ABSTRACT

Title of Document:	UNDERSTANDING THE DYNAMICS OF TEACHER ATTENTION: CASE STUDIES OF HOW HIGH SCHOOL PHYSICS AND PHYSICAL SCIENCE TEACHERS ATTEND TO STUDENT IDEAS
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Attending to student ideas is critical for supporting students' science learning (Driver, Guesne, & Tiberghien, 1985; National Research Council, 1996). But, paying attention to student ideas in science class is difficult and does not happen often (Davis, 2001; Feldman, 2002; Levin, 2008; Levitt, 2001; Simmons, et al, 1999). Researchers have looked at how institutional expectations, curricular materials, and a teacher's cognition influence how that teacher picks up on and makes sense of student ideas (Ainley & Luntley, 2007; Levin, 2008; Rop, 2002; Tabak & Reiser, 1999; Wallach & Even, 2005). I argue that we do not yet have adequate ways of characterizing and understanding teachers' attention at the level of the interaction. I have evidence that suggests that when we look in such a fine-grained way, many of our current explanations for what teachers do and pay attention to are not sufficient.

The aim of this dissertation is to build on the burgeoning body of work on teacher attention by looking at how to characterize a teacher's attention as that teacher interacts with students in the classroom and studying how a teacher's attention is situated in the teacher's framing of his or her interaction with students. In short, a person's frame or framing of the situation is his or her definition of what is going on in the interaction (Tannen, 1993). I discuss the implications for how we can support teachers' attention to student ideas and some areas for future research motivated by the findings of this study.

UNDERSTANDING THE DYNAMICS OF TEACHER ATTENTION: EXAMPLES OF HOW HIGH SCHOOL PHYSICS AND PHYSICAL SCIENCE TEACHERS ATTEND TO STUDENT IDEAS

By

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Dedication

This dissertation is dedicated to Sui Yun Ho Lo (1924-2007).

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Overview of the Chapters

Chapter One

This chapter provides a review of some of the literature relevant to this study, namely literature on teacher attention and on teacher cognition. I use an episode from a pilot study showing a student teacher interacting with her students during a science lesson to motivate the discussion of the literature. I argue that we need to develop a way to understand how a teacher's attention is organized during those interactions with students.

Chapter Two

In this study, I explore how a teacher's framing of an interaction helps to organize the teacher's attention. In Chapter Two, I articulate my conceptualization of attention to student ideas and framing. Also in this chapter, I present the context for my research and the data for this study. I also describe the three teachers who form the three cases in this study.

Chapter Three

This is the first chapter in this dissertation that looks closely at teachers' attention to student ideas. I present the coding scheme for identifying when a teacher's attention is directed toward student thinking. The coding scheme is used to look at episodes from each teacher in this study that shows evidence of attention to student ideas.

Chapter Four

This chapter and Chapter Three should be considered a pair that explores how we can identify the direction of a teacher's attention and how it relates to student ideas. In this chapter, I present the coding scheme for identifying when a teacher's attention is directed away from student ideas. This coding scheme is used to look at episodes from each teacher in this study that shows evidence of the teacher's attention being directed away from student thinking.

Chapter Five

In Chapter Five, I present evidence of how each teacher framed their conversations with students in the episodes from Chapters Three and Four. Also in this chapter, I discuss how the teacher's framing of his or her interaction with students helped organize the teacher's attention in that episode.

Chapter Six

This chapter concludes the dissertation. I argue that this study challenges some of the current common conceptions of teacher cognition. I also talk about how a teacher's attention and a teacher's framing exert mutual influence on each other-when one shifts, so might the other. Lastly, I end with a discussion of the implications from this study for how we can support teachers' attention to student thinking.

Chapter 1: Literature Relevant to the Study of Teacher Attention

We need to make sense of teacher attention to student ideas

Constructivist views of learning support the claim that student ideas need to play a prominent role in science classes if students are to develop a deep understanding of science (Driver, Guesne, & Tiberghien, 1985). In classrooms that encourage learning, teachers create space for students to engage in authentic discussions about those ideas (Deneroff, Sandoval, & Franke, 2002; Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999; Hufferd-Ackles, Fuson, & Sherin, 2004; Tabak & Baumgarten, 2007). As students interact and examine their ideas with others in intellectually honest ways, they deepen their comprehension of how particular concepts do or do not fit together in science. Though opening up one's classroom to students' ideas is the critical first step, teachers will need to go beyond that to support student learning. The National Research Council (1996) calls on teachers to "display and demand respect for the diverse ideas, skills and experiences of all students," by "(f)ocusing on student understanding and use of scientific knowledge, ideas, and inquiry process skills". Teachers also will need to pay close attention to and make sense of what their students say, do, and think.

Teacher-researchers, in both science and other subjects, have documented the impact of focusing instructional attention on students' ideas. Students not only understand the concepts they study, they also develop eloquence, become passionate about their inquiries, and begin to think and act like scientists, or mathematicians, or historians (Ball, 1993; Chazan & Schnepp, 2002; Doris, 1991; Gallas, 1995; Lampert, 1990; Paley, 1986; vanSledright, 2002; vanZee & Minstrell, 1997). Additionally, researchers have documented conceptual learning gains when teachers attend to how their students are thinking as students interact with the learning material (Carpenter, Fennema, Peterson, & Loef, 1989; Linn, Lewis, Tsuchida, & Songer, 2000; Porter & Brophy, 1988).

Although attending to students' ideas is important for student learning, many teachers still do not attend to student ideas in their classrooms. This is true in spite of the way the teachers are prepared (Simmons et al, 1999), the professional development teachers experience (Levitt, 2001), or the kind of curriculum teachers use (Davis, 2001; Feldman, 2002).

One reason for this may be how difficult it can be to take student ideas about content seriously in the classroom (Doris, 1991; Gallas, 1995; Hammer, 1997; Paley, 1986). When students talk about their ideas, there is a tendency for lots of ideas to bubble out and for students to go down many different intellectual paths chasing after them. This can challenge the teacher's sense of control (Paley, 1986). There is an uncomfortable tension when students explore wrong ideas for fear of students developing deep-seated incorrect conceptions (Ball, 1993; Hammer, 1995). Also, what students may want to understand may not align with curricular goals (Rop, 2002).

Teacher educators have started to help teachers attend to and make sense of their students' ideas. There are a variety of ways to accomplish this. Experienced teachers can help mentor newer teacher in how to analyze student work or classroom situations (Athanases & Achinstein, 2003; Erickson & MacKinnon, 1991). Alternately, teacher educators can engage teachers in analysis of records of practice, such as videos of classroom activities or student work, to help teachers reflect on how students were thinking and learning during the lesson activities (Ball & Cohen, 1999). With changes in video technology, access to video records of classroom activities has been made easier. As a result, video records have gained popularity in professional development activities to help teachers learn to notice student ideas.

It is important to attend to student ideas. It is also important to help teachers learn how to do that. As teacher educators, we need to understand that attention in order to support it. And, as researchers, we need to develop ways to characterize and understand teachers' attention to student ideas that acknowledge the nuances and dynamic nature of attention. As will be seen in the following episode, describing teachers' attention may not be so straightforward. As a teacher interacts with students, the teacher's attention may, at one moment, be on one thing and at another moment be on something else. Understanding these shifts and stabilities has not been the focus of research thus far. This dissertation explores a framework for studying teacher attention that can account for the variability as well as steadiness in that attention.

Example of shifting attention: "What do you know about sound?"

Heidi, a student teacher in a mid-Atlantic third-grade classroom, planned to introduce the unit on sound with an informal discussion about some of their ideas on the topic. Her intention was to structure the conversation with a Know-Want to

Know-Learned (KWL) chart[1] (Ogle, 1986). Since science was only intermittently taught in this third-grade class, Heidi thought this kind of conversation would not only allow her access to what her students knew, it would also rekindle their enthusiasm for science early in the unit.

On the day of this lesson, at science time, Heidi brought her students to the floor in the front of the room for the conversation. Shortly after the discussion started, Heidi had the following exchange with her student, Marcus.

Heidi:	What do you know about sound?
Marcus:	Um, uh, that most of your sound is on the [top?] (points to the top of his head).
Heidi:	What do you mean by that, most of your sound?
Marcus:	Like it uh, like if you [can't?] hear anything more in your ear then the sounds can (points to the top of his head) go through your, the top of your head.
Heidi:	(3-second pause) I didn't know that. Alright, (turns to the chart paper) I'll write it down. (moves closer to the chart paper)
Marcus:	I learned it from the doctor.
Heidi:	Goes through the top of your head? (points to the top of her head) The sound?
Marcus:	yeah, and it vibrates [in there?] (moves his hand back and forth).
Heidi:	(with greater emphasis and louder volume) Vibrations, I love it! Vibration, OK. (Writes the word vibrations on the KWL chart)

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[1] In KWL charts, there are three columns, a Know, a Want to Know, and a Learned column. Students are asked to brainstorm what they know about a particular topic. Comments are then written up under the Know column. The purpose of this column is to allow students an opportunity to brainstorm their ideas about sound irrespective of correctness. Next, they are asked what they want to learn about and that is written under the Want to Know column. Lastly, after students have explored a particular topic, they fill out the Learned column with what they have learned as a result of their explorations. This was initially developed by Ogle as a strategy for teaching reading but has since been used by teachers in other subjects (Ogle, 1986).

Heidi's misunderstanding of the K-column seemed like an understandable mistake. Her mentor teacher also thought that recording incorrect information on the K-column was problematic. But the mentor teacher seemed to understand the purpose of filling out the K-column was to brainstorm ideas about sound. After this lesson, her mentor teacher told Heidi that she typically used a modified version of the chart: "What do you think you know?-What do you want to know?-What have you learned?" to circumvent the problem of writing down incorrect information in the K-column.

From her lesson plans, Heidi had intentions of opening discussion space for student ideas (for the full lesson plan, please see Appendix C):

> Excerpt 1:
> **Objectives:**
> The students will:
> 1. Share their ideas and questions about sound
> 2. Investigate and describe sounds produced by tuning forks

From her plans, Heidi seemed interested in finding out what her students knew about sound so she could tailor the upcoming work in the unit to fit her class.

> Excerpt 2:
> **Assessment:**
> My assessment will be a formative assessment based on informal observations. Since this is their first lesson on sound, I want to know how much the class already knows about sound, so I will use the KWL chart to see where I need to focus the unit. Also, I will use their answers to the tuning fork questions and their additions to the KWL chart to see how much they learned about sound in this lesson.

Though she wanted them to talk about their ideas, it was not wholly clear what she would do with them if they were incorrect ideas. It was likely that Heidi had not fully thought that out. In an interview after the lesson, Heidi said that she intended to write down, "Mm. Pretty much what they think they know. I mean, whatever they tell me about sound is what I was wanting to put up there" (Interview, February 3, 2005). During class, she behaved as if this was how she wanted to proceed. She tried to gain a clear sense of what Marcus meant ("What do you mean by that, most of your sound? ... Goes through the top of your head? (points to the top of her head) The sound?"). She told him she would write it down ("Alright, (turns to the chart paper) I'll write it down. (moves closer to the chart paper)") and even checked to make sure she understood what he said ("Goes through the top of your head? (points to the top of her head) The sound?").

But, after Marcus said the word vibrates, Heidi emphatically highlighted and wrote down something that was not Marcus' idea ("Vibrations, I love it! Vibration, OK. (Writes the word vibrations on the KWL chart)"). In an interview, she also acknowledged that what she wrote was not what her student said. In reflecting on this episode, she said, "But then because (laughs) some of what they were sayin' was kind of off the wall and…wasn't really true then, I didn't put it up there…'cause they don't, they don't know that" (Interview, February 3, 2005).

Though her interview statements implied that she had decided not to write down Marcus' incorrect idea when she heard it, it is likely that was a retrospective rationalization of how the events unfolded. As I said earlier, she likely had not thought about it in her planning. Also, it was not until the end of the interaction that Heidi wrote down something other than Marcus' idea, after he told her "it vibrates." Throughout the rest of the interaction, Heidi acted as if she would write down Marcus' seemingly incorrect idea.

How does one make sense of Heidi's attention to Marcus' idea in this episode? In this episode, she did pay attention to what Marcus meant in his statements about sound even though at the end she disregarded his idea. She asked him for clarification, indicated that she would write down what he said, and even repeated his statement almost verbatim to check that she had it right ("I didn't know that. Alright, (turns to the chart paper) I'll write it down. (moves closer to the chart paper)…Goes through the top of your head? (points to the top of her head) The sound?”). In fact, it almost seemed that Heidi was simply going to write down the ideas her students had about sound, whatever they told her, which required her attention to Marcus’ thoughts about sound coming in through the top of one’s head.

But, at the end, she seemed to disregard his idea. When she excitedly exclaimed the word vibrations and recorded it on the chart, she was not highlighting what Marcus meant but a vocabulary word from the sound unit. There, it seemed her attention was caught by the connection to their future lessons. To characterize this episode as an example of a teacher not attending to a student’s idea because she brushed it aside at the end would ignore most of what Heidi did in this interaction. But to say that this episode is an example of a teacher attending to a student’s idea ignores would ignore the fact that she brushed aside Marcus’ idea at the end.

A teacher’s attention is slippery and can change in the blink of an eye. It is hard for teachers to pay attention to student thinking because that attention can be so easily pulled away. It is also hard for researchers to understand that attention if it is liable to such quick changes.

Research on Teacher Attention to Student Ideas

There has been a research movement to study how and what teachers notice. Some of this work grows out of professional development calls to help teachers learn how to pay attention to student thinking. Here, researchers work with pre- or in-service teachers in learning environments to develop the teachers’ skills at noticing student ideas that are captured on video or in written work. With advances in technology, this kind of professional development work has become more common (Sherin & Han, 2004). This line of work is focused on three things: how teachers see classroom events; how teacher educators can help change the focus of teachers' attention to see classroom events differently; and how cognition affects that attention. More recent work has moved past the professional development setting to look at teacher attention in the classroom setting. Researchers here have found that factors in the context, in addition to teachers' cognition, can shape teachers' attention. The approach has largely been to look at classroom interactions between students and teachers at a fine-grained level to see how these factors influence the attention in the moment.

Teacher attention and professional development.

The data for this research is typically from a professional development project or teacher-preparation course. Much of this work has been in the field of mathematics education. In these projects, teachers gather with research staff to view transcribed video snippets of their students engaged in mathematics class activities. The purpose of these meetings is to provide a context for the group of teachers to collaborate on their reflection of events and not to study exemplary teaching or a particular pedagogical model. Teachers are simply encouraged to talk about what they notice so as to question, reflect on, and learn about teaching and learning.

Video has been more widely used to support teachers' professional learning because it is a rich record of classroom events that can provide many entry points for reflection (Ball & Cohen, 1999; Davies & Walker, 2005; Levin, Hammer, & Coffey, 2009; Nemirovsky, Dimatta, Ribeiro, & Lara-Meloy, 2005; Rosaen, Lundeberg, Looper, Fritzen, & Terpestra, 2008; Sherin & Han, 2004; Star & Strickland, 2008; van Es & Sherin, 2006). Some have argued that teachers' professional knowledge is rooted in particulars (Heibert, Gallimore, Stigler, 2002; Ziechner, Tabachnik, Densmore, 1987). Use of video data is one way to root exploration of teaching and learning issues in specific moments of classroom activity rather than on generalities and assumptions the teachers may hold.

Conversations such as these can also provide insight into how teachers see classroom events and what is salient to their work as teachers (Herbst & Chazan, 2003; Nemirovsky, Dimatta, Ribeiro, & Lara-Meloy, 2005). By characterizing what teachers pick up on the videos and how they talk about it, researchers can also capture evidence of changes in how teachers see classroom events (Athanases & Achinstein, 2003; Sherin & Han, 2004; Sherin & van Es, 2002; Star & Strickland, 2008; van Es & Sherin, 2006;).[2] For example, Sherin and Han (2004) developed a coding scheme to study what teachers in their *video clubs* noticed in videos of their (or their colleagues') classes. The researchers were interested in understanding what teachers noticed and whether or not teachers' attention could be drawn to student thinking. Toward those ends, Sherin typically participated in the meetings either by asking teachers to talk about what stood out in the videos or by focusing the teachers' attention to issues related to student conceptions. Through the analysis, Sherin and Han were able to show changes in what the teachers noticed in the video snippets.

In Sherin and Han's study, four middle school mathematics teachers participated in the video club. The teachers gathered once a month to view and

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[2] Though the richness of the videos can serve as motivators for deeper discussions it should be noted that videos alone do not ensure close attention to how students are reasoning about the content (van Es & Sherin, 2006). In the video, as in the classroom, there are many things to which one might attend beside student reasoning. Providing a direction for the focus of conversations about the videos can help teachers sharpen their skills for attending to the substance of student ideas (Athanases & Achinstein, 2003; Star & Strickland, 2008; van Es & Sherin, 2006).

discuss a video snippet from one of two teachers from the group (the other two were uncomfortable about being videotaped) for a total of ten months.[3] Transcripts of the meetings were divided into segments: topically coherent portions of the discussion. The segments were coded and analyzed in several ways. First, the segments were coded for the kind of issue discussed: pedagogy, student conceptions, classroom discourse, mathematics and other. Second, the amount of time spent discussing each topic was calculated. Third, the authors noted who initiated each segment, whether it was a teacher or a researcher. Fourth, for segments on student conceptions or pedagogy, the authors further coded those categories to achieve a more fine-grained analysis of the data. With respect to student conceptions, their analysis divided the data into three different levels: level 1 was a simple restatement of what students said in the transcript; level 2 involved some analysis of student statements in an effort to understand what students were thinking or meant; level 3 moved beyond analysis of student ideas to characterizations of the nature of student work and syntheses of student thinking. With respect to pedagogy, the authors identified two types of conversations: conversations about alternative pedagogical strategies to what the teacher in the video did or conversations about how the teacher's actions impacted students' work.

In all the video club meetings analyzed, pedagogy and student conceptions were the most common topics. Initially, the teachers placed more emphasis on issues of pedagogy than on issues related to student conceptions, as evidenced by the high

[3] In this article, they only presented analysis of the first seven meetings because the last three meetings were focused on preparing, participating in, and debriefing about an in-service professional development day about using video to study one's own teaching.

number of teacher-initiated segments on pedagogical topics in the first three meetings. In the latter meetings, there was an increase in teacher-initiated segments on student conceptions, though they still maintained a strong interest in discussing pedagogical issues. There were also changes noted in the types of conversations about student conceptions or pedagogy. Over the course of the video clubs, the teachers shifted their focus from mostly level 1 type comments about student conceptions to mostly level 2 and 3 type comments. With respect to pedagogy, the teachers displayed a slight tendency to initially focus discussions on alternative pedagogical strategies and in the latter meetings try to explain the teachers' methods more.

Some researchers have associated these changes in what is noticed with changes in the teachers' cognition. They have looked at how these attentional skills are linked with the teachers' beliefs, knowledge, or level of expertise (Jacobs, Lamb, Phillip, Schappelle, & Burke, 2007; Jacobs & Morita, 2002; Wallach & Even, 2005). Wallach and Even (2005) conducted a four-month workshop to expand teachers' ability to solve mathematics problems and knowledge of students' mathematics problem-solving ability. In this paper, the researchers explored what the teacher heard (or interpreted) when she watched a video of her students solving some open-ended mathematics problems. The authors noted that the teacher's misinterpretations of student statements were linked with the teacher's cognition (beliefs, knowledge and goals). They showed evidence of how the teacher's conceptualization of the mathematics task and solution had an effect on how the teacher heard her students' approach to the problem, even ignoring some aspects of what the students did. Other researchers in this vein of work have suggested that this skill of noticing student thinking or seeing classroom events is constrained by the kinds of cognitive structures the teacher has available. They have argued that what is available may depend on the norms of that teaching culture (Jacobs & Morita, 2002) and may only be developed with time and experience (Jacobs, Lamb, Phillip, Schappelle & Burke, 2007).

