kendra: I think it was meteors because meteors maybe killed plants, and killed some dinosaurs because of the hot molten body ((Mr. S turns back in notes, writes)). And then, um, they probably moved to find some more food, and when they were moving there wasn't that much water, so they died. ((Evan raises hand))	
93.	Mr. S: ((starts new section of notes)) *And the water shortage, what, what, what, the meteor-what caused the water shortage*?	Pressing
94.	Kendra: The, um, heat from the meteor.	

95.	Mr. S: Evan?	
96.	Evan: Um, I think it was an earthquake, and the dinosaurs fell in. And then people- and then they died in the, in the soil, and when people dug, they saw the fossils.	
97.	Mr. S: *So you said possibly a giant earthquake swallowed then up so to speak*? ((Evan nods, Mr. S writes)) *Fell into the, into the areas where there was a, uh – giant hole, is that what you're saying*? ((Evan nods, Mr. S writes))	Confirming
98.	Jake: Oh yeah, like in the movie ().	
99.	Mr. S: Okay, all right, all right, Cooper?	
100.	Cooper: How did that hole get made?	
101.	Mr. S: Um, guess what? Guess what? Right now we're listening. Go ahead, Cooper.	
102.	Cooper: How'd the hole get made?	
103.	Mr. S: Okay, *he asked, he's asking, uh, Cooper is asking you a question, Evan*. ((timer goes off))	Maintaining
104.	Evan: It was part of the ().	
105.	Mr. S: Okay, um ((turns timer off)), go ahead, Evan.	
106.	Evan: The earth sort of just opened up, and they fell in.	
107.	Mr. S: Okay. Now, now we have a couple minutes where we're gonna take questions from outside the circle.	
Note. Italicized sections of transcript reflect responsive utterances.		

As the class period continued, Mr. S rotated who was in the inner circle twice, and each group got a different question – what kind of evidence would you look for to prove or disprove your causal story, and are there any possible connections between how the dinosaurs became extinct and how human beings might one day become extinct? These questions were agreed upon in advance by Mr. S and Ayush[36]. Mr. S then concluded class by asking all students to write something they learned through the day's discussion.

[36] Note how Ayush retained a co-planning role if not a co-teaching role. In this class specifically, Mr. S came up with the first and last questions, and Ayush came up with the middle question. Mr. S noted in an interview in September of 2012 that he and Ayush had weekly discussions in which they brainstormed questions for the topic coming up next.

Justifying Inclusion

The above episode met the criteria for inclusion in my dissertation. First, of Mr. S's 46 speech turns in the video, 26 contained responsive utterances. This represents a percentage of 56.5%, meaning the majority of Mr. S's utterances during the episode were responsive to students' ideas. Second, the episode was demonstrably resilient in the face of perturbations, as evidenced by Mr. S's quick return to where he left off when the phone rang (see lines 50 through 59) and his continued eliciting in the face of lacking participation in moments (e.g., line 29 when no one offered ideas, line 83 after Tatiana rebuffed his attempt to pull her into the conversation). His setting aside of inquiry Monday also reflected a form of resistance to a competing aim of curricular coverage, as I discuss below. Third, Mr. S reflected on the episode in two teacher meetings in January and March of 2011 and at a summer workshop session in July of 2011.

I also selected this episode as an example of a discussion that took place on inquiry Monday and used the fishbowl structure – two common characteristics of Mr. S's inquiry discussions his second year. I explore how both of these structures interrelated with Mr. S's attention and responsiveness to students' ideas in what follows.

Plausible Parts of the Coherence(s)

In what follows, I provide evidence for what might be part of the coherence(s) supporting Mr. S's attention and responsiveness to student thinking during this episode:

- The structural supports of "inquiry Monday" and the fishbowl
- Taking notes while students were talking
- Intrigue with respect to an unusual idea
- The sophistication of students' ideas

The Structural Supports of "Inquiry Monday" and the Fishbowl

The structures Mr. S set up for discussion in his second year were notably different from his first year. First, this episode took place on "inquiry Monday," in which the whole period was devoted to discussing a scientific phenomenon. At a teacher meeting shortly after the episode, Mr. S and Ayush reflected together on the benefits of inquiry Monday. Ayush asked Mr. S whether he noticed any differences in his own experiences running inquiry that year as compared to the previous year. One of the differences Mr. S identified was that the previous year, inquiry was part of an ongoing lesson, whereas it was now a standalone. Ayush noted that "having the whole seventy-five minutes… opens up a space in some sense" [Meeting, January 2011], which Mr. S emphatically ratified:

> That's the key difference. This year, the inquiry is, is kind of sitting alone by itself, connected to what happens during the week, but not – not so integrated to it that, that the inquiry can't take its own, go in its own direction, you know? ((to another teacher, Ms. M)) Before, I had, I had an inquiry, but it was… tied to an exploration. ((laughs)) It was tied to, uh, information. It was tied to- but this inquiry isn't tied to anything. There's no pre, there's no real pre, um, so far, there

> hasn't been any preset, um, destination. It's been okay, we're gonna raise this question, these are some possible answers, but there may be some others you don't know about. And they have been coming forth too. So when we open- I think when we, when we made a space for the other ((laughs)) possible causes, causal stories, uh, the kids have been – so far, you know, they've been, they've been coming up with them, you know? In a way that's been kind of refreshing and, uh, exciting in that way [Meeting, January 2011].

Building on Ayush's general idea that devoting a whole period to inquiry "opens up a space in some sense," Mr. S stated that inquiry the previous year was tied to particular explorations and information, whereas now inquiry was standalone with no preset destination; it could "go in its own direction." This more open version of inquiry created a space for other "possible causes, causal stories" that may not have had space the previous year. Without a particular destination in mind, or an exploration to get to, Mr. S was freer to follow students' ideas for an extended period of time, attending and responding to them based on their own merit rather than how they jive with an intended concept or activity. Moreover, Mr. S noted at a teacher meeting in January of 2011 that inquiry Mondays became somewhat self-perpetuating with students asking about and looking forward to the discussions – this distributed amplification from both the teacher and students hints at a plausible mechanism by which inquiry Mondays and, by proxy, Mr. S's focus on student thinking could be stabilized in the classroom over time.

Second, Mr. S implemented the fishbowl discussion structure described previously. The idea for the fishbowl arose in an earlier teacher meeting in December of 2010 when Mr. S and Ms. R got into a detailed discussion of how Ms. R implements the fishbowl discussion strategy in her classroom. Mr. S took notes on what Ms. R was saying and adapted her structure for use in his classroom. Throughout the episode, he repeatedly referred to the structure of the inner circle and the outer circle.