Comments.

Though this research looks at how teachers pay attention to classroom events, these researchers have not analyzed teachers' attention during instruction. This line of research is focused on two things: 1) characterizing teachers' reflections on records from their own or their colleagues' classes; 2) tracking teacher learning (as indicated by changes in the reflections that occur over time). Many of the projects were aimed at helping teachers develop their ability to see, reflect on, and make sense of classroom events over the course of the professional development project. As professional development, the hope was that improvements in teachers' ability to reflect on records of practice would result in improvements in teaching practice.

These studies typically used videos or artifacts from teachers' own classrooms for the professional development work, but very little analysis of what teachers actually did in the classroom were presented in the reports. In one study, by Davies and Walker (2005), the researchers attempted to show improvements in teaching practice as a result of changes in how the teachers analyzed videos of their classes. From self-reports, the teachers indicated that they changed their teaching. They reported they had longer wait times, noticed student gestures more when students spoke, and were more adaptive in their teaching. It is not clear just how the teachers were adaptive. Self-reports may provide useful indications of how these teachers would like to be seen but it does not provide sufficient evidence of what went on in the classroom.

The work in this area also looked at changes in attention but at a much broader level. Here researchers looked for how teachers changed over time and what change indicated real learning. Understanding cases like Heidi's requires looking at minute shifts in attention that occur as part of the ebb and flow of normal classroom activity. Even Sherin and Han's (2004) coding scheme, which parsed transcripts into smaller topically coherent segments, is not helpful for studying Heidi's shift in attention. Their coding scheme would reduce this episode to either a label of focused on student conceptions or not. This would hide the fact that Heidi did both.

Though these studies have not examined what teachers do in the classroom, there are some suggestions for what to look at in the classroom data. Though a deeper discussion will take place in Chapter Two, there are two points worth noting: 1) how a teacher responds to a student (e.g., wait time that allows for students to voice their ideas or restating what a student said) may provide some indication of where the teacher's attention is directed; and 2) the context in which the attention is situated matters.

With regard to this second point, how a teacher attends to ideas students present in class may depend on what is going on at that moment. Wallach and Even (2005) argued that hearing students' ideas is very complicated. Even in a simple situation like their study, where the teacher was watching a video of two of her students working on one type of mathematics problem, they noted that there were several factors, such as the teacher's conceptualization of the mathematics task and her content understanding, influencing what the teacher heard. In the classroom, there may be many factors interacting with each other, including the ones listed by Wallach and Even, to influence a teacher's attention that may not show up when teachers view the events on video.

Teacher attention in the classroom: contextual factors influence teachers' attention.

Research that looks at teachers' attention to the substance of student ideas in the classroom setting has shown that there are various factors that can direct attention, from teachers' knowledge to curriculum materials to community norms and expectations. Typically, researchers look closely at what goes on in the classroom, focusing on the interactions between teachers and students. Understanding the shifts in attention, such as the one captured in Heidi's episode, will help deepen our understanding of teacher attention.

The data for this kind of work is usually from classroom observations (e.g., field notes and video-taped recordings) and interviews that probe teacher thinking about events observed. Most studies utilize excerpts from the observation data to conduct stimulated recall interviews. In such interviews, the teacher is shown some snippet of classroom data from his or her own class. Interview questions probe for teacher thinking, rationale for actions, and explication of student behaviors from the teacher's standpoint. Other sources of data may include artifacts related to the lesson, such as lesson plans, handouts and curricular guides, and informal interviews conducted prior, during or after the observation visit. All of this data is combined to provide evidence of a teacher's attention, the direction of the attention, and the meaning behind actions adopted.

Some researchers argue that there is a special kind of knowledge specifically associated with paying attention to students' ways of making sense of subject matter in the classroom (Ainley & Luntley, 2007; Margolinas, Coulange, & Bessot, 2005). Ainley and Luntley (2007) argued that expert teachers know what to attend to in the classroom and how to be responsive to what they see students saying or doing. This attention-dependent knowledge is the "highly contextualized propositional knowledge that is made available by attending to aspects of the classroom situation. ... (This allows expert teachers) to see and make sense of events in the classroom… (and) to make highly contextualized decisions about how to act" (p. 4).

In this study, Ainley and Luntley developed a method for characterizing this knowledge and examining the role this knowledge has in teachers' classroom practice. The authors developed four codes to analyze the object and purpose of the teachers' attention in their data: affective/cognitive, conceptual/nonconceptual, reaction/response, and interrogating/noting. The classroom data was broken up into episodes and analyzed according to these codes.

The underlying focus of the teachers' attention in that episode was identified as either cognitive or affective. Affective episodes were ones where student affect was the primary motivation for much of the teacher's response. Cognitive episodes were ones where much of the teacher's work with students focused on student thinking. As the majority of the episodes were *cognitive*, they were further identified as either focused on *cognitive problems* (e.g., helping students fix errant thinking) or *cognitive opportunities* (e.g., extending student thinking).

Next, if, in the interview, the teacher seemed to have been aware of making a choice in this episode, it was coded as *conceptual*. Otherwise, it was coded as *nonconceptual*. According to Ainley and Luntley, conceptualization of an episode likely indicated that the teacher's attention was involved during that episode.

The reaction/response code indicated whether the teacher used a familiar strategy (*reaction*) or a novel one (*response*) in addressing a student in class. A teacher that is able to act on his or her attention-dependent knowledge is more likely to generate a response than a reaction.

The last set of codes, *noting/interrogating*, were specifically about how the teachers saw what their students were saying or doing. In the interviews, the teachers sometimes explicitly talked about what they thought was behind particular student actions, the direction those actions would lead the students, and their own teaching actions in relation to how they saw their students' work. If, in the interview, a teacher pointed out that a student had a different focus of attention than what the teacher had intended (e.g., the student had a wrong idea or an idea the teacher had not anticipated) but the teacher did not address it in class, this was coded as *noting*. Whereas, if the teacher inquired about what the student was thinking or doing to find a way to move that thinking forward, that episode was coded as *interrogating*.

Ainley and Luntley investigated the teaching of six primary and secondary mathematics teachers in England. From their observations (two observations from each teacher and associated interviews about episodes from those lessons), they generated three composite case studies to exemplify the patterns they saw.

The first composite teacher, Jenny, was portrayed as good at paying attention to her students, planning and conducting smooth lessons, and managing her students. However, her weak subject-matter knowledge held her back from acting on her attention-dependent knowledge. In the episodes, she often noticed the direction of her student's attention but rarely interrogated her students to help them develop their thinking. The authors saw her heavy reliance on the "centrally produced planning resources, which she (did) not feel fully in control of" (p. 15) as the result of her weak subject matter knowledge. She did not exploit the opportunities that arose during her lessons. Jenny did not know what the possibilities were in the content so she felt she had to stick closely to the script.

In contrast, the second composite teacher, Alice, was portrayed as someone who was able to act on her attention-dependent knowledge. The codes interrogating and response were commonly associated with her episodes. This teacher had strong attentional skills, pedagogical knowledge, and subject-matter knowledge. According to the authors, "Alice appears to have good attentional skills that allow her to access attention-dependent knowledge about her pupils' focus of attention. Her confident subject knowledge allows her to go with what she learns during the lesson, and adapt her teaching accordingly" (p. 18). But because she deviated from her lesson plans quite a bit to address what she saw in her students, she did not accomplish her lesson goals.

The first two cases show the importance of subject-matter knowledge in being able to use attention-dependent knowledge. In the third composite, the importance of attentional skill is apparent. The third composite teacher, Martha, was not able to access her attention-dependent knowledge though she exhibited strong content and pedagogical knowledge (at least on a theoretical level). Martha was an experienced teacher and a mathematics specialist. Her lesson plans were organized around carefully chosen sequences of tasks. When asked, she had a clear rationale for her plans in terms of the difficulties she expected her students to have with mathematics. However, in interviews about episodes from her classes, "her interview responses were typified by discussion of the rationale for aspects of her planning, or of the difficulties she anticipated that pupils would experience, rather than comments on particular events" (p. 19). Even in an interview with a video excerpt and transcript to assist in the remembrance of events and perceptions, Martha found it difficult to recall the episode they viewed. The authors attribute her difficulties with recall to her lack of good attentional skills when working in the complex classroom environment. This hindered Martha from accessing her attention-dependent knowledge and thus using her subject-matter and pedagogical knowledge effectively to respond to students. Instead, she tended to act on the basis of her plans and expectations drawn up prior to the lesson.

Other researchers have looked at factors beyond what knowledge or abilities a teacher has that might influence attention, such as the curricular materials. Roth, Anderson, and Smith (1995) found when teachers used researcher-generated curricular materials that encouraged the elicitation and confrontation of student misconceptions, the teachers were better able to focus attention on student ideas than the teachers who did not have such materials. These teachers revealed student misconceptions and worked to help students change those ideas. Other researchers have found that curricular materials can do more than simply encourage a particular mode of teaching. It can even constrain how a teacher sees the relevance of student ideas to the lesson. Tabak and Reiser (1999) found an alignment between the teacher's attention to student responses and the task definition as described in the curricular materials. In their study, the class discussed possible reasons why so many finches in a population of finches on the Galapagos Islands were dying. This was one of the investigation activities in the Biology Guided Inquiry Learning Environment (BeGUILE). The authors claimed that the teacher was more focused on the kind of explanation her students were generating (e.g. a complete versus partial explanation) "than on recognizing instances of more scientific responses" that may have been present in student statements (p. 7). This may have been because "(t)he investigation task (was) defined and presented as having an explanation as its final product. As a result, the teacher's expectation for the discussion may (have been) to articulate a set of explanations" (p. 14).

Rop (2002) found that institutional norms and expectations can also influence how a teacher sees the relevance of student ideas to the lesson and thus constrain attention. He conducted an ethnographic study of how one high school Chemistry teacher, Mr. Kelso, viewed questions by his students during class conversations. Rop was interested in the teacher's treatment of "thoughtful, content related and curiosity driven questions" (p. 717), which he called Student Inquiry Questions (or SIQ). Rop observed Mr. Kelso's class several times a week for a year and spent large portions of the day at the school. He also collected artifacts from the class, generated field notes and audio-recordings of classroom observations, and held informal conversations with Mr. Kelso and his students between classes. Lastly, Rop conducted audio-taped informal interviews with Mr. Kelso about his students and the lessons.

Analysis of the teacher's reflections and decision-making approaches revealed student-generated questions took on different (even contradictory) meanings as various forces came into play at different points in each lesson. Though he could see value in the questions his students asked, pressure to meet the department demands for covering an extensive curriculum was strong and reinforced the view that student questions were unwelcome interruptions to be dealt with as efficiently as possible. Rop explained that Mr. Kelso felt a strong obligation to thoroughly cover the curriculum. Since the "curriculum decisions were made collaboratively in committee… the other science teachers are expecting him to hold up his end of the bargain" (p. 732). These expectations influenced how Mr. Kelso viewed his students' questions. Student questions that did not directly promote progress on the curriculum were considered distracting.

During the official part of the lesson, which was 25 minutes of the 50-minute period, Mr. Kelso had a range of responses to help him deal with his students' questions: from providing quick answers to brushing off the question to labeling the question as irrelevant to the class. For example, in a discussion on ionic bonds, Mr. Kelso brushed off a student's question that was not directly related to the ionization energies and oxidation number (the objective of that day's lesson). At the beginning of the lesson, Mr. Kelso struck a table with a wooden meter stick as a way to explain how one removes electrons from an atom. He said that removing electrons from an atom required energy and this process was like "thwacking atoms with energy" (p. 725). The lesson continued with a discussion of how different atoms required different amounts of energy to ionize. A student, later in the lesson, asked, "What is the thing in nature that thwacks?" Mr. Kelso's response indicated that what did the thwacking did not matter for this lesson as much as how much thwacking was needed. Even after the student persisted in asking about how the ionization actually worked, Mr. Kelso provided a brief response, brushed off the question by saying they would talk about this later and quickly returned to discussing the stability of atoms.

However, student questions that were asked during the unofficial parts of the class (the last 3-5 minutes of the period) were not treated in the same manner. Since those moments were not associated with the curricular coverage time (the 25 minutes of lesson time), student questions were opened up for exploration and discussion. One day, in the final two minutes of class, Mr. Kelso and his students discussed a subject-matter issue raised by a student, Cara. Cara asked why she could not feel the billions of electrons in her pencil moving. In the discussion that ensued, Mr. Kelso offered reasons why Cara's question might seem reasonable, why Cara might not feel the electrons moving, and responded to any further questions and comments she had on this question until the period ended.

In the time dedicated to the lesson, disruptions, regardless of their intellectual potential, needed to be dealt with efficiently. "On the other hand, class time outside this framework may be available for limited pursuit of student questions," such as in the episode with Cara (p. 731). Rop argued that these two distinct ways of viewing his students' questions were, in large part, due to the professional expectations Mr. Kelso felt. He had an extensive chemistry curriculum to cover. To meet his department demands, he needed to make sure he could cover all the topics so his students were prepared for their exams and their future classes. But he also wanted to encourage his students' curiosity and interest in the subject matter. Once his professional duties were over, which was the case with the last 3-5 minutes of class time, he could relax his control over the class and allow for discussion of anything that interested his students.

Comments.

Heidi's example shows a teacher paying attention to the idea her student, Marcus, had. It also shows a teacher brushing aside that idea when she wrote down the vocabulary word "vibrations" on the chart paper. To understand a teacher's attention, we need a way to study it without ignoring the shifts in attention that may occur. Additionally, developing cases based on individual teachers, rather than on composites, will provide a more solid foundation for the field's research ideas about teacher attention.

Ainley and Luntley's (2007) coding scheme seem effective at characterizing episodes where the teacher's attention is steadily on one object and has one purpose. In Heidi's episode, we can code it as cognitive, as opposed to affective, because her work with Marcus was more focused on the ideas rather than his affect. For most of the episode, she inquired about what Marcus was thinking and made note that Marcus had an incorrect idea about how one hears. Then at the end, she replaced what

Marcus said with the word "vibrations". One might be inclined to code this as cognitive problem and interrogating, since she seemed to correct Marcus' errant idea by replacing it with a correct, but unrelated, one. But, this ignores the fact that before Marcus said "it vibrates," Heidi proceeded as if she was going to record the incorrect one ("Alright. (turns to chart paper) I'll write it down (moves closer to the chart paper)…. Goes through the top of your head? (points to the top of her head) The sound?"). It is not clear if, at that point, she intended to move his thinking forward at all.

It is probable that the curricular and the institutional expectations helped shape Heidi's attention in this episode. Students were expected to master certain scientific terms and concepts by the end of the sound unit. Heidi's mentor teacher and Heidi typically used fill-in-the-blank and vocabulary matching items on tests and quizzes to assess students' ability to identify terms and concepts. It is also likely that her knowledge also influenced what happened. She did not have a solid enough understanding of the content to see the connection between what Marcus said and the phenomenon of hearing. Heidi felt uneasy about recording Marcus' idea on the chart because it did not match what they would learn in the sound unit. This may help explain why Heidi ended up focusing on the word vibrations—it was one of the vocabulary words in the sound unit. But this does not explain why she agreed to write his point on the K-column and tried to make sure she got it right before she recorded it.

It may be, as Rop's (2002) and Tabak and Reiser's (1999) studies would suggest, that Heidi's attention is linked with how she conceived of the activity. But a teacher's conception of what is going on seems much more fluid than how others have considered the immediate activity. With the teacher in Rop's study, there were official and unofficial class times. Student questions were dealt with very differently in those two parts of the period. In Heidi's case, she did deal with what Marcus said in two different ways but it was during what was nominally the same activity. This entire episode took place while she worked with her students to fill out the K-column of the KWL chart. It may be that her sense of what they were doing at the time changed while she interacted with Marcus. She initially seemed intent on gaining a clear sense of what her students meant so she could accurately summarize it on the K-column. At the end, it is clear that she was focused on the vocabulary words in the sound unit. Heidi's attention shifted as did her purpose and role in the interaction. With these shifts, the curricular and institutional expectations seemed to exert more influence on Heidi. What we may need is a more nuanced way to understand these shifts in teacher attention and its relation to the changing constellation of forces that help shape that attention.

Research on Teacher cognition and practice

It is largely acknowledged that teachers' cognition influences their actions and hence their attention. What a teacher believes, knows, and understands shapes their goals and decisions, how they talk about and notice aspects of the classroom, and the interpretations they make (Connelly & Clandinin, 1996; Feldman, 2002; Jones & Carter, 2007; Kagan, 1992; Nespor, 1987; Pajares, 1992; Sherin, Sherin, & Madanes, 1999; Shulman, 1996). Much of this work, so far, has been built on the assumption that there is a stable, coherent cognitive core (e.g., a unified set (or possibly several but independent sets) of beliefs, attitudes, and knowledge) that drives the majority of a teacher's practice.

This view has a particular way of considering teachers who may exhibit inconsistent ways of thinking about teaching, learning, science, or other things related to the science teaching and the classroom. Novice teachers, or teachers in the process of changing their teaching, are likely to exhibit inconsistent behaviors. For example, they may teach in a way that does not agree with what they say. While in the process of forming or modifying their practice, there may be a period of instability for these teachers as new ideas replace old ones. Expert teachers, on the other hand, are seen as having well-developed, coherent, and consistent ways of thinking about teaching and learning. They are expected to teach in a manner that aligns with their beliefs and goals because they have the knowledge, skills, and experiences to carry out their philosophies effectively.

Some researchers take a more situated view of teacher cognition. They look to see how it is that some cognitive elements (beliefs, knowledge, or goals) may seem more applicable or relevant to some areas of a teacher's work and not to others. This view challenges the assumption that variability in a teacher's cognition is only the result of the learning process causing instabilities in that teacher's cognitive structures. Instead, stability or instability is seen as the result of a teacher being in a particular situation. This study contributes to this latter line of work on teacher cognition.

There is little distinction between teachers' beliefs and knowledge.

In the research literature, effort has been made to draw distinctions between teachers' beliefs and knowledge. Here are some examples: 1) some view knowledge as having a truth condition whereas beliefs do not; 2) beliefs have an evaluative, normative component that knowledge does not have; 3) teachers beliefs are prioritized so that some are more central to the person than others (Nespor, 1987; Pajares, 1992). But the line between the two seems quite blurry. Though there may be differences, there is also a lot of similarity in how teachers' beliefs and knowledge are defined and treated in the literature (Southerland, Sinatra, Matthews, 2001).

The knowledge teachers draw on is integrated with other pieces of knowledge, as well as with their beliefs (Heibert, Gallimore, & Stigler, 2002; Schoenfeld, 2000; Sherin, 2002). That knowledge is seen as episodic, highly detailed, and rooted in concrete experiences and specific situations (Craig, 2006; Heibert, Gallimore, & Stigler, 2002; Putnam & Borko, 2000; Zeichner, Tabachnik, & Densmore, 1987). Experience plays a large part in the development of teachers' knowledge (Borko & Livingston, 1989; Wilson, Shulman, & Richert, 1987). Given that teachers' work is highly variable and decisions are made in a short time span, researchers have argued that much of the time, teachers knowledge can be characterized as maxims, or general rules of conduct about teaching (Tsang, 2004). Lastly, some have argued that the knowledge teachers draw upon in their work may also have an affective and social dimension to it (Barnett & Hodson, 2001).

These claims about knowledge are similar to the claims about beliefs that researchers make. Beliefs are developed through the teachers' experiences and interactions with the world (Jones & Carter, 2007; Nespor, 1987). They are also linked into coordinated and structured systems (Bryan, 2003; Pajares, 1992). Beliefs have an affective and evaluative component to them (Pajares, 1992). Beliefs are also episodic, highly detailed, and rooted in concrete experiences and specific situations (Nespor, 1987; Pajares, 1992). Teachers use their beliefs to help them define tasks, situations, the world around them as well as themselves and their students (Kagan, 1992; Nespor, 1987; Pajares, 1992).

It is very difficult to separate teachers' knowledge from their beliefs on an empirical basis because teacher cognition has a basis in both (Jones and Carter, 2007; Southerland, Sinatra, & Mathews, 2001; van Driel, Beijard, Verloop, 2001; Zeichner, Tabachnick, & Densmore, 1987). Additionally, a teacher's beliefs, in many ways, functions like knowledge in terms of their impact on that teacher's practice (Kagan, 1992). Some researchers have started to acknowledge that understanding teacher cognition as it relates to classroom events entails studying the interaction between teachers' beliefs, knowledge and goals (Aguirre & Speer, 2000; Monteiro, Carillo, Aguaded, 2008; Schoenfeld, 2002, 1998; Sherin, Sherin, & Madanes, 1999). Though there may be differences between beliefs and knowledge, both affect how a teacher thinks and to what the teacher attends. Though this review makes no distinction between beliefs and knowledge, the terms and descriptions used by the authors will be preserved.

Core beliefs and knowledge drive instruction.

In this section, I will review the literature that takes a more unitary view of teacher cognition. By "unitary view" I mean a view of cognition that assumes individual teachers have stable coherent sets of beliefs and knowledge that drive the majority of their teaching work. Some of these sets are more central to the teacher than others and operate in a context-independent fashion; they are always active (see Hammer, Elby, Scherr, and Redish (2005) for a deeper discussion of the unitary view of cognition). In this view, understanding individual teacher's practice entails discovering what is central to a teacher's belief and knowledge system. A teacher's teaching behaviors are expected to be consistent with those central beliefs and knowledge. Only teachers in the process of changing or developing new practices may exhibit inconsistencies.

This view results in characterizations of teachers as having a central set of beliefs and knowledge that always actively influences what the teacher does and how the teacher thinks without regard for the influences of contextual features of a situation. In fact, sometimes the teacher may modify the situation so that he or she can enact practices that are aligned with those central elements (Cronin-Jones, 1991;Yerrick, Parke, & Nugent, 1997).

Traditional methods for studying cognition relied heavily on quantitative methods- surveys or codes from interviews and observation data that generated statistical information about patterns in the various teaching populations (Jones & Carter, 2007). These would then be used to generate descriptions of classes of individuals, usually along a spectrum of development (Haney, Czerniak, & Lumpe, 1996; McGinnis & Parker , 2001). Researchers recognized these large statistical sets of data were useful for seeing patterns in the larger group but not so much for describing the practice of individual teachers nor for understanding exactly how cognition impacted what teachers did (Speer, 2008). Rather than relying solely on quantitative measures, more and more, researchers turned to qualitative methods (e.g. descriptive case studies) or a mixture of qualitative and quantitative methods (e.g. surveys in conjunction with descriptive case studies) to study teacher cognition.

Though the methods may have changed, researchers were still looking to categorize an individual teacher as a type. Types were characterized by the sets of beliefs and knowledge that most influenced the teacher's work (Clermont, Borko, & Krajcik, 1993; Erickson & MacKinnon, 1991; Levitt, 2002; Richardson, Anders, Tidwell, and Lloyd, 1991). This classification was done so without consideration for how the context might have influenced a teacher's thinking.

For example, in Brickhouse's (1990) study, she generated three case studies of the beliefs teachers held about the nature of science, the teaching and learning of science, and the influence of those beliefs on their classroom practice. The beliefs were determined from interview statements and then correlated with broad descriptions of classroom practice that were based on observational data. The interviews were about the teachers' understanding of science and science teaching. According to Brickhouse, the two experienced teachers, Mr. Cathcart and Ms. Lawson, "operated from consistent, self-reinforcing…beliefs systems….The teachers' understanding of what science is and how students learn science in schools formed a consistent system of beliefs for guiding classroom instruction" (pp 60). Mr. Cathcart was characterized as having unsophisticated beliefs about the nature, teaching, and learning of science. Ms. Lawson was the opposite of Mr. Cathcart. She had fairly sophisticated beliefs about the nature, teaching, and learning of science.

The third teacher in her study, Mr. McGee, was difficult to analyze because he did not exhibit a consistent set of beliefs. "McGee had not reconciled his own conflicting beliefs or the impact of institutional constraints on his teaching" (pp 60). While he saw scientific knowledge as evolving, he taught in a manner that presented scientific knowledge as fact-based and immutable. Brickhouse's explanation for Mr. McGee's inability to reconcile these discordant views of science was due to his lack of experience.

Another line of work that is based on unitary assumptions is research that looks at the filtering effects of teacher cognition. Here researchers look at how teachers implement new teaching methods, a novel curriculum, or reform efforts. Teachers who do not have the appropriate knowledge or beliefs to enact the new curriculum or teaching methods may reinterpret matters so they could continue with familiar routines and maintain their old ways of thinking (Cohen, 1990 ; Cronin-Jones, 1991; Feldman, 2002; Sherin, 2002; Yerrick, Parke, & Nugent, 1997)

Cronin-Jones (1991) presented case studies of the influence of two teachers' beliefs on their enactment of a new curriculum. Overall, the teachers' existing belief structures were incongruent with the underlying philosophy of the intended curriculum, thus hampering successful implementation. With one teacher, activities that did not align with her values were dropped from the enacted curriculum. The other teacher transformed open-ended activities into strongly teacher directed activities, which matched with her belief that students needed a lot of teacher direction. These teachers' belief systems were robust stable structures that did not change even with the use of new curricular materials.

In another example, Yerrick, Parke, and Nugent (1997) presented evidence of how teachers filtered the messages from their professional development experience to reinforce their old ways of thinking and doing. The authors studied the impact of their professional development program on the lesson plans and assessment tools the teachers developed. Data for this study came from videos of small group work in the summer professional development institute and the teachers' journal entries. In those journals, the teachers recorded their interpretation of institute activities and the relevance of those activities to their own practice. Samples of classroom assessments and lesson plans both before participation in the professional development institute and for two months after the institute were collected to track changes in the teachers' teaching practice. Interviews conducted to gather more data on how the teachers thought.

The goal of the professional develop project was to change the teachers' treatment of scientific knowledge to align with more scientific ways of thinking and assessment strategies to align with more reform-oriented practices. However, post-summer-institute lesson and assessment plans the researchers collected indicated that these teachers did not alter their practices. In the interviews, the teachers reinterpreted the messages from the professional development institute to rationalize their teacher-centered approaches. For example, the summer institute workshops encouraged the asking of open-ended questions in teaching. In data collected after their participation in the institute, the teachers did ask more questions than before. But, these questions were focused on finding facts and simple answers that closely scaffolded students toward the teachers' curricular goals. This way of defining “open-ended questions” was not a view promoted by the institute. Though Yerrick, Parke, and Nugent, acknowledge the possibility of institutional factors influencing teachers, they argued that the real issue lay with the ability of the teacher to understand the reform philosophy of the curriculum.

Novice teachers cannot consistently enact their ideals.

Brickhouse’s (1990) article describes a common way of thinking about teacher cognition: there are differences between expert and novice teachers. Expert teachers have more appropriate, detailed, complex, connected, and coherent schemas for helping them make sense of and respond to different classroom events (Ackerson, Flick, & Lederman, 2000; Borko & Livingston, 1989; Erickson & MacKinnon, 1991; Field & Latta, 2001; Meyer, 2004 ; Putnam & Borko, 2000). Because they have a larger and more integrated repertoire for addressing changing classroom events, they are better able to align their teaching with their core commitments than novices (Ackerson, Flick, & Lederman, 2000; Brickhouse, 1990; Clermont, Borko, & Livingston, 1993).

Novice teachers or teachers in the process of changing their practice, on the other hand, are more likely to exhibit inconsistent thinking (Brickhouse, 1990; Levitt, 2002; Simmons, et al, 1999). These inconsistencies are typically seen in evidence that shows the disparity between what a teacher espouses in an interview and what the teacher does in the classroom (Bryan, 2003; King Shumow, & Lietz, 2001). For example, a teacher might articulate reform-oriented beliefs about teaching and learning but teach in ways that do not reflect those beliefs (e.g, teach in a traditional lecture-based manner). This may be because novices lack the knowledge, beliefs, or abilities to support enactment of what they profess (Brickhouse, 1990; Bryan, 2003; Levitt, 2002; Richardson, Anders, Tidwell, & Lloyd, 1991). Their schemas for understanding and negotiating classroom events are less connected, elaborate, and accessible (Borko & Livingston, 1989; Erickson & MacKinnon, 1991; Jacobs, Lamb, Phillip, Schappelle, & Burke, 2007; Kagan, 1992b).

One example of a novice teacher professing a view that did not agree with her actual teaching can be seen in Bryan's (2003) study of a prospective elementary school teacher. Through extensive interviews and classroom observations, Bryan (2003) found that the prospective teacher in her study held two contradictory nests of beliefs. In the interviews, the teacher articulated a well-connected set of beliefs that reflected a hands-on approach to learning. Bryan argued that the beliefs stated in the interviews represented the teacher's sense of what teaching ought to be, or her vision of practice. But in her classroom, she taught in a manner that reflected a traditional teaching approach. This latter set of beliefs was grounded in the prospective teacher's past learning experiences. According to Bryan, the teacher had not yet developed the knowledge and skills to enact her vision of practice. As a result, the old way of thinking still held control over her teaching practice.

Comments.

These studies view teacher cognition and its influence on a teacher's practice as a context-independent phenomenon- what I call a unitary view of teacher cogntion. In this view, the beliefs and knowledge that are most central to the teacher's beliefs and knowledge system form a coherent, robust, stable set that is always active and create the foundation of a teacher's teaching practice. An implicit assumption is the context is something a teacher reacts to or manages, in accordance to his or her abilities and core beliefs; the context does not have an influence on a teacher's cognition. When a teacher is in the process of changing or developing new practices, the change may not show up in the teacher's classroom teaching though the teacher may verbally ascribe to the new view. This is because the old system has not yet been replaced.

This assumption that the centrality of a belief or piece of knowledge (or set of beliefs and knowledge) is context-independent does not seem supported by the data from Heidi's lesson. From the interview and her behavior in the class, Heidi believed that information labeled as knowledge must be canonically correct and that the teacher needs to help her students develop their knowledge. Her discomfort with recording Marcus' seemingly incorrect statement was rooted in these beliefs. But, this still does not explain why Heidi would agree to put Marcus' original idea on the K-column before he said, "it vibrates."

A common sense answer is that Heidi, at that time, had no other choice. What they were doing at the moment was filling in the K-column with what her students told her. She was expected to put up what Marcus said. Somehow, this expectation may have played into how Heidi treated Marcus' idea. She needed to write down what he said. In the next section, I will discuss how some researchers have looked at the interplay teachers' cognition and how the teacher conceives of the situation at hand.

To understand episodes like Heidi's, we may need to look more closely at the interaction between the teacher and students. In the next section, I will explore a model of teacher interactive decision-making that looks closely at teacher thinking in the context of the interaction, the Teacher Model Group's model "Teaching-in-context". This model is a unitary model of teacher cognition that looks at teacher thinking as events unfold during student-teacher interactions. This work is quite relevant to the focus of this dissertation.

"Teaching-in-context": review of the Teacher Modeling Group's model.

The Teacher Model Group (TMG) developed a model to "provide a rigorous theoretical characterization of the teaching process (by) employing an analytical framework that explains how and why teachers make the choices they do, in the midst of classroom interactions" (pp 133, Schoenfeld, 2002).[4] The TMG modelers sought an explanatory mechanism for how a teacher's cognition (relevant beliefs, goals and aspects of the teacher's knowledge base and their conditions for activation) led to certain actions and decisions, given the events in the interaction. Also, because this model aims to understand teaching in the context of the interactions teachers have with students, this model seems to have much potential for explaining Heidi's episode.

Schoenfeld (2000, 1998, 2000) has argued that any study of teacher cognition must consider the interplay between a teacher's knowledge, beliefs and goals in shaping classroom action. In his description of the model, Schoenfeld (1998) acknowledged that teachers may have many kinds of beliefs (e.g., beliefs about

[4] The TMG model has gained traction with other researchers as well. Montiero, Carrillo and Aguaded (2008), used this model to study a group of pre-service teachers in Portugal. In their study, they found a strong connection between a teacher's beliefs and actions and between the knowledge and objectives pursued. As their findings do not add much to this review, detailed exploration will only be focused on the work done by the Teacher Modelling Group.

students, the discipline of science, and science teaching). Different beliefs and knowledge elements may have different levels of activation depending on the situation at hand (e.g., during the science lab, the teacher may draw on her beliefs and knowledge about hands-on learning). It is not clear how the TMG modelers consider teachers who express or enact conflicting beliefs. They seemed mostly concerned with showing how a teacher's decisions to adopt different teaching actions in response to changes in the situation (e.g., an unexpected student response) still acted in a manner consistent with the teacher's core set of cognitive elements.

Data for these studies came from videos and/or observation notes of classroom events and in-depth interviews. Researchers analyzed the conversations in the video transcripts line by line to determine not only the progression of the lesson but also the apparent goals, beliefs and knowledge active during that segment. These videos were also used in interviews with the teacher. They helped the teacher recall events and thoughts that arose during the lesson. Furthermore, the interviews were used to gain further access into the teacher's thinking, plans and rationale for particular actions.

Terms and definitions in the model.

In the TMG model of teaching, a teacher's actions are driven by the teacher's knowledge, beliefs, and goals. The knowledge and beliefs are used to generate the plans for achieving those goals. As the actual lesson progresses, the teacher may adopt new actions and abandon initial plans and goals in accordance with what he or she encounters in the class. Before moving on to a detailed discussion of how this model was used, some constructs and definitions need to be articulated.

Lesson image.

The lesson image is essentially what the teacher thinks will occur in the day's lesson. It has much more detailed than the lesson plans the teacher generates. It "includes everything the teacher envisions happening in the lesson- the day's sequence, the forms of interactions with students, what is flexible and what is not (e.g., ``I'll start by collecting homework, but then I'll take whatever questions they want to ask and will deal with them for up to 10 minutes''), and his or her sense of how the discussion will go" (pp 250, Schoenfeld, 1999Schoenfeld, 2000). Contained in the lesson image are expectations of what students may say or do, the kinds of challenges students may face during parts of the lesson, and the contingency plans to help mediate those challenges. In general, the lesson image is constructed prior to the actual lesson and is what the guides the lesson.

Goals.

Goals are what the teacher would like to accomplish. At any moment, there is likely a constellation of active goals the teacher is striving towards. Strength and duration of activation may vary. Some goals may be highly active for a very long time while others may only apply to the current situation or are temporarily suspended (e.g., helping students develop particular habits of mind or helping students determine the solution to a particular problem). Additionally, goals may vary in their scope: *overarching goals,* which may govern over several units or even the entire curriculum, *unit goals,* which may govern over the lessons or a thematically linked set of topics, *lesson goals,* which may govern over the activities of a particular lesson, and *"local" goals,* which are goals for particular interactions with specific students- the "in-the-moment" goals. Satisfying a goal may depend on the constraints of that situation. Sometimes, the constraints are such that a goal may need to be put on hold or abandoned altogether.

Action plan.

Central to this model is the action plan. This is the prospective mechanism, or sets of actions, by which the goals are achieved. In terms of the structural hierarchy, this is at a lower level than the lesson image and is more closely associated with the actual interaction between the teacher and student. The level of detail in these plans depends on where and how comfortable the teacher is willing to improvise a response to events in the interaction with students. Action plans may be created a priori or drawn up in the moment, either drawn from memory, such as a routine, or constructed ad hoc to deal with the current situation. What is available as a productive plan to follow depends on the cognitive tools (e.g., beliefs and knowledge) the teacher may have.

Action sequence.

Analysis starts by parsing out the classroom events into action sequences, or chunks of the lesson that cohere on phenomenological grounds. Each action sequence corresponds to at least one goal. But it is typical that more than one goal is active. This details what occurred in the lesson with the students. Most of the time, the action sequence matches with the action plans and the lesson image is preserved. Sometimes, a teacher may encounter something unexpected which violates the lesson image. As a result, the action sequence may proceed differently from the action plan.

Knowledge and beliefs.

In this model, the teacher may have different categories of beliefs (e.g., beliefs about teaching, learning, or content matter) that help provide the rationale for what teachers do and the goals they pursue in the interaction. Their enactment is supported by the knowledge (e.g., routines, scripts, or schemas for dealing with classroom events) the teacher has available. At any point in time, a constellation of the different beliefs and knowledge sets may be activated (and activated at varying levels of priority). They can help the teacher decide on what goals are relevant and what lesson image or action plans best helps the teacher pursue those goals. If things go unexpectedly, different clusters of beliefs, knowledge sets and goals may be activated. This newly activated set will help a teacher decide on what the new goals and action plans will be to respond to the changes in the situation.

Lesson image and goals drive action.

The TMG used their model to extensively analyze the work of three teachers, Deborah Ball, Mark Nelson, and Jim Minstrell (Schoenfeld, 1998; Schoenfeld, 2002; Schoenfeld, Minstrell & van Zee,1999; Zimmerlin & Nelson, 1999Zimmerlin & Nelson, 2000; Schoenfeld, 1998;). Nelson, at the time of the study, was a student teacher in a high school Algebra I course. Minstrell was teaching a high school physics class, had been for many years, and was considered a master teacher by many. He is a science education researcher and teacher educator. Ball was teaching a third grade mathematics class. She has had many years of experience in the field of mathematics education, as a teacher, teacher educator, and researcher.

In the episodes from each teacher's class, the lessons started much in accordance to the lesson image and action plans each teacher had. Then an unexpected event occurred that violated the lesson image. New action plans and goals were pursued to address the unanticipated issue. Beliefs that supported these changes became active. In Nelson's case, his students had difficulty resolving x^5/x^5. In Minstrell's case, a student had presented a novel way of considering averages of numbers. In Ball's case, the lesson image, which had the goal of having her students reflect on their learning, was interrupted twice. The first interruption occurred because her students disagreed about whether or not zero was an even number. The second interruption came about because Ball, in response to a student's comment, asked if all even numbers were made up of even numbers.

Though new local goals were created, they were in concert with the initial slightly broader goals each teacher had for their lessons. Minstrell and Ball both believed it was important to help their students develop disciplinary ways of thinking in their respective subject areas. Also they wanted to help their students learn to participate in "communities of disciplined inquiry (and) … to experience mathematics/physics as a sense-making activity" (pp 132, Schoenfeld, 2002). Schoenfeld (2002) showed that in Minstrell's and Ball's cases, they addressed the interruptions of their lesson image by using well-developed and familiar routines which allowed them to pursue their large goal of "support(ing) students' engagement with the content and their reflection on both the content and their understanding of it." When the interruptions were properly addressed, the teachers returned to the original lesson image. Even though each teacher veered away from their intended plans, they were show to act in ways consistent with their central beliefs about disciplinary teaching and learning.