The fishbowl discussion structure seemed to stabilize Mr. S's attention and responsiveness to student thinking in a fairly direct way. During the teacher meeting shortly after the episode, Mr. S noted that he was "gonna stay with the fishbowl unless something else comes up better" [Meeting, January 2011]. Ayush then asked Mr. S what he liked about the fishbowl, and whether there was a difference in his facilitation between a whole-group discussion and a fishbowl discussion. One of the points Mr. S made was that he's "able to listen more clearly to what kids are saying – because there are only four or five kids around the table, at most six?" [Meeting, January 2011]. He also noted that side conversations throw his focus off, and he brainstormed different ways to keep the outer circle students more consistently engaged. Thus, although Mr. S was interested in tweaking what he was doing to minimize side conversations, he noted a fairly direct mechanism by which the fishbowl discussion strategy stabilized his focus on student thinking – it allowed him to focus on fewer students, more deeply, at a time.

However, the fishbowl discussion structure is, by nature, selective in stabilizing attention to ideas from students in the inner circle, and detracting from ideas posited by students in the outer circle. For instance, when Mr. S got the phone in line 51, the following exchange occurred between students:

> Jose: How could a tsunami be in a desert?

Cooper: Who said they were in a desert?

Jose: Most dinosaurs are.

Student: So ().

Blaine: Hey, hey, hey, but that's the, the dinosaurs that live in the water. ((Mr. S hangs up phone, returns))

Student: There's desert- there's water in the desert.

Mr. S: Okay, now again, the people on the outside have to wait, wait until we, we get to the questions from the outside [lines 53-59].

In this exchange, Jose, Blaine, and other students in the outer circle attempted to substantively engage with Cooper about his tsunami idea. However, when Mr. S returned, he oriented to the fact that students in the outer circle were talking rather than to what they were saying, and he shifted attention back to students in the inner circle. He also reminded students in the outer circle to wait their turn several times throughout the episode (lines 17, 29, 39). Thus, there were specific tradeoffs associated with the participation rules in terms of whose thinking Mr. S attended and responded to at a given time, but Mr. S saw the more limited participation as beneficial for his ability to engage deeply with students' ideas.

Taking Notes While Students Were Talking

A salient carry over from the first episode was Mr. S recording students' ideas as he was listening, although this time it was not on the board but on his own piece of paper. At times, Mr. S prepared himself to write before students even started speaking (lines 1, 21, 29), providing a physical manifestation to all involved that he was ready to listen. At other times, Mr. S wrote as students were offering their ideas (lines 6, 22, 46, 62, 69). There is some evidence that Mr. S differentiated between new ideas and previously-mentioned ideas as he wrote, as illustrated in the following exchange with Kendra:

Kendra: I think it was meteors because meteors maybe killed plants, and killed some dinosaurs because of the hot molten body ((Mr. S turns back in notes, writes)). And then, um, they probably moved to find some more food, and when they were moving there wasn't that much water, so they died.

Mr. S: ((starts new section of notes)) And the water shortage, what, what, what, the meteor- what caused the water shortage?

Kendra: The, um, heat from the meteor [lines 92-94].

Here, when Kendra mentioned meteors (the first idea mentioned by Evan starting in line 2), Mr. S flipped back to a previous page of notes to write. As Kendra started discussing

the idea of there not being much water, however, Mr. S flipped forward to a blank section and asked her for more information about the water shortage. In other words, he seemed to add Kendra's meteor idea to a previous section of his notes (likely about meteors) and physically separated her water shortage idea as a new thing in his notes, suggesting that he used his notes in grouping students' ideas in real time. At a teacher meeting, Mr. S indicated that he got the idea of noting students' ideas by causal story from Ayush[37]:

> Particularly one thing Ayush said when I spoke to him on Sunday that I, I implemented on (pause) Monday, I wrote down Story 1, and I wrote down what it was. Story 2, and then what it was. Story 3, and that's what- I literally wrote that down [Meeting, January 2011].

Later, he used his notes to recap distinct causal stories he heard, and both a meteor shower and a water shortage resulting from the heat of the meteor were included.

Another way in which taking notes interrelated with his attention and responsiveness to what students were saying was that he referred to his notes in confirming his understanding of students' ideas, which provided students with an opportunity to correct his understanding (and Mr. S to correct his notes). For instance, consider the following exchange between Mr. S and Cooper:

> Mr. S: So you- you're saying that the carnivores ate the herbivores- the ones that ate the, the, the, the plants?
>
> Cooper: Yeah.
>
> Mr. S: Okay.
>
> Cooper: No, they, they killed everybody. Like, they killed each other because like, they killed the plant-eaters ((Mr. S writes)), and then like there weren't any more, um, stuff to eat, so they were going against each other, and they died.
>
> Mr. S: Okay, so they ate all the- the plant-eaters, and then once they ate all the plant-eaters, then they killed each other, and they, they killed each other so that there were no more dinosaurs [lines 25-29].

Mr. S originally revoiced the part of Cooper's idea that involved carnivores eating herbivores, and Cooper clarified that the carnivores ate the herbivores *and* each other. Mr. S jotted something down in his notes as Cooper was talking, and his subsequent revoicing included both parts of Cooper's story. Although Mr. S expressed some trepidation about taking notes while students were talking, he ultimately felt it was

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[37] This provides further evidence that Ayush still participated in the planning of the inquiry and thus played an indirect (at minimum) role in supporting Mr. S's attention and responsiveness to the substance of students' scientific thinking.

beneficial: “I think it was helping to facilitate more, if I wrote down the little notes of what the kids said” [Meeting, January 2011].

Intrigue with Respect to an Unusual Idea

At the beginning of the conversation, Mr. S immediately encountered an idea that seemed to intrigue him. In line 6, Evan suggested that a meteor shower killed all the female dinosaurs, and the males couldn’t reproduce. Mr. S confirmed his understanding of Evan’s idea, “So you’re saying that the meteor shower, um (pause) basically killed all of the females and left the males alive?” [line 7]. It is notable that Mr. S paused for several seconds between the idea of the meteor shower and its differential effects on females and males, as if Mr. S was still processing what Evan was saying or thinking about how the two bits were related. When Evan replied in the affirmative (line 8), Mr. S pressed him to articulate how the meteor differentiated between males and females (lines 9 and 11). Here, I look at his questioning in more detail to flesh out why I claim Mr. S was intrigued:

> Mr. S: How did the, how did the meteor know that it was the female and not the male? How did it, how’d it differentiate?
>
> Student: There were-
>
> Mr. S: Uh uh uh uh, he’s answering. What? (4-second pause) What do you think? How did the meteor ((smiles)) decide that just the females, how did- why did the females die and not the males? That’s the point I’m raising if you said a meteor shower. (10-second pause) [lines 9-11]

In his questioning, Mr. S pressed Evan several times and protected Evan’s space to respond, which was not unusual in the episode. What was unique was Mr. S’s subtle affect toward Evan’s idea – smiling as he questioned Evan, being a bit playful with his wording (how did the meteor “know,” “differentiate,” “decide,” all of which gave the meteor an unusual level of agency). He seemed simultaneously amused and puzzled by the idea, and he continued to pursue further explication from Evan, supporting other students in asking similar questions until he let Evan off the hook in line 21.