To show how the model is used to analyze teaching, a more detailed presentation of Nelson's case will be discussed. Nelson was a student teacher at the time. There are many similarities between his case and Heidi's example. The authors, Zimmerlin and Nelson (19992000), presented a detailed analysis of a segment of Nelson's classroom teaching to show how one analyzes teaching with the TMG model of teaching. At the time of data collection, Zimmerlin was Nelson's supervisor. The segment they analyzed is in the middle of an hour-long lesson on dividing algebraic expressions with exponents. Earlier in the lesson, the Nelson and his students had worked through several problems until they developed the generalized form: (a^m)/(a^n) = a^(m-n). In the segment presented, Nelson's students were working on the problem: (x^5)/(x^5) = 1.

This lesson was video-taped by Nelson and observed by Zimmerlin.[5] The TMG began by analyzing individual student/teacher interactions. The discussions with Nelson about those interactions revealed the triggers, goals, and plans, which informed the researchers of the minute-to-minute decisions Nelson made while teaching. However, Zimmerlin and Nelson felt that this analysis failed to provide an adequate picture of the teaching process. By zooming out to the lesson image, they were able to develop a clearer picture of the teaching process. In this article, the authors used analysis of Nelson's lesson image and the action sequence to explain the teaching observed in the segment.

In Nelson's lesson image, there were a series of nested action plans that described the overall flow of lesson activity. These contained expectations of what difficulties his students would encounter, how his students might interact with the material and what Nelson would have to do to help his students. He planned on discussing several problems involving the division of algebraic expressions with

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5 After his observation, Zimmerlin discussed the segment in a post-observation debriefing meeting with Nelson. Initially, the video was a part of a student teaching assignment intended to encourage teacher reflection. Nelson eventually used this segment of videotape in his Supervised Teaching Seminar.

exponents. For the easy problems, Nelson's action plan was: 1. Call on students for the answer; 2. Confirm the correct answer; 3. Check for any student difficulties. Nelson had a variant of this plan for helping students with the slightly more challenging problems. This entailed walking his students through the solution procedure. In his lesson image, he expected his students to have a lot of trouble solving the problem: [x^5]/[x^5]. Here, he planned on decomposing the problem with the class to show that all the x's in the numerator canceled out the x's in the denominator, thus showing the solution was one.

In this lesson image, Nelson had several goals, some over-arching and some local. The over-arching goals were: 1. "help students see where algebraic notations and procedures come from, and why algebraic rules are true" (pp 268) and 2. "develop a classroom atmosphere in which students contribute to classroom activities" (pp 269). For each action plan there was at least one local goal associated with it. These goals were mostly content goals. In the segment presented, the goal of "building student understanding of zero exponents" had the highest priority (pp 269).

For the most part, the lesson proceeded as planned. However, there were some unexpected difficulties when the class worked on [x^5]/[x^5]. Just as Nelson expected, his students had difficulty with this problem so he carried out his plans for decomposing the algebraic expressions and representing the division as (x*x*x*x*x)/(x*x*x*x*x). Though all his students agreed that the x's would cancel, they disagreed about what the result of canceling would be; some argued that the answer was zero. Nelson adjusted his plans and used the example of 5/5 to show that when the numerator and denominator are the same, they cancel each other out and the end result is one. However, the confusion remained and he ended up telling his students that [x^5]/[x^5] and x^0 were both equal to one, which his students wrote in their notes. After this problem, Nelson returned to his lesson image.

Zimmerlin and Nelson argued that Nelson's lesson image and high priority goals could explain much of the teacher's actions and decisions, even when he veered away from his lesson image. Nelson's lesson image was disrupted when he saw that his students had a lot of difficulty with canceling out the x's. To manage this interruption, he "developed, on the spot, a new action plan to try to patch his lesson and accomplish his goals" (pp 274). The authors argued that, though the new action plan had a new local goal associated with them (to deal with the confusion), the new goal and action plan aligned with the existing goal of showing that (x*x*x*x*x)/(x*x*x*x*x) = 1 and ultimately that (x^0) = 1. Since Nelson was new to teaching, he did not have access to well-formed routines to help him manage his students' confusion. This, the authors argue, helped explain why Nelson ended up just telling his students what to write in their notes about this problem. When he felt the new (unexpected) situation was dealt with appropriately, Nelson returned to his lesson image.

Comments.

In using the TMG model to explore Nelson's (as well as Ball's and Minstrell's) class(es), these researchers were explicit that any variations in the teachers' actions or goals could be linked directly back to the core beliefs and knowledge each teacher had activated at that moment. When a teacher deviated from their lesson image, it was because the teacher made a rational decision based on their core system of beliefs and knowledge to respond to changes in the situation in a particular way. The new goals were the result of the teacher using this core set of cognitive elements to respond to changes in the situation. For example, in the case with Mr. Nelson, the authors argued that by knowing what his lesson image, his priority goals for that lesson, and the set of cognitive skills he had for dealing with his students, they could explain Nelson's actions (and reliably predict future encounters, assuming that Nelson's core cognitive elements stayed the same).

In this dissertation, I am challenging the notion that a teacher's decisions are necessarily rationally derived from a central system of beliefs. This sort of account does not take into consideration the context in which the teacher is situated. As I said earlier, some aspect of the situation in which Heidi found herself set-up an expectation that she write down Marcus' incorrect idea even though she was uncomfortable with it. In the next section, I will review some of the current work that takes a more situated view of teacher cognition.

Activation of knowledge and beliefs may depend on the situation.

Research that takes a more situated view of teacher cognition looked at how the centrality of a teacher's beliefs or knowledge may depend on the context (Kang & Wallace, 2005; Pajares, 1992; Tobin & McRobbie, 1997; Tsang, 2004). Much of this line of work investigated how a teacher may associate a set of beliefs and knowledge with some realms but not others. Tsang (2004) found teachers in his study drew on one set of knowledge to guide their planning and reflections but did not use that knowledge to guide classroom teaching, even though that knowledge was relevant to the activity at hand.

Though the teacher in Tobin and McRobbie's (1997) study articulated sophisticated beliefs about the nature of science (e.g. science was an evolving discipline), those beliefs had little influence on his classroom teaching. Instead, his beliefs that students learn by receiving knowledge from the teacher and that teachers should maintain control over the curriculum had the most influence on his teaching. According to the authors, the constraints of the teacher's teaching situation promoted these beliefs and hindered enactment of his sophisticated nature of science beliefs.

It is not just a matter of what is articulated outside of the classroom differing from what the teacher does inside the classroom. The beliefs that support a teacher's classroom practice also exhibit context-dependent centrality. Kang and Wallace's (2005) found that a teacher may have dissimilar epistemological beliefs associated with different laboratory activities. They conducted a detailed study of three experienced secondary science teachers' epistemological beliefs, goals, and practices regarding laboratory activities. One of the teachers, Tom, exhibited two distinct sets of epistemological beliefs about science in his teaching practice: science is a factual body of knowledge and science is problem solving. In his class, these beliefs justified two kinds of labs- structured labs for verification of concepts and phenomena and open-ended labs for students to try out ideas and construct their own solutions. The structured labs were associated with the goal of helping students prepare for the state graduation test. The open-ended labs were associated with the goal of reaching out to students who were scared of science and letting them do something similar to what real scientists do.

Further challenge to unitary assumptions about teacher cognition comes from a study by Aguirre and Speer (2000). They looked at how the different beliefs a teacher had interacted with the goals to influence the decisions that teacher made during interactions with students. Here, it seems that there is evidence that a teacher's cognition may vary at an even finer level- at the level of the interaction.

In their model of teacher cognition, teachers may hold a variety of beliefs (e.g., belief about learning, belief about teaching and belief about subject matter) that may activate or deactivate depending on the circumstance. Within the entire collection of beliefs, some may conflict with others. At any moment a subset of the entire collection of beliefs, or a belief bundle, is activated and influences the selection and prioritization of goals and actions. These belief bundles do not necessarily exhibit long-term stability. Some dissipate as events in an interaction unfold. For example, Aguirre and Speer showed that with one of the teachers in their study, Mr. Martin, activated a different belief bundle than the one he started with while he worked with a student on a mathematics problem.

From the interviews, Aguirre and Speer saw that Mr. Martin's beliefs could be organized along two lines, which the authors called a standard set and a collaborative set. The standard beliefs were deeply ensconced, developed from his 11 years of teaching and associated with well compiled routines. He thought of math as a collection of tools and isolated facts that students learned individually. The teacher was the source and dispenser of knowledge. The collaborative beliefs were newly established, the result of using new curricular materials that supported collaborative mathematics learning. Mr. Martin had a limited repertoire of routines and skills to support enactment of these beliefs. Associated with this second set, Mr. Martin thought the teacher should encourage group process and not be the direct source of knowledge. He also thought of mathematics as sense-making and that students learned by constructing their own understanding or by working in groups (though it did not seem that he had a clear idea of how that construction could be used to support the development of higher order mathematics skills).

The collaborative and standard beliefs had the potential to be in conflict (e.g. teacher as direct source of knowledge or supporter of students constructing their own understanding). The authors argued that for Mr. Martin, these beliefs were not necessarily in direct competition but may have just operated in different domains. They saw that under particular circumstances, certain beliefs were at a higher state of activation than others. Mr. Martin's practice evolved such that the collaborative beliefs were more active when he used the new curriculum materials and worked with students in small group work. In those moments, instead of directly telling students what to do, he would closely monitor their mathematical progress and provide students with hints. In the case they presented, Mr. Martin's students were engaged in group work exploring a graphing problem. During the interaction with one student, Mr. Martin shifted from his collaborative beliefs to his standard beliefs. He ended up pursuing goals for his interaction with one student that were supported by his standard beliefs rather than his collaborative beliefs.

In this class, students were asked to determine the minimum number of games a customer needed to purchase in order for the Pretendo gaming system to be cheaper than the Sega-Genesis system given that the initial costs for Pretendo was higher than

Sega-Genesis but the longer term costs were lower. During the initial group work time, Mr. Martin's goal was to encourage collaboration amongst his students as they explored the graphs in an attempted to solve the problem. His initial interactions with students were aligned with this goal. However, when a student asked for his feedback on a mathematically correct but incomplete graph, Mr. Martin's goal switched. A second goal of having his student correct her graph herself was developed. He tried to help by giving her hints and monitoring her progress. When she responded to his hints and leading questions with "I don't know", this triggered yet another goal shift, to the third and final goal for this interaction. Goal Three was to correct the student's graph and he did so by simply telling her what to do. As the first goal was put on hold and new goals developed, the standard beliefs moved to a higher level of activation to support these new goals and the collaborative beliefs no longer impacted his work with his student.

Comments.

Context matters. The centrality of a belief or knowledge may depend as much on the teacher's system of beliefs and knowledge as on the situation in which the teacher finds him or herself. Aguirre and Speer's (2000) study suggest that changes in the situation that may affect belief activation may occur *within an interaction*. In their study, as the interaction unfolded, different (conflicting) beliefs activated.

In Heidi's episode, she did not act on the beliefs that were apparent in her teaching and interviews about teaching and knowledge. If she did, she would not have acted as if she would record Marcus' incorrect idea. In that moment, some besides those beliefs influenced her decision to record what Marcus said. It may be linked with how Heidi interpreted what they were doing which committed her to writing down Marcus' idea. Understanding a teacher's attention to a student's idea in episode's like Heidi's will require looking at the interplay between the interaction and the teacher's cognition.

Research questions

As a teacher opens up his or her classroom to student ideas, unpredictable things may happen. During these interactions, a teacher may or may not shift attention away from (or to) those ideas. Understanding what helps maintain as well as shift teachers' attention is a a problem worthy of study, especially if the field would like to support teacher's work in the classroom. Toward that end, I will focus on the following questions in this dissertation:

1. What is evidence of whether or not a teacher attended to student ideas?
2. What influences a teacher's attention? In Heidi's case, we see that she maintained her attention to Marcus' idea, going so far as to attempt putting it on the chart, even though she was uneasy writing it in the "What do we know" column.

Chapter 2: Theoretical Framework, Research Context, and Methods

In this chapter, I will articulate my framework for identifying and analyzing a teacher's attention to student ideas as well as for analyzing the teacher's framing of the interaction he or she has with the students. The episode from Heidi's class, presented in Chapter One, serves as motivation for the discussion in this chapter. After revisiting the data, I will present some of the relevant literature on attention and framing theory to explain how we can understand Heidi's attention in that episode. In summary, Heidi's attention to Marcus' idea seemed constrained by how she framed the discussion she had with him. At the end of this chapter, I will provide a description of the data, the teachers in this study, and the collection process.

Recall, Heidi wanted to introduce the new science unit on sound by finding out what her third-graders knew about the topic. She intended to make this introduction as relaxed and engaging as possible. She thought a KWL chart would give her the flexible structure she needed to be able to talk with her students informally. Early into this discussion, Marcus tried to explain an idea he picked up from his doctor—that sound could enter through the top of one's head.

Heidi:	What do you know about sound?
Marcus:	Um, uh, that most of your sound is on the [top?] (points to the top of his head).
Heidi:	What do you mean by that, most of your sound?
Marcus:	Like it uh, like if you [can't?] hear anything more in your ear then the sounds can (points to the top of his head) go through you're the top of your head.
Heidi:	(3-second pause) I didn't know that. Alright, (turns to the chart paper) I'll write it down. (moves closer to the chart paper)

Marcus:	I learned it from the doctor.
Heidi:	Goes through the top of your head? (points to the top of her head) The sound?
Marcus:	yeah, and it vibrates [in there?] (moves his hand back and forth).
Heidi:	(with greater emphasis and louder volume) Vibrations, I love it! Vibration, OK. (Writes the word vibrations on the KWL chart)

In an interview, Heidi explained what she was looking for during this part of the lesson. In an interview, I asked her what she wanted to write down on the K-column. She explained:

> Mm. Pretty much what they think they know. I mean, whatever they tell me about sound is what I was wanting to put up there…But then because (laughs) some of what they were sayin' was kind of off the wall and…wasn't really true then, I didn't put it up there…'cause they don't, they don't know that" (Interview, February 3, 2005).

Heidi attended to Marcus' thinking for most of the exchange and I argue that this attention was supported by how she framed her interaction with her student. By frame, I simply mean a person's sense of what is happening or what we might presume his or her answer to the question "What is it that is going on here?" would be. This framing is often tacit, and can be inferred by the intentions, expectations, goals, and assumptions about appropriate roles that are suggested by an individual's actions in each situation.

According to Heidi's original plans, she wanted to write down "pretty much what they think they know…whatever they tell me about sound." Basically, Heidi and her students were working on filling out the Know-column of the chart with their ideas. At that point, the K-column was a space for recording summaries of her students' thinking about sound. Her role was to understand and collect those thoughts. And we could infer that she was framing the interaction as something like, 'Filling in the K-column with what students said.'[6] In this framing of the interaction, it was important for Heidi to pay attention to her students' ideas.

In paying attention to Marcus' idea, however, she could not help but notice what she saw as incorrect in his statements. Hearing through the top of one's head was "off-the-wall" to her and made her uneasy about recording it on the chart. Even though Heidi said in the interview that she did not record incorrect ideas in class, she acted as if she was still committed to making sure she put up an accurate summary of what Marcus said ("Alright, (turns to the chart paper) I'll write it down. (moves closer to the chart paper)…. Goes through the top of your head? (points to the top of her head) The sound?"). Her actions suggest she was still framing it as 'Filling in the K-column with what students said.' Given how she initially framed the interaction, it was likely that there was nothing else for her to write at that moment except what Marcus told her, even if she was uncomfortable writing it. Her interview statements were likely retrospective rationalizations for behaviors that emerged later in the episode.

Her discomfort with writing down noncanonical statements likely destabilized her initial framing of what they were doing. When Marcus mentioned that the sound vibrated in one's head, Heidi's attention switched to the vocabulary word *vibrations*.

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[6] We should not assign too much meaning to the exact wording of the frame labels. A person's framing is much richer and more dynamic than labels can capture. It includes things like the roles, the goals, and expectations. I chose descriptive phrases that appealed to our commonsense understanding of the interaction because it is the best I can do now to make it shorthand. It is possible to have assigned the frames with symbols, numbers, letters, or colors but we would inevitably try to translate those into short descriptive phrases to help us keep track of what we were reading.

By recording vibrations, she violated the expectations of the initial activity. A new frame emerged. She no longer tried to put up a faithful representation of her student's point ("But then because (laughs) some of what they were sayin' was kind of off the wall and…wasn't really true then, I didn't put it up there." Interview, February 3, 2005). The K-column was now a space for collecting correct information.

It is unlikely that Heidi decided to change her sense of the interaction. It was probable that Heidi had only decided to write down vibration because she was uncomfortable. Given that she recorded vibration, which was at least related to a word Marcus used, perhaps she thought she was staying within the bounds of the original frame. By writing a word that was at least tangentially related to Marcus' statements she could still write what her students told her while mitigating her uneasiness with putting incorrect information into a space labeled, "What we know." If these actions continued, then a different frame, such as, 'Filling in the K-column with canonical information,' may emerge and stabilize.

In Chapter One, I reviewed several different perspectives on understanding teacher attention and teacher practice. They point to the importance of investigating both the teacher's cognition and the activity in which the teacher is engaged for examining teacher attention. A teacher's attention is mediated by how he or she thinks in that situation, which is influenced by his or her knowledge, beliefs, and goals, as well as more externally embodied pressures, like curricular aims and institutional expectations (Ainley & Luntley, 2007; Kang & Wallace, 2005; Levin, 2008; Rop, 2002; Tabak & Reiser, 1999; Wallach & Even, 2005). By studying attention and its connection to how the teacher framed the interaction, we are able to see how that sense of what is going on at the moment helped to organize the teacher's attention.

Attention and attending

This section will describe how I am conceptualizing attention and what I take as evidence of attention.

Conceptualizing attention.

By *attention* here I mean simply the everyday meaning of the focus of one's mind. By *attending*, I mean the focusing of one's mind on something. When a teacher is paying attention to a student's idea, the teacher's mind is focused on the substance or meaning of the idea the student is trying to communicate.

Like Ainley and Luntley (2007), I see attention as an "active perceiving and involves selection on behalf of the subjects" (p. 4). In most classrooms, there are many things going on and it is likely the teacher is aware of many of those things (e.g., how students are behaving, how much time has passed, how students understand the material, and how students are using the equipment). A teacher may not necessarily focus his or her mind closely on all of those things going on in the classroom. Each teacher not only filters out a lot of information, but also tacitly prioritizes that information so that he or she pays attention to only one, or a small subset. In this study, I look at how the teacher's attention relates to the student ideas that are present in the interaction.

Analyzing attention.

The challenge in this study, though, is to identify where a teacher focuses her mind. I am only able to infer attention from the data I gather (classroom observations and interviews), in the form of the teachers' behavior and statements. Heidi's repetition of Marcus's words, her tone of voice, her mimicking of his gesture, and her question to him for clarification are evidence she was focused on the meaning he was trying to communicate. A short time later, her selection of the word *vibration*, a word he did not use but that is part of the curriculum, and her disregard of what she had learned he meant to say are evidence her attention shifted elsewhere.

Of course, observations of behaviors and statements can be misleading. For example, one may pretend to pay attention by adopting some behaviors to look like one is attending (e.g., a teenager pretending to pay attention to a parent's lecture on keeping to curfew hours). Typically, rigorous examination and triangulation of the data can show the difference between pretense or not.[7]

Chapters Three and Four discuss the categories of evidence I found in this study that can be marshaled together to make an argument about where a teacher's attention is directed. An assumption I make is that no single category or piece of evidence is necessary or sufficient for making claims about where a teacher's attention is directed.

In Chapter One, some of the research I reviewed presented coding schemes for identifying when and how a teacher attended to student ideas. As I discussed in

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7 One wonders if there are special cases where the pretense is of such high quality that one cannot identify the difference between pretend or not, even under the most rigorous examination. I will take precautions to guard against this by also checking my interpretations with others.

that chapter, there are problems with using those coding schemes. The literature on teacher noticing was focused on studying teachers' reflection on classroom events as captured on video. Ainley and Luntley's (2007) coding scheme had categories that could not characterize Heidi's episode well. Although they do not work well for studying shifts in teacher attention at the level of the interaction, they have suggestions for where to look and how to look for evidence of teacher attention to student ideas.

Detailed analysis of classroom discourse and the interviews can show what a teacher noted and what students said and how that teacher interpreted it (Levin, 2008; Rop, 2002). From this data, I will look for how the teacher identified, described, restated, interpreted, synthesized, or extended a student's idea in such a way that the teacher's response seems rooted in the meaning of that idea (Ainley & Luntley, 2007; Jacobs, et al, 2007; Sherin & Han, 2004).

Analysis of teacher attention begins with looking at how the content of each teacher's response relates to what a student communicates. Seeing the relationship between what a teacher says and what the student states requires analyzing the words as well as the discourse cues. In any interaction, the content of a response is often more than the words stated. The person's register, prosody, intonation, gestures, and other meta-communication cues indicate how the words are meant to be taken.

During an interview, which takes place after the lesson, a teacher may not recall an event. This is not necessarily an indication the teacher did not pay attention to that event. Remembrance is not a necessary consequence of paying attention to something. It is possible to hold something in one's consciousness but not recall that matter at a later date. One's memory is not always reliable (e.g., whenever I implement a new organization system, regardless of how much time I put into thinking out the details of the system, I invariably forget where I put things, such as my keys). In other words, a teacher not remembering what a student said *in an interview* is not an indication the teacher did not pay attention to what the student said *during class*.

The specific codes for analysis, which will be seen in Chapters Three and Four, were not developed prior to analysis of each case. The initial analysis of each case was written up separately. After the analysis of each episode was written up, it became clear there was some overlap between the categories of evidence from each teacher's example in this study. As a result, I looked over the analysis of each episode and developed more generic codes. I then reanalyzed the episodes using these more generic categories.

Framing and frames

From the literature reviewed in Chapter One, there are many explanations for why Heidi focused on the vocabulary word vibration. For example, it is possible to use a description of her knowledge, beliefs, and goals to draw a reasonable explanation of Heidi's actions (Brickhouse, 1990; Schoenfeld, 2000; Tsang, 2004). The analysis of Heidi's episode might proceed as follows: Heidi believed that if one knows something, it must be true or at least indicated as correct by authorities on the matter. As the teacher in that classroom, she was the authority for determining correctness. She also believed that, as the teacher, she was responsible for helping her students develop their knowledge (or store of correct information). As a new teacher, she may not have had the experience or knowledge to successfully use the KWL chart as it was intended.

On this view, Marcus's point about hearing was wrong in Heidi's eyes and should not be written down as something he knew. Heidi had not considered a situation where her students would tell her something "off-the-wall" and had no plans for how to handle what Marcus said. When Marcus said, "it vibrates", she likely saw an opportunity to highlight the connection between what a student said and a vocabulary word—a familiar routine for Heidi.

Another explanation is to look past Heidi's specific thoughts and look at how she is part of a system that supports what she did at the end (see for example: Levin, 2008; Rop, 2002; and Tabak & Reiser, 1999). Heidi and her mentor teacher regularly planned assessments together. With regard to science, these assessments typically focused on identifying concepts and terms explored in the unit. Vibration was one of the vocabulary words in this unit and could be expected to show up on the unit test. Given that Heidi was already uncomfortable recording Marcus's incorrect idea, it was likely that Heidi saw Marcus's last statement as a way to link his contribution to the correct ideas of the unit. This is consistent with the approach focused strictly on Heidi's cognition but adds to it by linking the analysis to larger structures that exist beyond this interaction.

However, these perspectives do not explain why before Marcus said "it vibrates" Heidi agreed to write down the incorrect idea Marcus stated even though she was uneasy about it. She said, "(pause) I didn't know that. Alright, (turns to the chart paper) I'll write it down. (moves closer to the chart paper).… Goes through the top of your head? (points to the top of her head) The sound?" She could have told Marcus that he was wrong or ignored his remarks and moved to another student. Instead, she physically and verbally indicated that she intended to record Marcus' point that sound goes through the top of one's head.

These perspectives on the teacher as an individual or as part of a system do not give insight into the moment-to-moment dynamics of attention and shifting attention, such as Heidi's here. For that, I turn to the ideas of frames and framing. In this section, I will describe how I conceptualize framing and frames and what I take as evidence of a teacher's framing of an interaction.

Conceptualizing frames and framing.

As I described earlier, Heidi's framing is essentially her sense of what is happening in that interaction. A person's framing is frequently tacit and can be inferred by how the individual conducts him or herself or talks about the events. This interpretation of events is an ongoing process (MacLachlan & Reid, 1994).

There are many ways a teacher may answer the question, "What is it that is going on here?" Not only are there different kinds of frames (e.g., a dissertation defense versus a conference presentation) there may be different levels of frames, where the frames are nested into each other (Gordon, 2002). For example, at one level, we may consider Heidi as having framed things as an elementary school activity. Going down a level, we may consider her as framing it as a third-grade science class. And going yet to a further level down, she framed it as an introduction to the sound unit. This study is about teachers' attention to student ideas during their interactions with students. The kinds of frames I am interested in are about the activities the teacher and students engage in that are related to ideas in science (whether the students' ideas or someone else's ideas).

Cognitive aspects of frames.

People do not encounter social situations as blank slates. Their experiences in the world generate expectations that help guide how they make sense of what they encounter. Various researchers have theorized about these sets of expectations. In this section I will mainly talk about research that treats these sets of expectations as cognitive constructs. At the end, I will discuss how my sense of framing fits with the ideas in this line of research work.

Bartlett (1932) theorized and studied the connection between past experiences and perception. These past experiences create expectations that influence perceptions. He argued that "the past operates as an organized mass rather than as a group of elements each of which retains its specific character" (Bartlett, 1932, p. 197), which he called the schema. This organized mass of past experiences affects how one perceives and responds to current situations because the current events can be related to what has been experienced in the past. Schemata can be seen to operate whenever there is a regular pattern of behavior because "a particular response is possible only because it is related to other similar responses which have been serially organized" (p. 201). Though the term schema also implies "some persistent, but fragmentary, 'form of arrangement,'" Bartlett cautions against considering these as rigid passive structures. He explained:

> The organised mass results of past changes of position and posture are *actively* doing something all the time; are, so to speak, carried with us, complete,

> though developing, from moment to moment. …It would probably be better to speak of (these schemata as) 'active developing patterns' (Bartlett, 1932, p. 201).

Tannen (1993), like Bartlett, also studied the influence of expectations on perception of events. As a sociolinguist, her approach in one study was to analyze the way her participants talked about a film they watched. In her study, two groups of participants, one Greek and one American, watched a short film and were asked to talk about what they had seen in the movie. The film, which showed a short sequence of events, had sound but no dialogue. After viewing, participants were asked to recall what they saw. In the interview, the way participants talked about what they recalled showed evidence of participants' expectations for activities such as film viewing and storytelling. She also found that these expectations can serve as a sort of filter and shape an individual's experience. This was particularly evident in the false recollections and inferences participants made about the film events. Tannen referred to these structures of expectations as *frames*, and spoke of what the subjects were doing as *framing*.

Minsky (1975), an artificial intelligence researcher, also concerned himself with how individuals' expectations influence recognition and comprehension. He used the term frame to describe "a data structure for representing stereotyped situations" (p. 212). These data structures are essentially networks of nodes that represent information pertaining to the situation and relationships between the nodes. In these structures, there are terminals, or slots, to be filled with specific instances or actual data gathered from the current circumstances. Expectations or presumptions provide default assignments to the terminals. These default assignments function as "textbook cases", which can help the individual identify incoming information As terminals are filled, they also key further assignments and help one know what to expect.

Minsky (1975), like Bartlett, highlighted the importance of past experiences in shaping perceptions and that these are organized into structured sets of expectations. However, the static aspect of Minsky's model makes it difficult to use in analyzing interactions, where change can be a major component. For Minsky, new frames needed to be drawn up if there were changes in what was represented. For example, a bottle floating down a river may be represented by several different frames. Each frame corresponds to a snapshot taken at a different point in time showing the bottle at a new location down the river. Minsky was concerned with developing computers that could behave and process information as a human would. At the time Minsky developed his model, the technology was such that it was not possible for computers to process more continuous dynamic streams of information. His model may have been constrained by the technology available.

Hammer, Elby, Scherr, and Redish (2005) looked at how student expectations helped students frame the intellectual work of their physics classes. In Hammer et al's model, a person's knowledge, beliefs, and reasoning abilities are "comprised of many fine-grained resources that may be activated or not in any particular contexts" (p. 4). These resources form the knowledge, reasoning abilities, and expectations a person uses to conduct him or herself and to make sense of ongoing events. There is no requirement that these cognitive resources generate coherent unified systems of knowledge and beliefs. Depending on the situation, an individual may think and behave in one way, at one moment, and a different, even conflicting way, in another.

These resources organize to help a person frame what is occurring. Hammer et al (2005) explain:

> By a “frame” we mean, phenomenologically, a set of expectations an individual has about the situation in which she finds herself that affect what she notices and how she thinks to act…(W)e take framing as the activation of a locally coherent set of resources, where by “locally coherent” we meant that in the moment at hand the activations are mutually reinforcing. (p. 9)

In this model of the mind, how one thinks can fluidly shift depending on what the person is experiencing. This is similar to how Bartlett considered schemata, ‘active developing patterns.’ The resources one uses to think are activated or deactivated based on the current circumstances. As different resources are activated, the way a person frames things may change.

In this study, I adopt this view of framing, wherein the “organized mass" of past experiences creates dynamic structures of expectations about a situation that constitutes how a person frames what is happening. These frames influence how one notices and interprets events, and they are comprised of context-sensitive cognitive resources. Changes in resource activations may be subtle or dramatic, thus leading to slow or sudden changes in one’s framing. The frames I study are different from Minsky’s (1975) and closer to the phenomenological side of Hammer et al’s (2005) sense of frames and framing. I am more interested in a teacher’s interpretation of events than in the knowledge structures the teacher has.

Heidi's case illustrates the dynamics of framing. In the moment of listening to Marcus's interesting idea, the evidence suggests she framed what she was doing as making sense of what he was saying, and that was the focus of her attention. As it became clear he was talking about sound moving through the top of the head, and she moved to complete the K-column, her framing of the situation became unstable. Perhaps it was the thought of recording something incorrect on the page that activated resources associated with the belief she had that teachers conveyed correct information to students. As a result, she was uncomfortable writing down something she believed to be false.

When Marcus talked about sound vibrating inside one's head, Heidi interpreted that statement as an opportunity to do something she felt more comfortable doing- writing correct information on the chart. By shifting the focus to the vocabulary word, her beliefs about teacher as authority and about helping students acquire correct information became active and supported her decision to disregard Marcus' errant statements.

Social aspects of frame.

The social aspects of a teacher's framing of his or her interaction with students refer to the more interactive elements of the teacher's frame. In this section, I will mainly discuss the research that is more focused on these interactive elements and what aspects of this work I use to build my conceptualization of framing: 1) how the teacher aligns him or herself with others in the interaction; and 2) how the teacher communicates to others how he or she frames the situation.

Roles.

In framing an interaction, a person may take on a position or status in that situation that may govern how that person "manage(s) the production or reception of an utterance" (Goffman, 1981). These alignments are a part of how the teacher frames, which means that shifts in alignment will result in shifts in the teacher's sense of what is it that is going on. By taking on a certain position in the interaction, the teacher also establishes relationships to the other participants and indicates the status the teacher assumes the others will take. Each position is associated with roles, or activities one would normally expect a person in the same position to engage (Goffman, 1974; Tannen & Wallat, 1993).

In this study, my interest is on what roles the teacher adopts in the interaction (and also the roles the teacher attempts to assign to the students). The teacher's role may change (and also their framing) as situations arise that alter how the teacher interacts with students or interprets what students say or do. While I acknowledge a person's role is as much adopted by an individual as it is laid on that person by others, I am interested in understanding how the teacher understands what role he or she is in, whether that is a role the teacher consciously chooses, and how that role relates to the teacher's attention and his or her framing of the situation.

Once a frame is established, there are constraints on what the participants can or cannot do, as determined in part by the roles they are allowed to adopt in that frame. Sawyer (2003) studied improvisational comedy groups to explore how frames emerged from interactions. He showed that as the frames became more settled in each scene, it developed a life of its own. The frame came to constrain what the players could or could not do, the relationships between the players, and the possible meanings of their past, present, and future actions or words. This may help explain why Heidi continued to act as if she was going to write down Marcus' idea even though she was not at ease with that decision. In her initial framing of the situation, her role only allowed her to write down what her students told her. The inertia of the original frame was greater than her discomfort at that time and constrained her actions. Towards the end of the conversation, the original frame destabilized enough to allow for shifts in how she thought of her role and what she thought about what they were doing.

Metamessages.

People communicate with each other, often in implicit ways, about how they frame ongoing events. These metamessages indicate how one's actions and words are intended, what kind of activity he or she thinks is going on, and what that person thinks is his or her status and role in that activity.

Anthropologist Bateson (1972) argued that verbal communication between human beings "can and always does operate at many contrasting levels of abstraction" (p. 177). Bateson's interest was in how people come to understand the messages they communicate to each other (e.g., this is a joke versus this is an act of aggression), not just the literal meaning of the words. In normal conversation, information is regularly conveyed at many levels. At one level, there is the literal content of the statement (e.g., "the top of your head"). At another, there is information about how the statement was intended (e.g., a tone of voice indicating sincere interest) as indicated by things such as tone of voice or gestures. These levels of abstraction are part of the construction of the ongoing activity. As we interact with one another, we send along metamessages that communicate about the communication. Bateson described these “metamessages as psychological ‘frames’ which can guide and correct the way we interpret our exchanges with each other. These messages tell us not what they say but what they mean” (MacLachlan & Reid, 1994, p. 41).

Tannen & Wallat (1993) conducted a detailed study of a medical examination to look at how individual’s behaviors in that meeting corresponded to what they termed *interactive frames*. Interactive frames refer to “a definition of what is going on in interaction that indicates how a message is to be interpreted” (p. 59). In their study, a cerebral palsy patient visited her doctor for a checkup. The patient was a child and was accompanied by her mother. Also, this meeting was filmed with the intent of using the film in training future medical residents.

During the medical examination, the doctor shifted between three different frames: 1) a social frame, which included entertaining the child and establishing rapport with the mom; 2) an examination frame, where she examined the child, reported to the film crew, and ignored the mom; 3) a consultation frame, where she consulted with the mom, keeping the child “on hold”, and ignored the film crew.

While in the consultation frame, the doctor responded to the mom’s question with detailed responses and conversational language to help the mom understand what the doctor meant. In the examination frame, while reporting her findings to the film crew, the doctor adopted what Tannen and Wallat (1993) termed the “reporting register.” Here she spoke without hesitation and used more formal medical terms. The assumption here was that the real audience was the future medical students, not necessarily the film crew. While entertaining the child, she adopted a teasing register (e.g., the doctor inquired about whether or not she would find peanut butter and jelly in the various parts of the child's body the doctor needed to examine. These different registers helped to indicate to the others in the room who the doctor was talking to and what the doctor was doing.

Given the complexity and ambiguities in human communication, one needs to indicate to others how to understand what one says and what it is that one is doing. In my conceptualization of framing, the metamessages are a part of a teacher's framing of the interaction. In the interaction, the teacher communicates to students how they ought to consider what the teacher is communicating as well as how the teacher understands the students. The metamessages a teacher conveys are often not explicit declarative statements but are folded into the way the teacher conducts him or herself.

Comments.

In summary, I follow with Hammer et al's (2005) depiction of framing: the activation of a locally coherent set of resources that help an individual construct the individual's expectations for any given situation in which he or she finds him or herself. These frames correspond to the teacher's interpretation of what is going on. There are social and cognitive aspects to a teacher's framing of a situation. The cognitive aspects highlight how and what one thinks (e.g., the kinds of knowledge, beliefs, schemas, expectations, and other cognitive resources that are appropriate to the situation at hand). The social aspects highlight the more interactive aspects of a teacher's frame: 1) the metamessages indicate how the teacher wants to be understood as well as how the teacher understands his or her students; and 2) the teacher's sense of his or her role(s) as well as what he or she expects students' roles to be in that interaction.

Analyzing frames.

In the complex social environment of the science classroom, there are many frames at play (e.g., frames about socializing in the classroom or transitioning between parts of a lesson). In this dissertation, I am primarily interested in how teachers frame their interactions with students when students offer up their ideas. To participate effectively in a shared activity, such as a discussion, a teacher needs to communicate to the other participants how he or she frames the interaction (Tannen, 1993). How the teacher interprets the interaction can be indicated by the gestures, prosody (the stress, intonation, and rhythm of what is said), footing, register, intonation, pacing, attention, and the words the teacher uses (Goodwin, 2000; Gordon, 2002; Hammer, Elby, Scherr, & Redish, 2005; Hoyle, 1993; Scherr, 2008; Sawyer, 2003; Tannen, 1993; Tannen & Wallat, 1993). Regarding the content of teacher statements, I looked at: 1) what the teacher highlighted or marked as relevant; 2) inferences or interpretations the teacher made; and 3) the teachers' omissions of, or incorrect references to, what students said.

Looking at Heidi's episode in a bit more detail may elucidate the method of analysis. In the first seven turns of dialogue in Heidi's episode, Heidi seemed to have framed the interaction as "Filling out the K-column with what students said." Heidi's attention was directed at what Marcus told her about hearing. Her questions and tone of voice indicated that she was not clear what he meant and needed him to clarify his statements (e.g., "What do you mean by that, most of your sound? ...Goes through the top of your head?”). Though there is some indication that she was unsure about putting down what Marcus (indicated by the 3-second pause), she seemed committed to writing down what her students told her (“I didn’t know that. Alright, (turns to the chart paper) I’ll write it down (moves closer to the chart paper)”).

In the very last line of this episode, Heidi’s tone of voice and volume is qualitatively different from the first seven lines of dialogue. The quality of her voice and her smile indicated that she was very excited about the word vibrations. What she highlighted here with her excitement was not Marcus’ idea but a vocabulary word. This change in how she responded suggests she changed how she participated in the exchange with Marcus. Changes in how one participates can indicate changes in how one frames the interaction.

In addition to the classroom evidence, evidence from the interviews can be used to indicate what was pertinent to the interaction, what roles were appropriate, what the teacher expected, what goals were pursued, and how the teacher thought about the events. These are all a part of the teacher’s framing of an interaction.

Collection process

This study utilized two different kinds of data: classroom data and interview data. The classroom data took the form of digital videos and field notes of classroom activities, as well as copies of student work, texts read in lessons, curriculum guides, worksheets and other such materials relevant to the classroom activity. The classroom data was analyzed for evidence of what the teacher attended to and how the teacher framed the interaction he or she had with the students. The interview data was comprised of informal follow up interviews and semi-structured stimulated recall interviews that utilized video clips to encourage teachers to recount their thinking that was concurrent with the events in the video. The interview data was used to provide support for the analysis of classroom data as well as to gain insights into the teacher thinking associated with the interactions in the classroom. In the following sections, I will discuss the data and the collection process in more detail.

Before we begin a discussion of the details, I would like to make a few general comments about my data collection and methodological approaches. The episodes and participants were chosen purposefully (Miles & Huberman, 1994) to help me explore this phenomenon of teacher attention to student ideas. These were used to develop examples of how teacher attention is organized during their interactions with students.