Moreover, this idea was memorable for Mr. S. He mentioned it when a similar idea came up in another class period, and he also spontaneously brought the idea up during a teacher meeting shortly following the episode:

> Several groups in different classes mentioned that the, the female species of dinosaurs were, were eaten, were eaten somehow, consumed, or died off – for various reasons, and that the males had no, no, no, no male- no female, um, um, um, members of the species to, with which to have, uh, reproduce [Meeting, January 2011].

All of this evidence – how Mr. S interacted with Evan around his idea during the episode, and how salient it remained to him after – suggests that Mr. S was intrigued by Evan’s idea (and related ones).

Further information about how Mr. S interacted with Evan's idea comes from a teacher meeting approximately two months after the episode, when Mr. S had opportunity to watch the video. He smiled when Evan posed the idea and laughed after his own "Okay, okay" in line 9 of the video. We paused the video at that point, and Mr. S recapped Evan's idea and alluded to what he did next:

> I was trying to understand from him, how did all the females- whatever did- whatever it was that was the cause of the killing off of the dinosaur, how was it that they, that the- what was it about the females that made them susceptible to this mass extinction? [Meeting, March 2011]

Here, Mr. S indicated that he was most interested in understanding more about the male/female distinction. He noted that Evan never really came up with a clear explanation and wondered if it had something to do with the culture in which Evan was immersed:

> I wondered when he spoke, I wondered if, coming from a patriarchal society or culture, how much of his, his, his rationale is somewhat based on this idea that the female is the weaker vessel, and somehow she is more prone to die off because of this mass environmental change that took place [Meeting, March 2011].

Mr. S's continued intrigue with respect to Evan's idea suggests a mechanism of mutual reinforcement between Mr. S's attention and responsiveness to Evan's idea and his curiosity. As Mr. S attended to Evan's idea, he became curious about why Evan was thinking what he was thinking, which supported continued attention to Evan's idea, and so on. Moreover, given that this was one of the earliest exchanges that took place during the episode, it is plausible that Mr. S's curiosity was piqued for what other students might offer as well. As Mr. S noted in an interview:

> If the focus is the kids' thinking, then it's gonna create- it's gonna cause you to think about follow-up questions, you know? Um, I mean the kids themselves are gonna put you in a posture where you're gonna be wondering well, why, why do you say that? [Interview, October 2012]

The Sophistication of Students' Ideas

A final point Mr. S reiterated while discussing the video in the teacher meeting was the sophistication of students' ideas during the discussion. He primarily talked about the kinds of explanations that students were giving, citing Evan's and Cooper's early ideas specifically:

> Their ideas had, had, had validity in that they were, they had a clear, um – story as to how it could have happened in terms of it, if all the females died, then there's no way for them to procreate, and if they can't procreate, then they become extinct. In the Cooper situation, there's a clear causal story. If they ate everything

> up, and there was nothing else to eat, and they were eating each other, eventually the last two were standing, and then one ate the other [Meeting, March 2011].

What struck Mr. S about these students' ideas was that they reflected clear causal stories for how the dinosaurs might have become extinct, either through an inability to reproduce or cannibalism. With Cooper's idea in particular, Mr. S also said that he saw a potential connection to current issues of sustainability for humans, namely overharvesting. It is possible that these are realizations Mr. S made in the teacher meeting rather than at the time in class. However, he may have felt that what his students were doing was promising and worth continuing at the time, even if he had not articulated for himself why. Plus, given how primed he was to be thinking about possible connections between dinosaur extinction and human extinction in light of the third question he was planning to ask students, it is reasonable to think that Mr. S may have noticed the potential connection in Cooper's idea at the time, reinforcing his attention and responsiveness to students' ideas.

This sense of sophistication was also reflected in an interview with Mr. S more generally as something he has noticed while facilitating inquiry discussions: "Some of the things that they came up with I recognized were perhaps very, very, uh- for lack of a better word, sophisticated" [Interview, September 2012]. He highlighted how both Ayush and his co-teacher were impressed with the level at which students were thinking, his co-teacher in particular noting that seventh-grade students were discussing ideas he hadn't thought about since college. Mr. S also noted how seeing students make connections is "the joy of teaching" [Interview, September 2012] for him. Thus, in a manner similar to seeing students participate who typically don't, seeing students come up with sophisticated ideas and make connections during conversations centered on their ideas might reinforce Mr. S's attention and responsiveness to student thinking in the moment and more broadly.

Summary

In the second episode from Mr. S's classroom, Mr. S instituted structures that faciliated his openness and attention to students' ideas. "Inquiry Monday" permitted him to follow students' ideas without concern for where he needed to end up, and the fishbowl discussion structure allowed him to focus more deeply on fewer students' ideas at a time. Additionally, taking notes while students were contributing may have facilitated his confirming, grouping, and recalling of students' ideas as the discussion occurred. It is interesting to note that these elements were all planned ahead of time, and planned in concert with Mr. S's colleagues (Ms. R for the fishbowl, Ayush for the note-taking). He set himself up for success in several ways.

Yet there were also parts of the coherence(s) that were reflective of what happened *in* the space rather than in planning *for* the space. For instance, Mr. S demonstrated curiosity with respect to Evan's idea about differential effects on males and females, sustaining his interaction with Evan in the moment and his continued contemplation about what Evan might have meant. Mr. S also noted several positives about what he saw students doing, such as articulating clear causal stories for how the dinosaurs might have become extinct and putting forth ideas in which he saw potential connections for discussing human extinction. The interesting and sophisticated nature of

what Mr. S saw students doing in the space he set up through the structures he selected likely reinforced his focus on student thinking, as students took up his plan in a productive manner.

Episode 3: Where Would You Drop the Keys? (Take 2)

Situating the Episode

The third episode from Mr. S's classroom occurred on March 14, 2011, approximately two months after the second episode. Mr. S posed the same key drop question to students that he had in the first episode, but he used the structures from the second episode – a full class period devoted to discussion, and the fishbowl discussion structure.

Full Transcript and Coding

Table F-3 contains the full transcript and coding for the third episode from Mr. S's classroom. The transcript in the left column comes from approximately sixteen minutes of discussion among the first group of inner circle students. Italicized sections of the transcript in the left column are what I consider to be responsive utterances on the part of the teacher, the nature of which I document in the right column.

Table F-3

Transcript and Coding for Third Mr. S Episode

1.	Mr. S: Remember, the central question is do I drop it before, above, or after I pass the container? Evan, you wanted to say something?	
2.	Evan: I was gonna ask is that a trick question?	
3.	Mr. S: *No, it's not a trick question at all*.	Clarifying scenario
4.	Student: How is it a trick?	
5.	Mr. S: *It's not a trick question at all*. Um, Cooper?	Clarifying scenario
6.	Cooper: Um, above?	
7.	Mr. S: *Above*.	Maintaining
8.	Cooper: Because like the gravity, like, when you put it up, it goes down.	
9.	Drake: = It's heavy.	
10.	Mr. S: Okay, so, so, um, so *Cooper said that, that because of gravity, if it's heavy*, if it's heavy, then- um, gentlemen? Move back just a little bit Terell. Gentlemen, move around, move around, Tim, move around.	Maintaining
11.	Drake: = He's in my space. ((laughter))	
12.	Mr. S: Move back just a little bit Terell.	