The Modifications Project: a description of the data from the overarching project.

The data for this study is part of a larger data set from a research and professional development project called, “What influences teachers’ modification of curricula?”, which was supported by NSF grant No. ESI 0455711. This project, which I will refer to as the Mod Squad Project, lasted three years. Initially, the project was focused on kinds of modifications to curricula teachers made in the course of teaching and what influenced those decisions. Our original hypothesis was that modifications that were responsive to student thinking would have a positive impact on student learning. After a few months into the project, we changed the focus of the project because: 1) teacher modifications were mostly superficial and could hardly be counted as modification of curricula (e.g., replacing the use of cross and check marks with smiling and frowning face icons); and 2) it was rare that the teachers taught in response to student thinking in class. After extensive discussions among the project research staff, as well as among the staff and the teachers, we decided to change the project's focus. For the next year and a half, the focus of the project was on helping teachers develop their skills for attending to and making sense of student ideas. In the final year of the project, the teachers selected an episode from their data set and wrote a case study about that episode.

In the Mod Squad Project, the teachers were organized into subject matter cohorts: physics, biology and environmental science. The teachers met for two weeks during the summer (from 8 a.m. to 4 p.m. each business day) to engage in professional development activities. In addition to those summer meetings, each cohort met twice a month during the academic year for two hours after school. Since the data for this dissertation came from the activities related to the school year and not the summer professional development, I will explain only the academic year activities. At these meetings, two teachers from each cohort would present a short video segment, which we called a snippet, from their classes. Each teacher's snippet was allotted an hour for discussion. During those discussions, teachers and research staff explored what evidence of student ideas could be seen in the videos and how those students engaged in the practices of science. A team of research staff members, at least one of the principal investigators and a research assistant, were assigned to each cohort. All members of the team were equally active in the planning and facilitation of the meetings. As a research assistant of the physics cohort, I also collected the data on each physics teacher for this project.

With each observation, I recorded the lesson on video and audio tapes and took detailed observation notes on the discussions in the classroom and what was written on the blackboard. When possible, the teacher provided me with copies of student work, the curricular guides, the texts read, the worksheets, and other such materials that were relevant to the lesson. It was not always possible to obtain copies of these ancillary materials because the teacher sometimes returned the student work before copies were made or some of the associated materials were lost. Occasionally, the teachers supplemented that collection by taping their own classes.

After each observation, I also conducted follow-up interviews asking each teacher to reflect on the lesson. I made observation notes as well as an audio tape recording of each interview. Each follow-up interview took between 20 minutes to one hour. During these conversations, the teachers and I would discuss what portions of the class we found notable with the intent of selecting a section to present at an upcoming cohort meeting. Sometimes, the teacher did not have a preference. At this point, depending on whether or not we had enough presentations for the next meeting, I would suggest that the teacher look over a copy of the video (that I would provide in a day or two) and identify a portion of the lesson he or she would like to present or I would make a suggestion of what segment to use. More often than not, I selected the segment for the teacher to present. I chose segments based on what part of the lesson I thought was the richest in student thinking about the lesson topic or had the most potential for engendering teacher discussions about student thinking, learning and teaching, at the cohort meetings. I also conducted some more in-depth video-stimulated recall interviews, which are discussed in more detail below.

The data set for this dissertation.

In the following sections, I will describe in more detail the data for this dissertation as well as how it was collected and selected for analysis.

The class data.

The teachers in this study were part of the physics cohort. These teachers taught ninth-grade physics or introductory physical science in high schools located in the urban fringes and suburban neighborhoods that surrounded a major mid-Atlantic metropolitan area in the United States. All students are identified by pseudonyms.

I observed each teacher in this dissertation at least twice each semester that the teacher participated in this study. For the most part, I was able to observe the teacher more frequently. The teacher chose which classes and lessons were observed. They tended to choose ones that had lots of student activity and conversations. These lessons were likely atypical. It was clear from informal discussions with all the teachers in the Mod Squad Project that they thought of 'taping time' as a time when there should be a lot of student talk, which may or may not be the norm for their classes.

I arrived at each observation with video and audio-recording equipment and a notepad to record the events. I tried to position myself and the recording equipment in such a way as to minimize intrusion on the lesson.

From Heidi to this dissertation.

Before I explain how the episodes for this dissertation were selected, I will explain how I came to study this phenomenon in the first place. The episode presented at the beginning of this dissertation is from a pilot study I conducted the year prior to the onset of the Mod Squad Project. That year, I was Heidi's methods instructor and supervisor. I asked everyone I supervised if they would be interested in participating in a pilot study for my dissertation on how pre-service teachers think about the teaching and learning of science. She and three other teachers agreed to participate in that study.

The episode took place in the spring, during Heidi's student-teaching experience. From my observations of Heidi up to that point, she seemed like a competent new teacher. She seemed comfortable leading class activities, managing students, and preparing for her lessons. Heidi seemed fairly good at listening to and building on student ideas, especially in reading-comprehension activities.

At that time the episode also perplexed me. She started the exchange with responses that resulted in a deeper exploration of Marcus's idea but then ended the interaction on a note that effectively replaced his statements with a canonical idea. I was confused by why this episode occurred the way it did. As her supervisor and as a researcher, I wanted to understand why she responded to Marcus the way she did and what she thought about that episode.

In my role as her supervisor, I conducted a post-observation discussion with Heidi where we discussed the difficulties she experienced in using the KWL chart, as well as with the other aspects of the lesson, and explored ways to overcome those difficulties. Heidi's mentor teacher was present for part of this discussion. As per her mentor's suggestion, she decided that in the future, she would modify the KWL chart so that the Know-column would become a "What do you *think* you know?" column instead. Though she did recognize the difficulties she had with the chart, it is not clear how effective I was as her supervisor in helping Heidi see the conflicting metamessages in her responses to Marcus. I have since lost contact with Heidi and have not had a chance to share with her my analysis of the episode.

In my work as a research assistant in the Mod Squad Project, I encountered the same perplexing situation during two observations. In both classes (the set of episodes from Joanna and Dave), the teachers wanted to engage students in an activity that would allow students to talk about their ideas about a certain topic. In addition to interacting with students in ways that resulted in deep exploration of students' thinking, these teachers' responses encouraged students to engage in authentic scientific practices, such as critiquing claims and developing mechanistic explanations for phenomenon. In many ways, these teachers exhibited teaching practices that answered the NRC (1996) calls to "display and demand respect for the diverse ideas, skills and experiences of all students" (p. 46) by "(f)ocusing on student understanding and use of scientific knowledge, ideas, and inquiry process skills" (p. 52). But in those same activities, though at a different moment, the teachers seemed to also ignore their students' ideas. Again, I wondered what might have contributed to the shifts in their attention.

Interview data.

In this study, I used two kinds of interviews: follow up interviews and video-stimulated recall interviews. The interviews provided an opportunity to gain the teacher's perspective (Bogden & Biklen, 2003). The follow up interviews were very loosely structured, informal interviews aimed at gathering information about the teacher's general sense of the lesson at the time (Patton, 1990). These generally occurred immediately after the lesson. These interviews represented attempts to capture those fleeting impressions that were a product of the many factors present at that moment, such as a teacher's cognitive and emotional state, the forces acting in that situation (e.g., curricular or department demands, teacher goals, and the social lives of students that impact their work in the classroom) and the events that led up to the lesson.

How and what a teacher thinks, as well as what he or she says about that thinking is situated in particular contexts (Barnett & Hodson, 2001; Clandinin & Connelly, 1996; Speer, 2005; Tsang, 2004). To understand what that teacher might have thought about the particular circumstances, the interviews needed to help root out what the teachers said in individual examples and situations. The stimulated recall interview had a slightly more formal structure and utilized a video snippet from one of their lessons (Lyle, 2003; Speer, 2008). These latter interviews were used to gain access to the teacher's thinking as it related to the details of that snippet.

Follow up interviews.

As described earlier, after each observation, I conducted a follow up interview. These typically lasted somewhere between 20 minutes to one hour. In these open-ended discussions, teachers would sometimes mention other things relevant to their lives as teachers, e.g., department pressures to keep pace with the curricular schedule or factors from outside of the class that impacted what was going on in that lesson, such as an upcoming science fair.

Stimulated recall interviews.

In addition to the follow up interviews, I conducted a series of stimulated recall interviews with each participant to help me understand what went on in the episodes. Each interview lasted about an hour and was focused on a select 10 to 15-minute video segment of a lesson. The video segments used in these interviews helped stimulate recall of events and thoughts from that lesson. I intentionally used video segments that were longer than the episode in which I was interested, because it was important to understand what led to and followed the episode to help flesh out the context for that interaction.

During the interview, the teacher and I watched a video segment, pausing every 10 conversational turns (approximately one minute). After pausing, we would informally talk about that clip. I used the questions in Appendix A as a loose guideline to help structure the discussion. These short segments helped make the details of the interaction between the teacher and the student(s) the central focus of the teachers' comments. In the pilot study that included data from Heidi's class, longer segments tended to result in more general or abstract comments that reflected the teachers' declarative philosophy about teaching and learning, or evaluations of their teaching, rather than an explication of what was going on.

Occasionally, the teacher began commenting without prompting about the classroom data before 10 turns or one minute had passed. If this happened, we stopped the video and discussed the teacher's comment or what had occurred on the video. When the discussion came to a natural end, we would begin viewing again.

Participant selection

Participants were chosen for this study purposefully (Miles & Huberman, 1994). Originally, five high school physics and physical science teachers from the Mod Squad project were invited to participate in this dissertation study. These teachers were selected because they seemed comfortable discussing their thinking in interviews. Furthermore, students in their classes seemed comfortable talking in class. From this original set, only two teachers, Dave and Joanna, are presented in this dissertation.

One of the difficulties I encountered was that it was rare that I saw teachers attend to the substance of student thinking in their classes. It is hard to understand why teachers shift their attention away from student ideas if they do not attend to those ideas in the first place. I invited John (the third teacher presented in this dissertation) to participate in this study because I saw evidence that John sometimes paid attention to the substance of his students' ideas. Moreover, in those moments when he did pay attention to their ideas, his students seemed to engage in authentic science inquiry practices. In addition to enlarging my data set, John added a new dimension to the study. John was a more experienced teacher than Dave and Joanna. Though his case did not exactly mirror Joanna's and Dave's cases, his attention did seem to be constrained by the way he framed the interaction, just as it did in Joanna's and Dave's cases.

It is not surprising that some of the teachers in this study did not exhibit evidence of attention to student ideas in their classrooms. As noted in Chapter One, there is research that shows that teachers do not attend to student ideas unless there is substantial support to encourage and direct attention in that way (for example: Levin, 2008; Levitt, 2004; Sherin & Han, 2004; Simmons et al, 1999; Star & Strickland, 2008; van Es & Sherin, 2006). Attending to student ideas is not common practice. This may be because there are substantial pressures that direct attention away from student ideas (Levin, 2008; Rop, 2002).

Participants and their classes.

In this section, I will briefly describe the episodes I present in this dissertation. There are two episodes from each teacher. A more detailed discussion of each episode will take place in Chapters Three and Four where I show the analysis of the teacher's attention. For readers interested in a discussion of the background of each teacher and their classes, please see Appendix D.

Dave's two episodes: The Galileo Questions Worksheet.

The two episodes discussed in this study are from the beginning of a lesson that took place in the spring, where students worked on a worksheet aimed at eliciting student ideas about falling objects. This worksheet was developed as the result of conversations during one of the cohort meetings in the first year. During this meeting, Dave presented a snippet of his students calculating problems on falling objects. As we watched the video, it became apparent that the presentation of the calculations did not provide much insight into his students' thinking. In our discussion, we explored a series of questions scenarios to elicit student ideas about falling objects. One of the Mod Squad Project leaders, Andrew Elby, collected our ideas and generated the Galileo Questions Worksheet (see Appendix B).

Though the class had already moved past the topic of falling objects, Dave decided to have his students spend a class period on the worksheet, just to see where they were conceptually. On the day of the class, Dave asked his students to start by working privately or with a neighbor on the worksheet. During this seatwork time, Dave repeatedly told his students to write down what they thought in response to the scenarios and questions that were presented and not be concerned with whether or not the answers were correct. After the seatwork time, Dave convened a whole class discussion on the student answers to the worksheet questions.

Joanna's two episodes: Introduction to the phase changes unit.

The two episodes analyzed in this dissertation are from the warm-up discussion in the introductory lesson to the phase changes unit. Initially, Joanna had planned on having a short warm-up discussion about the science behind the sport of curling. Her hope was to engage her students' interest and possibly draw connections between the law of conservation of energy and the topic of phase changes. However, the conversation did not go as planned; they never touched on the law of conservation of energy. Even so, Joanna was so impressed by the level of sophistication in the dialogue that she let it go on for more than 28 minutes. In a 45-minute class period, this was a significant portion of the lesson.

John's two episodes: Reciprocal reading activity.

The two episodes analyzed in this study are from what is known in John's class as the reciprocal reading activity. This is an activity John learned about during a county professional development workshop aimed at exposing teachers to different activities that would help students develop reading-comprehension skills. This was a modified version of Palincsar & Brown's (1984) reciprocal teaching strategies. It is not clear whether the modifications were John's own or from the professional development workshop.

In his class, students were asked to read a passage in the textbook, typically a paragraph-long explanation of a scientific concept or term. Then different students either volunteered or were assigned the roles of the summarizer, the word finder, and the questioner. John explained in an interview that he occasionally would have students predict what the next paragraphs would discuss. After reading, the person assigned to the role of summarizer would summarize the passage in a sentence or two. John would record this on the board for the class to copy into their notebooks. Usually, John would ask if anyone in the class had anything else to add to the summary. If so, he would also record those additions.

The word finder identified a word that he or she thought was difficult and the questioner posed a question that he or she had about the reading or related to the reading. Typically, John solicited answers, thoughts, or further questions from students about definitions for the word finder's word or the questioner's question. If student responses were not forthcoming, then John would ask other questions to encourage students to think about related situations or words. His hope was to help students learn to figure things out by themselves or turn to each other for help when they encountered things they did not understand instead of relying on the teacher for answers. Occasionally, the class discussion continued past the original question or word to talk about related topics of which the students were curious.

Chapter Summary

Whether her attention was directed toward or away from Marcus' idea, Heidi's attention seemed linked to how she framed their exchange. When framed as something like, "Filling in the K-Column with what students said," she attended to what Marcus meant because in the activity at hand, it was important for her to understand what he said. When it was framed as something like, "Filling in the K-Column with canonical information," attending to what her student meant was no longer important, especially if their ideas were wrong. Instead, her attention was directed toward the correct ideas associated with the curriculum she used.

In this study, attention to student ideas means the act of focusing one's mind on those ideas so as to try to understand the meaning of what students communicate. A person's frame is essentially that individual's answer to the question, "What is it that is going on here?" Unlike attention, which involves awareness, one's framing of a situation is often tacit. How one answers this question has implications for how one thinks, acts, and relates to others in that interaction. There are cognitive and social aspects to one's frame. Since one's framing of a situation is dependent on others as much as on how one behaves and sees things, how one frames an interaction is vulnerable to shifts. Lastly, as a frame becomes established, it may exert constraints on a person. This may help explain why Heidi continued with her intention of writing Marcus' idea even though she was uneasy with writing down a noncanonical statement.

Chapter 3: Teachers' Attention Directed Toward Student Ideas

Introduction

In Chapter One, we saw Heidi interact with Marcus. For most of the episode, she seemed to be focused on the substance of Marcus' idea, or what he seemed to be thinking. She asked him things like, "What do you mean by that, most of your sound?" and "Goes through the top of your head? (points to the top of her head) The sound?" And yet, there is a sense she was not focused on what Marcus meant when she exclaimed the word vibrations. As discussed in Chapters One and Two, we do not have a good way of identifying when a teacher's attention is directed toward or away from students' ideas during their classroom interactions with students, especially if that attention shifts.

In this chapter, I focus on episodes from the teachers that show their attention is directed toward the substance of their students' thoughts. I will begin by laying out the categories of evidence used to identify when a teacher's attention is directed toward student ideas. Then I will apply this to each example to show instances of these teachers attending to their students' ideas.

The work in this chapter and Chapter Four should be considered a set that explores how we may characterize teachers' attention to student ideas during teacher-student conversations. In Chapter Four, I will look at episodes where it seems attention is directed away from what students are thinking.

Categories of Evidence for Attending to Students' Ideas

As discussed in Chapter Two, analysis of teacher attention relied heavily on classroom data; the interview data was used to explain motives and rationale to supplement this analysis. From the analyses of the three teachers, categories of evidence emerged. The teacher attended to student ideas if in the responses to students, he or she: 1) built on student ideas; 2) asked a student for clarification; 3) interpreted student ideas; 4) explored aspects of students' ideas; 5) reflected students' ideas back to them; 6) called the class' attention to a student's idea; 7) returned to a student's idea at a later time; 8) noted differences between student ideas.

The differences between the categories are not always clear. For example, in building on a student's idea, a teacher may also explore or interpret aspects of that idea. The inter-category differences are not central to the argument of this dissertation. What is germane is that there is evidence the teacher attended to the substance of student thinking.

Some of the categories of evidence are weaker than others, such as reflecting students' ideas back at them. Supporting evidence from interviews or other pieces of data may be used to bolster arguments made from such evidence. For example, one can repeat the sounds one registers with the ears but not have any sense of the meaning behind those sounds (e.g., first-graders reciting the Pledge of Allegiance). But if the teacher, in the interview, explains that he purposefully reflected the statement back to the student to focus the discussion on what the student said and the class data supports this explanation, then there is strong evidence the teacher attended to his student's idea.

Built on students' ideas.

Extending on an idea is evidence the teacher paid attention to the idea. A teacher needs to have heard and understood what a student said to know where to go with that student's idea. If the teacher incorporated actual phrases a student used in ways that preserved the meaning of what was said, this is strong evidence the teacher was paying attention. Using the student's words in a new way, while still maintaining the original intent, requires attention to what was said.

However, simply using the words that students say does not mean the teacher was attending to the ideas. For example, a teacher highlighted a word in the student's statements and used that to launch into a lecture that was unrelated to the crux of what the student articulated. This does not count as evidence the teacher paid attention to the student's idea. In order for what the teacher did to count as evidence of attention, the teacher needed to use what was said in such a way that preserved the original point.

Asked a student for clarification.

When a teacher asks a student to clarify what she meant, this counts as evidence the teacher was paying attention to student thinking. There was something behind the words the teacher wanted to understand (or wanted the class to understand). If in asking for clarification, the teacher asked the student to explain specific details of her idea, that is strong evidence of attention. To recognize that certain details of the idea were unclear, the teacher needed to have been paying close attention to the substance of what was said.

Interpreted students' ideas.

To process the meaning of what a student communicates, a teacher needs to sustain a focus on what is said so it can enter into awareness. In any interaction, it is possible to misinterpret what another person says. Misinterpretation may be considered evidence of attention if it fulfills the criteria that, given the circumstances, it was a reasonable misinterpretation. However, this is different from attributing ideas to students that seem inappropriate.

Consider the following hypothetical example to illustrate the difference between the two. A class discusses what might happen to the bottle cap if a sealed bottle is heated. One student suggests, "The cap will fly out because it got hot." There are many ways to interpret that statement. Two possible interpretations are: 1) the student thought the bottle's contents got hot and it pushed the cap off, much like the buildup of steam inside a boiling kettle; 2) the student thought the bottle cap got hot and moved off, like popcorn heating up and popping. An unreasonable interpretation would be to claim the student was talking about the law of conservation of energy because he understood the process of energy transfer from the flame to the bottle cap. There is not enough evidence in the student's statements to justify such a leap.