13.	Drake: He's in my space.	
14.	Mr. S: Okay, so, now, um, *Cooper said that because it's heavy, what happens, Cooper, I have to, I have to drop it-*	Maintaining
15.	Cooper: No, gravity puts, like, pulls it down.	
16.	Mr. S: So, because *gravity's pulling it down*. ((Drake raises hand)) Um, Drake?	Maintaining
17.	Drake: Because, uh, weight is the amount of gravity pushing it down?	
18.	Mr. S: *Weight is the amount of gravity pushing it down, okay. And what does that have to do with me dropping it- you said above, right*?	Maintaining, pressing
19.	Drake: Yeah.	
20.	Mr. S: *So why do I need to drop it above, because of what now*?	Pressing
21.	Drake: The gravity on it pushes it harder because it's-	
22.	Mr. S: *The gravity pushes it harder*, okay. Does anybody think I need to drop it after or before I get to the container, in the circle? ((student outside circle speaks)) Um, you're in the listen-only mode. Um, Chavez, what do you say?	Maintaining
23.	Chavez: Oh, above the container.	
24.	Mr. S: *So everybody in here thinks- you say above too*, Teresa?	Identifying similarities
25.	Teresa: Mm-hmm.	
26.	Mr. S: Okay, so, so my question then, my next question is what is the reason why we should drop it above the container versus before or after the container? ((Tim, Evan, and Chavez raise hands)) Um, Tim?	
27.	Tim: Because if we drop it before or after the container, it won't get in the container. ((Kendra raises hand))	
28.	Mr. S: *Where will it go if we drop it before the container*?	Pressing
29.	Tim: On the ground.	
30.	Mr. S: *On the ground in front of the container, or on the side of the container, or behind the container*?	Pressing, inserting
31.	Tim: On the side.	
32.	Mr. S: *So if I drop it before I get to the container, would it fall here* ((gestures in front)), *there* ((gestures behind)), *or on either side*? ((Tim and Drake gesture in front)) *It*	Pressing, maintaining

	would drop in front of the container.	
33.	Drake: Or it might hit the metal part of it.	
34.	Mr. S: *Or it might hit the metal, you mean like the rim of-*	Confirming
35.	Drake: Yeah.	
36.	Mr. S: *The container*?	Confirming
37.	Drake: Because like you're moving too, so it'll go a little bit, but not all the way.	
38.	Mr. S: Okay, okay, uh, Kendra?	
39.	Kendra: Are you tossing it or just dropping it?	
40.	Mr. S: *You're just, you're just going by, you're just dropping it*.	Clarifying scenario
41.	Student: Right.	
42.	Kendra: Oh.	
43.	Mr. S: *Does it make a difference if I toss it versus drop it*?	Pressing
44.	Students: Yes.	
45.	Mr. S: Hold on, hold on, hold on, if I-	
46.	Kendra: If you toss it, it has more force? And if you just drop it, it just goes straight ((gestures down)).	
47.	Mr. S: *So if I toss it, then it won't go the same way as if I just drop it*?	Confirming
48.	Kendra: Yes.	
49.	Mr. S: Okay, okay. Teresa?	
50.	Teresa: Some people have bad aim, so they can't even aim towards the trash can. ((laughter))	
51.	Student: Teresa!	
52.	Mr. S: *So some people don't play basketball very well, to use, uh, Kendra's analogy, so they-*	Returning to idea later
53.	Teresa: And then they don't feel like picking it up.	
54.	Mr. S: = *They might need to be guided to the location, is that what you mean*?	Confirming, inserting
55.	Teresa: Like, they just toss it, and they miss. They don't want to pick it up, so it still ends up on the ground.	
56.	Mr. S: Okay, so, so, hold on, hold on, so Kendra- not Kendra, so Teresa- again, everybody on the outside is in listen-only mode. *So Teresa, you said some people have bad aim, so those people who have bad aim, should they drop it before they get to the container, or above, or after*?	Maintaining, pressing

57.	Chavez: Above.	
58.	Teresa: They should- above. They know they're a bad player.	
59.	Student: Teresa!	
60.	Teresa: That they're a bad player.	
61.	Mr. S: *That they have bad aim*. Okay. So now let's, we want to get back to – why, why above? *Cooper, you had some explanation why, what's the reason for it*?	Maintaining, returning to idea later
62.	Cooper: Because the gravity, like, because of its weight, the gravity will push it down, it'll like fall directly in.	
63.	Mr. S: *It will fall directly in*? ((Cooper nods)) So, okay. Um, is there any other reason why it will- why we should drop it above? Um, you had your hand up, Chavez.	Confirming
64.	Chavez: I did, oh – you should do it above because if you, um, like, um, if you toss it in, um, it's like less chance that it'll go in, sometimes even if you're a basketball player, because you could miss.	
65.	Mr. S: *So in other words, if I, if I just let it go right above, it's more-*	Maintaining
66.	Chavez: You're more accurate, like, it'll go in. But if you toss it, even if you're a good basketball player, you could still miss.	
67.	Mr. S: *Why would a toss make it more likely to go in as opposed to me just dropping it*?	Pressing
68.	Chavez: Because it, if you, if you drop it in, like, it just goes in, but if you toss it, sometimes you'll miss, just like, um, Teresa said?	
69.	Teresa: And some people are too lazy to pick it up.	
70.	Mr. S: Okay, so *have you ever seen anybody go by a container and just leave their trash there or something they didn't want*?	Pressing
71.	Students: Yes.	
72.	Mr. S: Okay, hold on, hold on, hold on, hold on, hold on. So, so, now, again, again, we're, we're, we're in listen-only mode on the outside of the circ- the pool, and we're in one-at-a-time mode in the inside. Okay, so, um, are there any other reasons why I should drop it above the container*, other than Cooper said, the gravity's gonna pull it down*. Why else might I drop it	Returning to idea later

	above the container? Are there any other reasons why I should drop it above the container as opposed to before or after? ((Teresa raises hand)) Teresa?	
73.	Teresa: Because that's good world – save, you're like saving the world? ((laughter)) Like if you leave it on the ground like that, and you like put it before or after, you leave it on the ground, then you're like, what are you doing to the world? You're, yeah, washing your hands of it.	
74.	Mr. S: *So, so, so what you're saying, Teresa, is that- what you're saying, Teresa, is that the, the* (pause) ((looks up)) *that there's a stronger likelihood if I don't drop it above the container, it's gonna fall on the ground, right*? ((Teresa nods)) *So what is, what, what's giving that* ((Drake raises hand)) *strong*- we'll get to you in a moment, Drake. *Why is it strongly likely that it's gonna fall outside the container if I don't drop it above*? (pause) *What's making you more certain of it, of it falling out of the container if I don't drop here* ((holds keys above)), *as opposed to here* ((holds keys before)) *or there* ((holds keys after))?	Revoicing, confirming, pressing
75.	Teresa: Because I'm thinking before and after, it's just gonna fall on the ground anyway. I'm just thinking-	
76.	Mr. S: *But what, what, why, why will it fall on the ground if I drop it before or after*?	Pressing
77.	Kendra: It has no force.	
78.	Mr. S: *Because what*?	Attempting to hear
79.	Kendra: It has no force.	
80.	Mr. S: *What do you mean, it has no force*?	Pressing
81.	Kendra: Like, you'll be dropping it, so like the gravity would just push it down.	
82.	Mr. S: *So when I'm walking by it* ((mimics walking)), *kind of quick but not too quick, you're saying it's just gonna fall in there*?	Confirming
83.	Kendra: It's gonna fall on the ground, right in the trash can.	
84.	Mr. S: *If I don't drop it above, it's gonna fall right in the trash can? If I, if I drop- if I'm walking by the trash can, and I just let it go before, it's gonna, it's not gonna go in the trash can*? ((Kendra nods)) Okay, okay, Drake,	Confirming

	you wanted to say something?	
85.	Drake: I have two things. The first thing was it might, the second thing was why don't we just stop and then put it in and walk away?	
86.	Mr. S: *Because I'm in a hurry. I don't like stopping at trash cans. I'm, I'm, I'm in a hurry so I'm, I'm really- I'm trying to go to my meeting, I'm trying to go to my class, and I just want to toss it in there and keep going*.	Clarifying scenario
87.	Drake: Why can't-	
88.	Student: Throw it away at the meeting!	
89.	Drake: Why can't you just keep it in your pocket and then throw it away the next day, or keep it home and then ().	
90.	Mr. S: *Okay, okay, so, so – so let's say, let's say I'm a- let's say I'm somebody who's working. All my job is to pick up trash with a trash picker-upper and drop it in the trash can, all day long. So I don't want to stop at each trash can I want to put it in. So I'm picking up trash- you ever see people pick up trash for a living*?	Clarifying scenario
91.	Drake: Yeah, you mean those people who have that thing and they go like this ((mimics using trash picker-upper)).	
92.	Mr. S: *Exactly, so let's say I'm doing that all day, so I'm going by the trash can all day long, picking up, dropping off, keep going. I don't want to stop. So you're saying I should drop it above, right*? ((Evan and Cooper raise hands))	Clarifying scenario, returning to idea later
93.	Drake: Right. Can we try an experiment?	
94.	Mr. S: Well not ((holds hand toward Drake)), maybe not, maybe-	
95.	Drake: We could walk toward the trash can with something and throw it away.	
96.	Mr. S: *What will that, what will that show us*?	Pressing
97.	Drake: If I'm right or not?	
98.	Kendra: Oh, ((raises hand)) I know what it can show.	
99.	Mr. S: Okay, yes?	
100.	Kendra: It could show that when you drop something, like, the gravity pushes it down.	
101.	Mr. S: Okay, speak louder so everybody can hear it. *So, so Drake said maybe we should try to take the keys and do what now, Drake*?	Maintaining
102.	Drake: Uh, walk past it kind of fast and then –	

	test if it'll go-	
103.	Mr. S: Hold hold hold, hold on. On the outside, everybody, including Oliver, we are in the listen-only mode. Okay? Um, and inside, we're one at a time.	
104.	Teresa: I have a question.	
105.	Mr. S: Uh, just hold on, just hold on. Uh, *Drake, what did you say now*?	Attempting to hear
106.	Drake: If we, like, somebody walks past it kinda fast and then lets go before, above it, and after it to see which one will work?	
107.	Mr. S: Okay.	
108.	Kendra: Like a trial.	
109.	Mr. S: Okay, so, what, um, so this is a question I want you to think about. Um, does it – does it matter the weight of the container- I mean the weight of the, the weight of the, the keys?	
110.	Students: Yes.	
111.	Mr. S: Let's say the keys were made out of, out of plastic or paper. ((Evan raises hand))	
112.	Drake: You would, you'd have to do it harder.	
113.	Mr. S: Um, what, would I- um, Evan?	
114.	Evan: If it was made out of paper, it would float over the container and just go outside.	
115.	Drake: It would fall slowly.	
116.	Mr. S: *So if they were paper, if the keys were made of, um-*	Maintaining
117.	Kendra: Is it windy outside?	
118.	Mr. S: *Oh, so we're throwing in other variables. Windy, how would the-* okay, so now, if the, if the keys are light, let's say they're wooden keys, okay? Um, Evan- um, um, please sit correctly ((to Tim)).	Inserting, maintaining
119.	Tim: He stole my pencil, so I took it back.	
120.	Mr. S: Um, Tim, sit correctly please. So Evan, so if I'm (pause) if, if I'm, if the keys are light, and I drop them, uh, I still would need to drop them above the container?	
121.	Evan: No because it would fall outside, since you're moving?	
122.	Mr. S: So where, where should I drop them if the keys are light?	
123.	Evan: Before.	
124.	Drake: = After.	
125.	Mr. S: *Before, why before, why, why should I drop them before when the keys are light*?	Maintaining, pressing

126.	Evan: Because you're moving.	
127.	Drake: ((waving hand)) No, no, no, no.	
128.	Mr. S: *What difference does it make, Evan*? ((timer goes off, Mr. S silences))	Pressing
129.	Student: Done.	
130.	Terell: Thank you!	
131.	Student: Next people!	
132.	Mr. S: Hold on, hold on. Teresa, Teresa, now we're- thank you. Hi, Mr. M. So Teresa, now, so, so, Teresa hold on, hold on, we're, Mr. S's gonna let you all know when you're done. *Evan, so why, Evan, would I drop them before if they're lighter? What, what difference does it make? Why, why would I need to drop them before*?	Pressing
133.	Evan: Because of the force of the movement.	
134.	Drake: No ((waving hand)), I have-	
135.	Mr. S: *What force*? Hold on, hold on, um, we're, we're, we're speaking one at a time. Terell and Drake, we're listening.	Pressing
136.	Evan: Gravity?	
137.	Drake: ((waving hand)) I have ().	
138.	Mr. S: *Gravity, what about gravity*?	Maintaining, pressing
139.	Drake: ((groans, hitting head)) I disagree a lot.	
140.	Mr. S: Just wait for him to speak then.	
141.	Drake: Okay.	
142.	Mr. S: Um, *Evan, what do you say about gravity*?	Pressing
143.	Evan: ((shrugs)) I don't know.	
144.	Mr. S: *What, what effect does gravity have on it, on me doing it before if, if the keys are lighter*?	Pressing
145.	Tim: Oh my God.	
146.	Evan: It'll allow it to move in front and- in front of the trash can.	
147.	Mr. S: *Gravity's gonna move it in front of the trash can? How does it do that? How does it do that*?	Maintaining, pressing
148.	Drake: It's not making sense here ((waving hand, Tim raises hand)).	
149.	Mr. S: Oh no, well, let's not say who's making sense and who's not making sense. Let's just try to put your, your, your view and then we'll see what comes of it.	
150.	Drake: This is gonna take less than a minute, what I'm going to say.	