Reasonable misinterpretation and inappropriately attributing ideas to students are two ends of the same spectrum. Judging between two is a somewhat subjective process — after all, it relies on one's interpretation of the circumstances. There are ways to test that judgment. In generating the analysis for this study, I compared my initial reading of the situation with what others saw. First, each teacher had the opportunity to closely revisit the episode in the stimulated recall interviews and provide their assessment of their own interpretation. Second, the episodes were watched and discussed at the cohort meetings and/or Mod Project research staff meetings. By checking my analysis against others, I was able to confirm, refine, or reject my initial thoughts.

Explored aspects of students' ideas.

Exploration of students' ideas requires holding one's attention on those ideas. There are many ways to explore ideas. For example, a teacher may discuss with a student the implications of her idea. In some ways, talking about the implications of an idea may involve interpreting the idea or extending the idea. This category of evidence frequently overlaps with other categories. However, I purposefully kept this as a separate category because teachers sometimes inquire about aspects of their students' ideas simply because they want to explore it and not necessarily because they want to clarify or build on what students said. Additionally, the differences between the categories are not as relevant to the arguments as that there is evidence of the teacher's attention.

Reflected students' ideas back to them.

When a teacher reflects back to students what they say, such as Minstrell's *reflective tosses* (van Zee & Minstrell, 1997), this shows some evidence of attention being directed toward student thinking. However, this is not very strong evidence of attention. Other pieces of evidence will be required to produce a strong argument about the teacher's attention. For example, a person may repeat what another person says without being aware of the meaning of the words, much like the thousands of first-graders in the United States who recite the Pledge of Allegiance by repeating after their teacher.

There is a more complicated example of this situation. It is also possible the teacher heard a student and reflected it back to the student but then directed the conversation away from what was said. Consider the following example.

Student:	The battery sends out electrons from the negative end and protons from the positive end. The charges meet in the light bulb and that's why it lights up.
Teacher:	(raises one eyebrow and speaks with a skeptical tone) The battery sends out electrons from here (points to the negative terminal of the battery) and protons from here (points to the positive terminal of the battery)? Well, that's wrong. The battery only sets up a potential difference which causes the charges in the rest of the circuit to move. Now can anyone tell me why the charges in the circuit move?

The teacher repeated what the student claimed about the battery and the gestures used to supplement the teacher's words matched with what the student said. This indicates that the teacher did, in the moment, pay attention to the student's idea. But there is evidence the teacher's attention was quickly directed away from the idea. At the end of that turn, the teacher made the correct idea central to the discussion. More about how to determine when a teacher's attention is directed away from students' ideas will be discussed in Chapter Four.

Called the class' attention to what a student said.

When a teacher calls attention to what a student said, that is evidence the teacher paid attention to the student's ideas. Like evidence in the reflection category, this also is weak evidence. Calling attention to what a student says may sometimes be a classroom-management move and does not require attending to the meaning behind the words (e.g., "Everyone quiet down and listen to what Julia has to say, please"). If the teacher exhibited other evidence of attention, such as presenting an interpretation of the student's idea or making what was said a critical part of the subsequent intellectual activities of the class, then there is a stronger argument for saying the teacher attended to the student's idea.

Returned to a student's idea at a later time.

When a teacher returns to what a student said at a later point in time, that is evidence the teacher paid attention to the student's idea. The teacher heard the idea, stored it in memory, and brought it up again at a relevant moment. Sometimes, a teacher may make curricular modifications in response to a student's idea. In other words, the teacher changes what the class does (or was going to do) because of what a student said. This is one example of returning to a student's idea. A curricular modification that is responsive to student thinking is strong evidence a teacher paid attention to the student idea.

Noted differences in students' ideas.

When a teacher notes differences in ideas students express, the teacher paid attention to those ideas. 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.

Section summary.

This list is not definitive. It is simply what has emerged from this set of data. It is possible there may be other categories of evidence as well. Before we proceed with a presentation of the data, some final comments are needed. As discussed in Chapter Two, it is important to look at more than one line uttered by the teacher. In understanding the sustained focus of the teacher's mind, it is necessary to look at the entire interaction. Additionally, it is important to look at more than one category of evidence to develop an argument about the attention in the interaction. Lastly, it also is important to understand a teacher's responses in relation to what the students say or do (as was noted in the category on interpretation) and not just what the teacher said (or did) in isolation.

Dave's Class on the Galileo Worksheet

This episode is from the day Dave had his students work on the Galileo Worksheet, the one developed during a Mod Squad Project Physics cohort meeting. At the beginning of class, he instructed his students to work privately or with a neighbor on the worksheet for 15 minutes. During this time, Dave walked around the class, checking in on various student groups, and addressing any questions or concerns they had. As he walked around, he reminded his students to write down what they thought in response to worksheet questions and to not be so concerned with getting the right answer.

After those 15 minutes passed, Dave called his class together to talk about students' answers to the questions. Discussions about the questions varied from students disagreeing about the answers to critiquing the wording or scenarios in the questions to comparing the scenarios with real-life situations. For most of the questions, Dave did not indicate what the correct answer was and only solicited ideas from students. But in one question, Question 2, Dave provided the correct answer after the first student presented his answer.

As explained in Chapter Two, Dave's intention with this day's lesson, consistently stated in multiple interviews, was simply to understand his students' ideas. He hoped that by seeing where his students were, he would be in a better position to correct any student misconceptions about gravity. He also saw this day's work as an opportunity to help his students expand their logical thinking skills. By encouraging them to explore and develop their ideas, both in conversation and on paper, he hoped he could help his students strengthen their reasoning abilities.

A few minutes after the beginning of the seatwork time, Dave wandered to the back of the room where George and Naveed worked. After Dave sat down on a stool by them, George initiated a discussion with Dave about the first question on the worksheet, which is presented below.

1. A bowling ball and a small rock are dropped at the same time from the same height. Which one lands first? Here is a student's answer:

   STUDENT: "They land at the same time. If there were no air, the bowling ball would land first. But air resistance slows the bowling ball down, so they land together."

   Do you agree with the student's reasoning? Disagree? Explain.

George began by explaining that he did not think that would happen. Instead, he argued, the bowling ball would fall more slowly because it did not have air assisting its fall.

53.	George:	If there wasn't no air the ball would be coming down very very slow.
54.	Dave:	If there was no air?
55.	George:	Yeah.
56.	Dave:	So you're saying it would come down slower if there was no air.
57.	George:	See like this (holds a book up and moves it down slowly) very slow. Like this, very slow, steady, because there isn't any air.
58.	Dave:	So you're saying air makes things fall faster.
59.	George:	Yeah. (turns to write on worksheet)
60.	Dave:	OK.
61.	George:	(8-second pause while writing) How high is this thing? Like if you dropped it, how high is it?
62.	Dave:	For which one.
63.	George:	For number one.
64.	Dave:	Number one, it doesn't matter, any height.
65.	George:	I mean, if you drop this from a certain height, it wouldn't, [the book?/they both?] wouldn't hit the ground.
66.	Dave:	Not at the same time?
67.	George:	Nah.
68.	Dave:	(pause) So are you saying the higher up that you drop something, like, the less likely they are gonna hit the ground at the same time?
69.	George:	Yup.
70.	Dave:	OK why?
71.	George:	Because it's heavier. Say look, say like, if I got, if I stand on top of this (slaps the top of the lab bench), right, and [we drop?] this (holds up a book), [along?] with this (reaches for another object) the binder's gonna drop first.
72.	Dave:	The, that one's (pointing to the book) gonna drop first?
73.	George:	No (slaps other object).
74.	Dave:	No this one. Why?
75.	George:	Because it's a lot heavier.
76.	Dave:	So, heavier, you're saying heavier objects fall faster than lighter objects.
77.	George:	Yup.
78.	Naveed:	That's not true.
79.	Dave:	You don't think that's true? Why not?
80.	Naveed:	On earth it's not true.

81. Dave: On earth it’s not true?
82. Naveed: Air resistance.
83. Dave: So air resistance plays a role in how fast things fall? Like how. How does air resistance affect how things fall?
84. Naveed: Like if you drop this book and this pencil, they’re gonna fall at the same time.
85. (George gets up to drop the binder and pencil
86. Dave: But…OK just be careful near the equipment, here do it over here.
87. George: Right here?
88. Dave: Actually, here, do it on that desk.
89. (George drops the objects and both hit the desk at the same time.)
90. Naveed: See, it didn’t. That’s why I got an A in this class.
91. Dave: So wait-do you still think that heavier objects fall faster?
92. George: (nods) I mean, for real though, if I stand up on top of here (pointing to the lab bench) and drop both of them (holding hands out at the same height), this (places hand on binder) gonna land first, before that pen.
93. Dave: If you’re, so you’re saying if you were up a lot higher, it would be more clear that this one would fall faster than the pen.
94. George: Yup.
95. Dave: OK, why, why do you think that?
96. George: I don’t know, I just know! It’s gonna happen.
97. Dave: OK all right. I’m trying to get you to think about why that would happen. So that’s what I want you to write down. Why do you think that would happen, why do you think heavier objects would fall faster than lighter objects.
98. George: Why?
99. Dave: Yeah.(to class) OK you’ve got about 5 minutes.

After this episode, Dave traveled around the room to check on students. Then he called the class’ attention and proceeded to hold the whole class discussion about the worksheet answers.

Evidence of attention to student ideas.

In this episode there is strong evidence that Dave focused attention on the ideas his students, George and Naveed, articulated. Dave’s questions and comments highlighted and reflected details of what they told him. He also interpreted and explored what they told him. As Dave explained in the interview, this was his effort to get his students to explain more of what they thought. To understand what parts of George's idea needed more articulation and to be able to ask about those parts, Dave needed to have been paying attention to George's ideas and how he was talking about those ideas.

Reflects student ideas.

In this interaction, seven of the 19 conversational turns that Dave made involved repeating back to the student what the students said (lines 54, 56, 58, 76, 79, 81, 93). For example, at the beginning of this interaction, for three turns of the conversation with George, that was all Dave did.

53.	George:	If there wasn't no air the ball would be coming down very very slow.
54.	Dave:	If there was no air?
55.	George:	Yeah.
56.	Dave:	So you're saying it would come down slower if there was no air.
57.	George:	See like this (holds a book up and moves it down slowly) very slow. Like this, very slow, steady, because there isn't any air.
58.	Dave:	So you're saying air makes things fall faster.

Dave explained in an interview, he had a pedagogical purpose for relaying what his students said back to them. For example, at the beginning of the episode with George, he wanted George to spend time thinking about his ideas.

> Dave: If that's an idea that's already entrenched in his mind, or even not firmly entrenched, but if it's like present in his mind, then I want him to at least for the time being like lock onto that idea and so maybe it's more firmly established for the time being, even though it's wrong because if, as long as he's thinking about it more and more and more, then hopefully he'll better understand what it is he's thinking, and so that if he's then confronted with a counterargument, he might be able to see how the counterargument works against his idea much more efficiently. Rather than if I just say to him right there, no, no, no, that's right, he might just stop thinking about it, and then is like oh, that idea is wrong, what did Mr. H say, let me just write that down really quickly and then that'll be my answer. So I'm trying to get him to maintain whatever it is that he's thinking. (Interview, June 14, 2006)

By reflecting his students words back at them, they have a chance to consider their own ideas and articulate more of their thinking. Again, in referring to the first few turns with George, Dave said he hoped it would encourage George to explain more of what he meant.

> Dave: Basically I'm parroting what he's saying, kind of like reflecting it back to him because by doing that, he might, I don't know, whenever you do that to somebody, they always feel a need to respond back even if you just repeat what they said. So, like me doing that is a way of me trying to like dig more and more out of him. (Interview, June 14, 2006)

Interprets student ideas.

But Dave did not simply repeat his students' statements verbatim. In several lines, he restated them with different words (lines 54, 56, 58, 76, and 93), which involved processing the meaning of students' ideas. One example deserves special mention. In line 58, Dave provided a contrapositive of George's statement.

57. George: See like this (holds a book up and moves it down slowly) very slow. Like this, very slow, steady, because there isn't any air.

58. Dave: So you're saying air makes things fall faster.

In an interview, Dave explained his purpose for stating the contrapositive of what George said.

> Dave: So he tells me one thing, I then reflect back the opposite, and then he gives me the opposite consequence so there, I mean he's showing me that he can think logically, like just in an exchange, but even though he does, even though the concept isn't right….Because I'm trying to get him to realize the logical implication of what he's saying….It's just for coherence of thought, like developing coherence and of thought. (Interview, June 14, 2006)

Dave hoped that by interpreting an implication of George's idea to him, he could help George develop his logic and cognitive abilities.

As noted earlier in the chapter, categories of evidence may overlap. With the contrapositive, Dave interpreted George's idea as well as explored an implication of that idea. This line is also counted as evidence of Dave exploring George's idea in the discussion below. As will be seen in the next discussion, the line between interpreting and exploring, in this case, is very blurred.

Explored aspects of students' ideas.

In lines 58, 68, 70, 74, 79, 83, 95 and 97, Dave asked his students questions that probed the rationale for their ideas. For example, in lines 65 and 67, George explained to Dave that he did not think the book would hit the ground at the same time. Then, in line 68, Dave reinterpreted George's statements to propose an argument about how height mattered in George's point ("So are you saying the higher up that you drop something, like, the less likely they are gonna hit the ground at the same time?")

In an interview, Dave explained that he felt George had an intuition about falling objects that had yet to be fleshed out. As a result, he spoke lines 68 and 70 in an attempt to get George to focus in on this and explore the intuition.

> Dave: (Then) he says if you drop it from a certain height (in line 65), so, so I think there… he has an intuition about like, the higher up you are, the more air resistance plays a role in the um, in the falling of an object. So then I say to him, so are you saying the higher up you drop something, the less likely they're gonna hit the ground at the same time, and he says yes, so I say OK so there's an idea there that I don't think he's explored. He just kind of has an intuition about it so there's something that glitters to me about (what he says about) air resistance and falling objects so I try to, so I say to him, OK why? So I shine the light back on him and then he feels compelled to explain to me why he thinks that. So, in this case, I'm just digging deeper and deeper and

deeper, and I'm forcing him to dig deeper and deeper and deeper. (Interview, June 14, 2006)

Dave probed aspects of Naveed's ideas as well. In line 83, Dave focused his questioning on the mechanistic reasoning behind Naveed's claim that objects on Earth fall at the same rate because of air resistance ("So air resistance plays a role in how fast things fall? Like how. How does air resistance affect how things fall?"). Though Naveed did not take the bait here, we can see this as an attempt by Dave to delve deeper into his student's reasoning about the mechanism for falling objects.

Comments on Dave's case.

The evidence in this case shows that Dave directed his attention to his students' ideas and how they thought about those ideas. He highlighted and reflected details of what they told him. He also interpreted and explored what his students presented. As he explained in the interview, he wanted his students to explain or develop their ideas, regardless of whether they were correct or not. He believed that if they understood their own thinking better, they would be in a better position to grasp the correct ideas when they encountered them.

Dave's attention to his students' thinking seemed to be part of a feedback loop that also reinforced that attention. By paying attention to what his students were or were not saying, he encouraged his students to talk more about their thoughts. As he explained in the interview statement above, he tried to "shine the light back on him and then he feels compelled to explain to me why he thinks that." There was simply more for Dave to attend to as his students exposed more of their ideas.

Joanna's Class on Phase Changes

On this day, Joanna planned to introduce a new unit her students would be studying: phase changes. She brought in a video of the American Olympic Curling Team competing against the Canadian Olympic Curling Team. After showing her students the video, Joanna asked them, "What science makes this Olympic sport possible?" Her intention, consistently depicted in multiple interviews, was to have a short 10-minute discussion wherein she could move into the day's lesson about phase changes. She anticipated her students would mention friction and melting water. These comments would be useful for moving the class into explorations of energy and phase changes. For Joanna, the main idea in the unit on phase changes was about how energy was involved in the transformation of matter from one phase into another.

As students offered up various science terms, Joanna asked them to explain how those terms came into play in curling. Some students noted that brushing the ice would create some friction and the friction would cause the ice to melt. The students disagreed about whether the melted water would help the stone slip more easily or if it would slow the stone down. Joanna was confused about why some students would think that water would slow the stone down. She took what she had initially considered a brief detour to simply address what she considered a misunderstanding.

It ended up being neither brief nor simple. The conversation ended up lasting 25 minutes. In that time, the discussion touched on the following topics: 1) how the ratio of the amount of melted water to the object's size affected the object's speed on ice; 2) how brushing created melted water; 3) inertia; 4) the role of friction in the curling stone's movement. Joanna ended the warm-up and moved on to the other activities in her lesson plan.

After the conversation was over, Joanna lectured on phases of matter and phase changes. While Joanna lectured, the students copied information from overhead projections onto the worksheet she provided. After the lecture, students worked on a different worksheet that presented them with scenarios depicting phase changes and asked them to describe what was happening in those scenarios. The bell rang before they could complete the discussion of the first question. The class continued with the second worksheet the following day.

When her students disagreed about whether water slowed or sustained the stone's progress on the ice, Joanna was concerned. She thought that slipping on wet ice was a part of everyone's basic experience in the world and wondered how some students could disagree with that. As a result, she decided to ask her students about whether or not one could slip on water. In response, students erupted into discussion of what they thought. Partly to quell the tumult, Joanna selected one student, Abe, to present his idea to the class.

22. Joanna: You do slip on ice. But can you slip on water?
23. Students talk at the same time: "I mean water…" "The reason why you slip on ice is because there is water on it." "Like if it was pure ice…"
24. Joanna: OK, so here's Abe's idea, say it again.
25. Abe: It—the reason why it's slippery on ice is 'cause there's a little water. If you have ice, with no water, with no melted water, then you'll probably [wouldn't slip on it].
26. Joanna: So you think that the melted—the little—(draws on the board) you're basically saying here's our ice and that there's like a little, little, little, tiny thing of water right there and that's what makes it super slippery. (Abe: Yeah) Is what you're saying. So someone who thinks that it makes it, slows it down, tell me why you think it slows it down, cause that's

our counterargument, right? So, so why do you think Melissa?

27. Melissa: Well I'm not sure, but like, maybe if it's like water then it's like just more stuff to go over.

28. Joanna: Oh, so you're kind of thinking like (Melissa: I don't know)…like what would be an example of that?

29. Melissa: Umm…I'm not sure. (students speak up) Like a puddle?

30. Joanna: Like a puddle? How would a puddle slow it down—like, what do you mean? Like what's an example of that?

31. Tiffany: Going into the water, you know, just like-

32. Joanna: Like if something is kind of like—

33. Rhonda: Well if you're doing a marble across a table or something, it would probably go slower in the water 'cause it has more stuff that it's going through.

34. Joanna: So it's kind of going deeper in the water right? So as it rolls in, it's actually sinking in and eventually the water is stopping it. OK. So what do you think Bette?

35. Bette: Also, like, molecules move slower—like, there's this thing where um, where molecules move fastest like air, solid, liquid, gas, and umm, gas, because it's less compact, everything is less compact, that things move slower.

36. Joanna: mmhmm.

37. Bette: Like, they move slower in water, they move the slowest through a solid, slower in water and fastest through gas cause gas is really separated. Maybe, so I'm not sure that it makes sense [but?/that?] it would go faster

38. Joanna: OK.

39. Bette: The slower because the water molecules are…

40. Joanna: Let's take that idea.

41. Bette: These are cold molecules too.

42. Joanna: So let's take this marble idea, right? Of it going from on the ground and all of a sudden it hits a water puddle. Was it going—when it was just rolling, right here, was it going through air or was it going through the ground?