151.	Mr. S: Okay, hold on, hold on-	
152.	Drake: You don't do it before.	
153.	Mr. S: Hold on, uh-	
154.	Drake: The wooden keys-	
155.	Mr. S: Hold on, hold on, we're waiting for Teresa and whoever else is talking to, to be quiet. Okay, go ahead, Drake, and then ((gestures to Tim)).	
156.	Drake: Okay, they're wooden keys, so you're walking, and then, like, when you walk, the air blows past you? So, like, the air don't, when you're walking, blow behind you. That's why you don't do it before. So you do it after, then it'll go in.	
157.	Mr. S: *So, so what is it, what is it about this air? They're wooden keys-*	Pressing, maintaining
158.	Drake: Because like they're lighter, so you're like walking kind of fast, so like- you know when you like run and stuff, the wind blows past you?	
159.	Mr. S: *The wind*.	Maintaining
160.	Drake: Not really the wind, like the air is moving past you. So, like, it's moving past the keys too. So when you let go, like, it stops though and then it like pushes them back a little. And then-	
161.	Mr. S: *So, so the wind pushes the keys back if they're wooden*?	Confirming
162.	Drake: Kind of, yeah, more.	
163.	Mr. S: *As opposed to metal*?	Confirming, inserting
164.	Drake: Yeah because the metal's heavier.	
165.	Mr. S: *So if the, if the wind is pushing the keys back against the – pushing against the keys, so shouldn't I drop it after, or before, or-*	Maintaining, pressing
166.	Drake: After.	
167.	Kendra: Yeah, yeah, after.	
168.	Mr. S: *I should drop it after*? ((Drake nods)) *Because the wind's gonna push it back*?	Confirming
169.	Kendra: Because if the trash can's right here, and then you're walking, the wind is going this way ((gestures against the direction of walking)) or whatever way, because you have to drop it after so it can go backwards.	
170.	Mr. S: *So, so I've heard people talk about gravity, um, someone- now we're into wind*, what other factor is it? The weight would have	Returning to idea later

	an effect?	
171.	Kendra: Velocity.	
172.	Tim: ((raises hand)) I have a question.	
173.	Mr. S: *Veloci*- yes, Tim?	Maintaining
174.	Tim: So like, are you walking right by the trash can, or are you walking, stopping, and then-	
175.	Mr. S: *I'm walking right by the trash can*.	Clarifying scenario
176.	Tim: Oh. Then you do it before.	
177.	Mr. S: *I do it before. What, now, why before*?	Maintaining, pressing
178.	Tim: Because, if you drop it, like, and you're walking and you just drop it right above, it's gonna fall over because – it's like (pause)-	
179.	Mr. S: Oliver, and Cooper.	
180.	Tim: If you drop, if you drop it right above and you're walking ((Mr. S holds finger to lips))-	
181.	Oliver: We're talking about it, because they-	
182.	Student: We have a question.	
183.	Oliver: We have a question.	
184.	Mr. S: Just hold, just hold your question.	
185.	Terell: I have something to say!	
186.	Mr. S: Go ahead, Tim. What did you say now?	
187.	Tim: I said you would drop it before because you're walking right past it.	
188.	Mr. S: *If you're walking past it, you would drop it before, so, so Tim said, Tim's changed his, his thinking on it because now he sees that the- that he has a better understanding of the, of the scenario. So since we're going past the trash can, Tim, you're saying as opposed to earlier*- Alan, we're listening- *Tim is saying that we'll drop the keys before we get to the trash can, and why, why before the trash can now*? And Alan, we're listening now.	Maintaining, inserting, pressing
189.	Tim: So that it could drop right in because if you're walking right past it and you drop it above, it's gonna fall behind it.	
190.	Terell: Thank you!	
191.	Mr. S: *What would cause it to fall behind as opposed to in it? What would cause it to do that*?	Pressing
192.	Chavez: (pause) Wind?	
193.	Tim: (pause) Air?	
194.	Mr. S: *The wind, the air*?	Maintaining
195.	Tim: Yeah.	
196.	Mr. S: *So air's just gonna move it back*.	Maintaining

197.	Drake: Well you're walking kind of fast-	
198.	Mr. S: *So there's some force in the air that's just gonna move the keys back*.	Maintaining, inserting
199.	Kendra: Wouldn't it move it backwards if he's walking?	
200.	Mr. S: *Or move it forward*? ((Terell pumps hand))	Confirming
201.	Tim: Yeah, it's like, it's like-	
202.	Mr. S: Hold on, hold on, Terell. Yes?	
203.	Tim: Like, if somebody goes hunting and they're shooting a deer, and the deer's running fast, you have to shoot before so that it hits-	
204.	Mr. S: *So but we're not talking about running now, we're just talking about walking fast, not running, but walking fast*.	Clarifying scenario
205.	Tim: Well still, yeah.	
206.	Drake: The trash can's not moving.	
207.	Tim: But you are!	
208.	Mr. S: Okay, so, so what ((Terell pumps hand)), so Tim, hold on, hold on Terell, *so Tim, you, you're telling Drake that the fact that we're, that I'm moving or that you're moving towards the trash can means we have to drop it before*?	Confirming
209.	Chavez: Yeah.	
210.	Mr. S: Why, Chavez?	
211.	Chavez: Because, because if you run, and-	
212.	Mr. S: *Now, we're walking now, we're not running*.	Clarifying scenario
213.	Chavez: (pause) Oh never mind, I thought you were running, that's why.	
214.	Mr. S: But we're walking fast, what do we have to do?	
215.	Chavez: You have to drop it, you have to drop it before because, um, if you drop it directly, like, like, for instance, this is the trash can, and you're walking, and you're walking fast, and you drop it like this ((mimics releasing after)), like, um, like it might fly out somewhere else because you're like walking, but if you, but if you do it before, you go like, you're walking and then you go like that ((mimics releasing before)), it might like go directly in, or sometimes it might just come out.	
216.	Mr. S: *What, what, so you're saying you have to do it before, so why, why before? What's the*	Maintaining, pressing

	causal reason? What causes us to have to do it before?	
217.	Chavez: It'll go directly in if you do it-	
218.	Mr. S: Um, again, hold on, Chavez, hold on. Um, we're waiting on Chavez to have the floor, uh, not Jose and not anybody else who's talking. Um, hold on. Chavez?	
219.	Chavez: Because if you do it before, it'll go directly in? But if you do it like, like-	
220.	Mr. S: *Why do we have to do it before again*?	Pressing
221.	Chavez: Because it'll go, like, IN, like the keys will go in the trash can or the thing will go in the trash can.	
222.	Mr. S: *What will cause it to go in the trash can if we drop it before as opposed to over, because earlier you said over*?	Pressing, returning to idea later
223.	Chavez: Like, like, like, like, like the speed of the keys also I guess coming off.	
224.	Mr. S: *The speed of the- so the keys have speed*?	Maintaining, pressing
225.	Chavez: Because you're walking, no, because like you're walking? (pause) And like, and like since you're walking fast, like, I guess the keys will also go fast too?	
226.	Mr. S: *The keys will go fast too*? Teresa, are we listening?	Confirming
227.	Teresa: Yes.	
228.	Mr. S: *The keys will go fast too*?	Confirming
229.	Chavez: (pause) Yeah.	
230.	Mr. S: *Why will the keys go fast too*?	Pressing
231.	Chavez: I don't know!	
232.	Mr. S: *I released the keys, wouldn't the keys just be there*?	Countering
233.	Kendra: Are they wooden or metal?	
234.	Mr. S: *Let's say they're metal, wooden, or plastic. Does it matter*?	Clarifying scenario, pressing
235.	Drake: Yes, it very much does.	
236.	Mr. S: *Why does it matter*?	Pressing
237.	Drake: Because the lighter things-	
238.	Kendra: The lighter things are, the easier they are to move. Like, if you have, like metal, it's gonna be heavy, but if you have like plastic or something, it'll be lighter?	
239.	Mr. S: Okay, okay. Now, this is what I want to do. Um, we're talked quite a bit in the inner circle ((Terell pumps hand)), now I want to	

open up to questions on the outer circle.	
Note. Italicized sections of transcript reflect responsive utterances.	

As the class period continued, Mr. S opened the discussion to the outer circle students. He then rotated another group of students into the inner circle to discuss the matter of speed more directly. In a teacher meeting shortly following the episode, Mr. S indicated that he and Ayush had decided on these questions ahead of time:

> The two questions we were- Ayush and I agreed I would ask would be, um, where should you drop the keys, before, over, or after the, the, the, the container?... The second question that we agreed I would ask would be, um, what about if I was running? What about if I was in a car? What about if I was on a speed- a fast-speed train? [Meeting, March 2011]

This discussion about speed turned into a discussion of what they would do if they were dropping supplies from an airplane to a village below. Students were still debating whether you would need to drop the supplies below you reached the village or after you passed the village at the end of the class period, and Mr. S asked them to more clearly flesh out their reasoning in preparation for continuing discussion the following week.

Justifying Inclusion

The above episode met the criteria for inclusion in my dissertation. First, of Mr. S's 106 speech turns in the video, 78 contained responsive utterances. This represents a percentage of 73.6%, meaning the majority of Mr. S's utterances during the episode were responsive to students' ideas. Second, Mr. S's focus on the discussion was resilient in the face of perturbations, such as students questioning the validity of the scenario under discussion (e.g., lines 2, 85) and Drake's bid to test it out (line 93), and demonstrated resistance in the form of inquiry Monday, as described previously. Third, Mr. S reflected on this discussion during two teacher meetings in March of 2011.

I also selected this episode as a natural point of comparison with the first episode from Mr. S's classroom, in which he asked students to grapple with the same key drop question. Previous discussions in our research group had highlighted this pair of episodes and distinctions in the kinds of explanations Mr. S was looking for in each.

Plausible Parts of the Coherence(s)

The third episode contained many elements that appeared in previous episodes. I briefly review those before turning to the new aspect evident in this episode.

The following elements played a similar role in this episode as in other episodes:

- The structural supports of "inquiry Monday" and the fishbowl discussion structure: These structures stayed essentially the same between the second and third episodes from Mr. S's classroom, with their concomitant affordances and limitations.
- Use of a common representation to facilitate communication: At times in the discussion above, Mr. S and students oriented to local representations that they

created. For instance, in line 27, Tim indicated that if you drop the keys before or after the container, they won't land in the container. Mr. S probed where he thought the keys would land if he dropped them before (lines 28, 32) and created a physical representation on the table, allowing Tim to point to the location he thought the keys would fall for clarification. Similar to the representation on the board in the first episode from Mr. S's classroom, discussion around this local representation facilitated Mr. S's understanding of Tim's thinking that the keys "would drop in front of the container" [line 32] if released before. Later in the episode (line 215), another student, Chavez, also created a physical representation on the table to aid himself in articulating his idea.

- Participation of students who did not typically participate: In an interview about the third episode, Mr. S identified Drake (one of the most active participants in the discussion) as someone who did not always participate:

> I think part of the reason why he wasn't very motivated was that he just wasn't being challenged. That kid would just sit back and observe, and the kind of analysis he was doing, I was like completely bowled over [Interview, October 2012].

There are similarities between Mr. S's description of Drake in the third episode and his description of Nat in the first episode. With both students, Mr. S noted their unusual level of participation in the discussion and was impressed with the sophistication of their ideas, indicating that they weren't being challenged by other approaches.

There was also a new plausible aspect for Mr. S in the third episode from his classroom – pressing students to articulate numerous causal stories for their conclusions. I devote the remainder of my analysis to this.

Pressing Students to Articulate Numerous Causal Stories for Their Conclusions

In discussion about the key drop question, it was important to Mr. S for students to not only say what they thought would happen, but to flesh out a causal story for how they thought it would happen. He acknowledged in an interview that he was operating under the 3C paradigm (causality, clarity, and coherence) introduced in the first summer workshop[38]:

> [The] paradigm that I'm going, that I'm basing it on, is do you have a causal story? I'm not always calling, calling, calling it that, but I'm trying to get at a causal story. I'm trying to get at is it coherent. I'm trying to get at is it clear. Okay, the things that we were taught in the workshops, right? That's what I'm trying to get at that, but I don't always say what's your causal story? But I will say, well, can you explain it, can you give a little more detail? [Interview, October 2012]

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[38] See Chapter 3 for more information about project activities.

Mr. S indicated that he was trying to get at students' causal stories for what they thought was happening, while not always using that explicit language. He further explicated what this looked like for the key drop question specifically:

> Mr. S: I was basically trying to get them to, to, to, to weigh in all the potential factors and also to, um, to come up with some kind of causal story as to how and where the, the item should be dropped. What are those factors, and uh, trying to get them to think more deeply about the movement of the, of the keys as related to the container.
>
> Jen: Okay, so like the factors are part of an explanation-
>
> Mr. S: Right.
>
> Jen: And the causal story is relating the factors to –
>
> Mr. S: The causal story, the causal story would, would utilize those various factors in its explanation as to how, how the keys would fall [Interview, October 2012].

Here, causal stories incorporated the causal factors that Mr. S focused on in the first episode but included more explanation[39]. A closer look at an emergent debate between Mr. S and Ms. R during a teacher meeting prior to the third episode suggests that, for Mr. S, causal stories also involve a sense of mechanism (a point emphasized in the second summer workshop). At the meeting, teachers were looking at student work about sinking and floating, and Mr. S questioned why Ms. R considered "causal story" and "mechanism" to be distinct:

> Mr. S: So the, so [the student] is saying that it's sinking because water's going through the holes, that's not a causal story?
>
> Ms. R: That's her, I took it as that's her mechanism of what the holes are doing.
>
> Mr. S: So, but how is it not a causal story? It's an explanation of how it takes place, how it floats, how it sinks, right? [Meeting, November 2010]

Later in the meeting, Ms. R gave a clearer sense of what she meant by "mechanism," and Mr. S again related this to his sense of "causal story":

> Ms. R: Mechanism is how is it working, what's causing it to, like the bicycle moving.

---

[39] Note, though, that Mr. S does not always distinguish causal factors and causal stories, as discussed in Chapter 5.

> Mr. S: See, what I think is that your, from what you just said, mechanism is what we've been talking about as a causal story [Meeting, November 2010].

For Mr. S, then, a causal story often goes deeper than the explanatory structure he used during the first episode and emphasizes *how* a given process occurs.

Moreover, Mr. S also indicated at a teacher meeting shortly after the third episode and in interviews that there are often subtle differences in students' causal stories. During a teacher meeting, Mr. S described what commonly happened if a student thought he agreed with another student but was asked to state it in his own words:

> And sure enough, they would start talking, and they would have a different causal story, similar but not identical, you know? And so that's the other thing that I'm trying to get the kids to see, that even though you may agree on what's gonna happen, your explanation or your causal story may be very different or may have a slight tweak or slight change in… meaning [Meeting, March 2011].

Recognition of such distinctions often resulted in debate among the students, which Mr. S felt led to "the best discussions" [Interview, September 2012]. He also saw truly understanding another's perspective and its similarities to and differences from yours as the essence of intellectual conversation, as evidenced in an interview:

> So the more I get, the more I can unpack, uh, their thinking, even though they may agree on a resolution, the more I can unpack kids thinking, the more I could, I could elicit other students to share, and then they begin to see, oh, I thought I agreed with that person, but now I realize I really didn't because when I get to the point of asking why, or the reason for it, their, their, uh, their conclusion, then I see we, we came to the same conclusion, but we, we reached it, we have a totally different reason as to why we believe that. And that, that to me is the, is the kind of like the, um – the beauty of intellectual discourse. That, that, um, we can agree but have totally different reasons why we agree [Interview, September 2012].

So how did Mr. S's focus on eliciting multiple causal stories play out during the selected episode and intersect with his attention and responsiveness to student thinking? First, although Mr. S pursued various kinds of reasons students offered at the beginning of the episode, such as how bad aim played into Teresa's understanding of what would happen (lines 50-61), he repeatedly returned to an idea Cooper offered early in the conversation as the kind of explanation he was after:

> Cooper: Um, above?
>
> Mr. S: Above.
>
> Cooper: Because like the gravity, like, when you put it up, it goes down [lines 6-8].

Later, Mr. S asked Cooper to repeat his idea by stating, "So now let's, we want to get back to – why, why above?" [line 61], suggesting that ideas like Teresa's were not quite in line with what he was looking for. He then made a more direct bid for students to provide reasons like Cooper's: "Are there any other reasons why I should drop it above the container, other than Cooper said, the gravity's gonna pull it down. Why else might I drop it above the container?" [line 72]. Thus, Mr. S's interest in eliciting numerous causal stories from students repeatedly drew his attention to Cooper's idea as an instantiation of the kind of explanation he was looking for and kept the discussion going as he sought additional causal stories from students.

Additionally, as students started offering more in the way of causal stories after Mr. S brought up the weight of the keys in line 109, Mr. S in turn pressed students for more details with respect to their ideas. This was most clear in Mr. S's lengthy exchange with Chavez, who suggested that the speed of the person carrying the keys would move the keys forward:

> Mr. S: What will cause it to go in the trash can if we drop it before as opposed to over, because earlier you said over?
>
> Chavez: Like, like, like, like, like the speed of the keys also I guess coming off.
>
> Mr. S: The speed of the- so the keys have speed?
>
> Chavez: Because you're walking, no, because like you're walking? (pause) And like, and like since you're walking fast, like, I guess the keys will also go fast too?
>
> Mr. S: The keys will go fast too?...
>
> Chavez: (pause) Yeah.
>
> Mr. S: Why will the keys go fast too?
>
> Chavez: I don't know!
>
> Mr. S: I released the keys, wouldn't the keys just be there? [lines 222-232]

In this exchange, Mr. S acknowledged Chavez's idea about the speed of the keys and followed up with questions that evidenced his close attention to what Chavez was saying, pressing Chavez to continue filling out his story. Mr. S's foregrounding of causal stories at this point in the conversation likely reinforced his attention and responsiveness to the causal stories students were offering.

Summary

In sum, several elements evident in the third episode from Mr. S's classroom carried over from earlier episodes, including the structures of inquiry Monday and the fishbowl, use of common representations to clarify students' ideas, and participation of a student who did not typically participate in class. Additionally, Mr. S's focus on eliciting

numerous causal stories from students sustained his attention to an idea most in line with this kind of explanation early in the episode and his continued pressing for and on students' causal stories throughout the episode.

Synthesizing Across Episodes

Looking across the three episodes from Mr. S's classroom, several commonalities are apparent. One commonality is the strong role that preplanning seems to play in Mr. S's inquiry discussions. In each episode, the opening question and often follow-up questions were brainstormed ahead of time, as were the structures that Mr. S used for facilitation – taking notes on the board in the first episode, and setting up the structures of inquiry Monday and the fishbowl discussion in the second and third episodes. Moreover, many of these plans were brainstormed in collaboration with other colleagues on the project. For instance, Mr. S commonly cited conversations with Ayush as integral to the planning process, and the fishbowl discussion structure was in part borne out of conversation with Ms. R about how she used it in her classroom.

Another commonality is the extent to which Mr. S attended to *who* was speaking in inquiry discussions, in light of students' previous participation in class. In the first episode, Mr. S noted several students who participated in new ways relative to how they had participated before, and Nat's participation in particular remained salient for Mr. S years after the fact. Similarly, Mr. S commented on Drake's participation in the third episode as atypical for Drake. Noticing who is talking does not necessarily stabilize attention and responsiveness to the *substance* of what students are saying, but Mr. S felt that part of what supported such students' increased participation was their sense that their ideas were respected and valued in inquiry discussions. Thus, he promoted their participation by closely attending and responding to what they were saying, potentially reinforcing their participation, and so on.

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