43. Class: Air. Through air.

44. Joanna: Through air, right? So it was going through air. Air has like a lot less resistance right? Like, what you're saying. So, Bette was saying that in the air all the molecules are farther apart. And, so it's easier for things to go through that.

45. Bette: And you can't just jump over that little—that little water, like, blockade almost, you can't just jump over that. (inaudible) get stop by that.

46. Joanna: (draws on the board) Right, it's kinda going through that. So by the time it gets here—here's our marble—it's going from air into some of the water. So, if there's a lot of water here, let's say the water was like…kinda high compared to the

		marble 'cause usually, a puddle is pretty deep. So, there'd be a difference between it going in the air and going on the water.
47.	Tiffany:	'Cause like, there's still, there's a hole in the ice now and there's water there.
48.	Joanna:	mmhmm.
49.	Tiffany:	[So there's ice and water?] (inaudible) And it's probably going to go in.
50.	Joanna:	So if the water is really thick on the ice, it will probably slow you down. So, if there's like—when there's big patches of water in ice, that's not desirable right? You're not going to try to skate into a big puddle of water if you're a hockey player. So, if there were big puddles like that, I agree with you, I think it would slow it down. But what if there was just umm…pretend you're driving. Oh yeah, Aisling, you have an idea?
51.	Aisling:	But wouldn't the water be a thin layer so wouldn't it make it faster? If it was on top of ice it would be, the [whole, like?] slippery?
52.	Joanna:	So it's different 'cause it's really thin. You're exactly right, 'cause here when we use our water puddle idea, the water is pretty deep. It's not that, like, microscopically thin layer that's on ice. So it's slightly different. So you're right that a puddle would slow something down, but I think you're also right that if it's a thin layer, like—here's our thin layer of water and here's the ice—that would be different somehow because if you're a car, right? Has anyone ever hydroplaned in a car?
53.	Bette:	My sister. (Students: Yeah.)

After a brief exchange with Bette about hydroplaning, Joanna delivered a few minutes-long lecture about how a thin layer of water would affect the marble differently from a thick layer. During the lecture, only Joanna spoke. When the lecture concluded, students talked about how they thought about the slipping on ice situation, noting any new insights or changes in thinking. Then, the class returned to Joanna's initial question about what other science they saw in the sport of curling.

Attended to students' ideas: Lines 22-34.

Joanna's episode did not lend itself to straightforward analysis. For part of this episode's interaction, there is strong evidence that Joanna attended to her students' thinking. She interpreted a student's idea. She asked for clarification of an argument her students made. She also contributed to the development of one of the arguments in this debate. For another part, there is fairly strong evidence that she did not attend to a student's (Bette) thinking. Then, at the end, the evidence is not so clear about where her attention was directed.

Interpreted Abe's idea.

In line 26, Joanna's restatement of Abe's idea highlighted a key aspect of what Abe was arguing about—that a little bit of water was needed for one to slip. However, her restatement was not a simple repeat of his idea. She exaggerated details of Abe's statements ("a little, little, little, tiny thing of water....makes it super slippery") which brought the mechanism for slipping on ice into the spotlight. Though this rephrased what Abe said, it still preserved the main point of his idea, which was a little bit of water was needed for slipping to happen.

Asked Melissa for clarification of her idea.

After Melissa presented the counterargument in line 27 ("Well I'm not sure, but like, maybe if it's like water then it's like just more stuff to go over"), Joanna pressed Melissa for an example to flesh out what she meant (lines 28 and 30). For example, in line 30, Joanna asked specifically how the puddle example Melissa proposed explained the counterargument ("Like a puddle? How would a puddle slow it down? Like what do you mean? Like what's an example of that?").

In the interview, Joanna mentioned she did not understand what her students were thinking with the counterargument. Joanna said, "Vanessa couldn't come up with an example. ['Cause?] I had no idea what they were talking about. ['Cause?] I would have though [???] made it go slower (Interview, June 28, 2007)." She needed Melissa to explain what her thinking was to her.

Built on students' ideas.

Joanna assisted with her students' development of the counterargument. In lines 31-33, Tiffany and Rhonda contributed by adding to Melissa's example of the puddle. Tiffany, in line 31, provided a process by which the marble would encounter more water ("Going into the water"). In line 33, Rhonda presented a real-life example of this scenario ("a marble across a table or something") and more details about the process of slowing down ("going slower…'cause it has more stuff that it's going through). In line 34, Joanna added an explanation for why the marble would encounter more stuff and why that would slow it down ("So it's kind of going deeper in the water right? So as it rolls in, it's actually sinking in and eventually the water is stopping it.")

Her contribution to the discussion here also indicated that she finally understood what the counterargument was. Joanna, a self-described visual learner, had processed enough of the ideas her students communicated to be able to translate it into a visual. In an interview, she explained that Rhonda's example led her to start drawing on the board, which helped Joanna see what they meant.

> Joanna: Then Rhonda comes up with this specific example that then I can draw… they actually kind of convinced me that yeah, as it rolls into the water,

well yeah, of course it would slow down…. OK, that makes sense. So I finally understood one argument for water on top of the ice slowing down whatever is on top of it. If you use (pause) puddles. And things that go into puddles [???] whether it's a marble or whatever. (Interview, June 28, 2007)

Initially, Joanna saw that she did not comprehend what her students meant. When she finally understood what they meant, she was able to contribute to her students' argument.

Did not attend to Bette's ideas: Lines 35-44.

In this part of the episode, the evidence shows that Joanna did not attend to Bette's ideas. In lines 35 to 41, Bette offered many points about the different phases of matter. However, it is not clear how these points furthered either argument in the debate nor how Bette thought of the situation under discussion.

35.	Bette:	Also, like, molecules move slower—like, there's this thing where um, where molecules move fastest like air, solid, liquid, gas, and umm, gas, because it's less compact, everything is less compact, that things move slower.
36.	Joanna:	mmhmm.
37.	Bette:	Like, they move slower in water, they move the slowest through a solid, slower in water and fastest through gas 'cause gas is really separated. Maybe, so I'm not sure that it makes sense [but?/that?] it would go faster
38.	Joanna:	OK.
39.	Bette:	The slower because the water molecules are…

40. Joanna: Let's take that idea.

41. Bette: These are cold molecules too.

At times, it seemed like Bette was talking about the relative speeds of the molecules in a substance, and at other times she was talking about the speed of objects moving through a substance ("Also, like, molecules move slower… molecules move fastest like air, solid, liquid, gas, and umm, gas, because it's less compact, everything is less compact, that things move slower…. Like, they move slower in water, they move the slowest through a solid, slower in water and fastest through gas 'cause gas is really separated."). It could also be that Bette conflated the motion of the molecules *in* a substance with the motion of an object *going through* a substance and the ambiguity in her language was the result of this conflation.

Additionally, it is not clear how she thought compactness of a material affected the situation the class was discussing. Her comments about this factor contradict each other: "gas, because it's less compact, everything is less compact, that things move slower…Like they move slower in water they move the slowest through a solid, slower in water and fastest through gas 'cause gas is really separated." It is possible she did not consider her points to have any logical connection but was just randomly feeling around the things she knew from her past science class on phases of matter.

In an interview, Joanna explained that she saw Bette as the latter — randomly bringing up what was on her mind.

> Joanna: I kind of just let her talk about that. Because I knew with her, she has to talk about things to make sense of it. I had actually talked to her about

> that before…. You know how where, some people have to say it, and while they're saying they're understanding what they're saying…. Like, they can't just think of the words in their head…. And I knew that she was like that so (pause) [???] she would eventually get somewhere…. I think you do-I think clearly, you have to know your students. Like, as much as possible you have to know (pause), like in that moment, what might be helping them.
>
> (Interview, June 28, 2007)

Joanna did not need to focus so much attention on what Bette said at the moment because Bette was speaking to sort out her own ideas and not everything she said would directly contribute to the conversation. Instead, helping Bette make sense of the ideas in the conversation meant giving her the space to air out what was in her head.

In lines 42 and 46, Joanna's response was to incorporate the words and phrases Bette used to generate her explanation of how water slowed an object down.

42.	Joanna:	So let's take this marble idea, right? Of it going from on the ground and all of a sudden it hits a water puddle. Was it going—when it was just rolling, right here, was it going through air or was it going through the ground?
43.	Class:	Air. Through air.
44.	Joanna:	Through air, right? So it was going through air. Air has like a lot less resistance right? Like, what you're saying. So, Bette was saying that in the air all the

molecules are farther apart. And, so it's easier for things to go through that.

45. Bette: And you can't just jump over that little—that little water, like, blockade almost, you can't just jump over that. (inaudible) get stop by that.

46. Joanna: (draws on the board) Right, it's kinda going through that. So by the time it gets here—here's our marble—it's going from air into some of the water. So, if there's a lot of water here, let's say the water was like…kinda high compared to the marble 'cause usually, a puddle is pretty deep. So, there'd be a difference between it going in the air and going on the water.

Though Bette would probably agree, it is not clear if Bette meant to say that it was easier for the marble to go through air than through the ground nor if she was trying to argue for the counterargument (that the water would impede the stone's motion). It does not seem to matter how Bette meant it because Joanna was able to use her words to explain the counterargument ("there'd be a difference between it going in the air and going on the water"). As Joanna explained in an interview, she was interested in forwarding a particular argument and not what Bette said about the phases of matter.

Joanna: I was trying to find a clear articulation of the counterargument…. But I really wasn't interested in the solid-liquid-gas thing…. So that's why I

> interrupted her, in 40, even though she didn't really want me to interrupt her. So I said "Let's take that idea", what I really need is the water. (Interview, June 28, 2007)

Joanna saw Bette as listing definitions and terms regarding the phases of matter, a topic her students should already have well understood. Reviewing the terms would not further their understanding of slipping (or not slipping) on melted ice.

> Joanna: I think the actual phases of matter they understand well. Like, most of them have—it's an easy concept for them. Molecules closer, farther apart, farthest apart…. Yeah, and the pictures of that aren't really-like, by the time they're in high school, even 9th grade, they have a pretty clear sense of that. They've been learning that for a while. So I just have found that's not really-that's sort of just too simple. Like, we don't have to spend time on that…. Yeah, her-her solid-liquid-gas thing. OK, got it. We all understand it. (Interview, June 28, 2007)

Joanna wanted her students to go deeper in their exploration of the counterargument, which can be achieved, as she said in her interview, by focusing on the melted water on the surface of the ice.

Unclear if Joanna attended to students' ideas: Lines 36-53.

At the end of the episode, though, the evidence is not strong. It seems to suggest that Joanna was more focused on presenting her summary of the main points of the discussion — that both sides were correct but were just talking about two different situations. Her summary of the discussion seems to build upon the ideas her students presented earlier. Though Joanna's response to her students indicated she heard their words, she seemed to be quite focused on delivering the summary points she developed.

For example, in line 52, after Aisling pointed out that there would be a small layer of water, thus making it slippery on the ice's surface, she told Aisling she was "exactly right" and then proceeded to show the class how both ideas were correct and related but referred to slightly different conditions (line 52: "when we use our water puddle idea, the water is pretty deep. It's not that, like, microscopically thin layer that's on ice. So it's slightly different. So you're right that a puddle would slow something down, but I think you're also right that if it's a thin layer, like—here's our thin layer of water and here's the ice—that would be different somehow—that would be different somehow because if you're a car, right? Has anyone ever hydroplaned in a car?"). It is not clear if Aisling intended to say that both ideas were correct, but it is clear that Joanna did. To do so, Joanna also needed to show how objects could slip on ice. Joanna brought the discussion back to the example she introduced (driving in a car and hydroplaning) to do that. As she explained in an interview, Joanna thought this example would allow her to tie both arguments together.

> Joanna: And so that's also what I would call like this moment, where like, OK, do I try and bring this all together (laughing) or do I just abandon this notion of bringing it all together because now I agree with both sides. (laughing) And-so that's where I said, "Pretend you're driving." That's me coming up with another example, like, OK, so I agree with the

> counterargument; let's come up with another argument, another situation. (Interview, June 28, 2007)

Both the interview and the class data suggest that Joanna was able to note what her students said but wanted to focus on presenting her summary of the situation. It seems that her primary focus was to show her students how the two sides were correct by using her example from driving.

Comments on Joanna's case.

For part of this episode, Joanna did focus her attention on her students' thinking. She interpreted a student's idea and asked for clarification of an argument her students made. She also helped extend the reasoning behind the counterargument. For part of this episode, there is also fairly strong evidence she did not attend to a student's (Bette) thinking. Then, at the end, the evidence is not so clear about where her attention was directed. This episode illustrates how difficult it can be to identify the focus of a teacher's attention; attention can shift fairly quickly.

By attending to how her students thought about the counterargument, new learning opportunities opened up for both Joanna and her students. Though Joanna did have an understanding of the phenomenon of slipping on water and of drag while traveling in water, she had not yet made the connection that she developed that day — that the ratio of water depth to object size helped to determine whether an object would slip on water or drag through water. In an interview, she explained that this discussion made a strong impression on her.

> Joanna: I remember feeling like I was having a fairly sophisticated discussion with them. Y'know, one where I-if you were together with five

> other sort of scientists slash educated people…Discussing some phenomenon you found interesting…That you all start convincing each other of different things. And you come up with new ideas yourself. Like I kind of felt like I was the one-I mean, it felt like I was the teacher, but I really felt like-kind of a student too....I mean, I knew I was always the teacher, because I was clearly the one in the front…calling on them….But, the fact that I was being convinced of things, um, when I say things later on which will [???] I get excited; "Oh! That's right! You're right!" (laughing)…That that is-it's not really a show….It's my conveying something to them naturally. (Interview, June 28, 2007)

Making a new connection in her content understanding was quite exciting for Joanna. This, possibly, helped reinforce her attention to her students' thinking.

In Chapter Five, where I will talk about Joanna's framing of this exchange, I will explore why her attention shifted away from Bette's ideas. In short, according to how Joanna framed her discussion, Bette's comments did not seem to contribute to the two arguments the class was developing.

John's Class on Heat Transfer

Late September in the second year of the project, John planned to have his students do a reading-comprehension activity, called the reciprocal reading activity, and then proceed to a series of short lab exercises, all on the topic of heat transfer. The lab exercises were a collection of short activities aimed at helping students observe the heat-transfer properties of different materials.

In the reciprocal reading activity, students were assigned various roles (summarizer, questioner, and word finder) to help the class think about the passages they read. At this point in the year, his students were acquainted with this reading activity. With every new topic, John had his students read from the textbook about the science terms associated with the next topic. John hoped this structured reading activity would help his students make sense of academic text, see fellow students as sources of useful information, and develop his students' critical thinking skills. For a more detailed discussion of the reciprocal reading activity please see Chapter Two.

On this day, the class went through three cycles of the reading activity before they moved on to the lab. The topics they read about were: caloric, heat and particulate motion, and heat and work. In the interview, John noted he was surprised by the discussions in this lesson. He felt that many of the questions, scenarios, and points they raised were good and warranted further exploration. To John, they reflected a deep level of intellectual engagement with the topic of heat transfer. At the end of this lesson, he wrote down what they talked about and set aside an entire class period, a few days later, for the purpose of investigating them.

In this case, rather than studying a single interaction, I chose to follow the interactions regarding the question a student, Annie, posed. At the time, Annie did not have an official role in the reciprocal reading activity. She interrupted the flow of the reciprocal reading activity by calling out a question about heating a bottle. John drew the class into a short conversation about Annie's question. Later, in the discussion of the next passage, John raised Annie's question again and engaged the class in a more extended discussion of what they thought about the scenario she posed. I made a decision to follow the discussions about Annie's question rather than looking at a contiguous episode, as I did with Dave and Joanna's classes, for two reasons. First, the two different discussions were about the same topic — Annie's question. Second, it seemed that Annie's question had gotten stuck in John's mind.

The relevant transcript from this lesson is presented in two sections. The first part is from the reciprocal reading of the passage on caloric. At the beginning of this transcript, Annie asked her question while John recorded the summary. The second part of the transcript is from the discussion after the class read a passage about heat and work.

24. John: Um, Benicio, what's the, what did they talk about here, um, moving particles.
25. Benicio: They talk about how um, particles are [all in motion?/always moving?].
26. (Students laugh)
27. John: Nah, that's a good start.
28. Annie: [???]
29. John: (writing on the board) Particles are always moving. And what else?
30. Benicio: (John writes down what he says) [The?] I guess, uh, well, heat energy makes it, uh, they all move like [???]
31. Female student: Alright, gringa. [???] [it's a fish?]
32. Benicio: (John writes on the board) And when they starts to uh, when it tries to, it starts to, um, um, they start to move farther apart.
33. John: Good.
34. Female student: [???]
35. Male student: Whoooop.
36. Student: Wow.
37. Annie: So what if we had a bottle and like we was heatin' it up and like we put the top on the bottle. Would the bottle, would the top fly off?
38. John: (writing on the board what the summarizer said) What do you think?
39. Annie: I don't know. I'm not sure. Like, [tie it up?] (gets up to pick up a fallen object)
40. John: (finishes writing, faces the class, 3-second pause) What do you guys, what do you guys think about, that would be a good question, although our questioner would have to come

up with her own. But, that's a good question. What do you guys think? (pause) If you heat up some, a bottle with, what did you say Annie?

41. Annie: Heat up a bottle and that [???] with the top on [top?/it?].
42. John: Alright. So, you're heating it up first and then putting the top or you're putting the top on and then heat it up?
43. Annie: Heating it up first then put the top on.
44. John: Oh, so you heat it up first and then put the top on. (lifts head up to look at the rest of the class) What do you think will happen?
45. Student: The bottle heats up.

(5-second pause)

46. Eddie: [???]
47. John: Yeah. So- (turns to the board)
48. Student: [or it'll melt?]
49. John: Oh, I see, I see what Eddie's saying. (John writes on the board) So Eddie's saying, when you have a bottle, right (some students chuckle) alright, um, alright, so, say there, say there's a bottle. And you heat it up, Eddie's saying that, uh, that everything's gonna, gonna leave. All the heat's gonna leave before, uh, you put the bottle top on. He said whatever's in here is gonna heat up, all the heat's gonna leave. If you put the bottle top on later, it won't make a difference. Is that what you're sayin'?
50. Eddie: Yeah.
51. John: Um, anybody think anything different? (John writes on the board) Annie's question is then if you take it off the heat over here. It's a terrible bottle, but, whatever. If you take it off and then put a top on, what would happen.
52. Male Student 1: When it's still hot?
53. John: Yeah, when it's still hot.
54. Male Student 1: Oh.
55. John: Anybody think anything's gonna happen?
56. Male Student 1: No. It'll be hot, the bottle's just hot. Very hot.
57. John: What do you think Annie.
58. Annie: The top might fall off. Fly off. I don't know.
59. (Multiple voices)
60. Male student 2: [I know?] It'll start dripping water.
61. Male student 3: The bottle gonna get foggy. (Multiple student voices) The bottle's gonna start sweatin'.
62. Annie: No, that's only gonna happen if you put the top on first. Then he's [???] Then it'll [fall off] first. i don't know. I guess it's just gonna cool [fast?/down?]
63. Male student: It'll store a lot of energy.
64. John: Alright, well, maybe we'll try this. I'll, I'll bring these materials next class and we'll try this out.

65.	(Multiple student voices)	
66.	Male student:	What [???] lab [??]
67.	John:	What will happen to [???] bottle.
68.	Annie:	Uh, nothing will happen because potential energy is being-, (waves her hand as if to brush off her statement) I don't know.
69.	John:	No, no, you guys, you guys, you guys know a good bit. It's a, it's a real good question. Uh, questioner, um, questioner, who is the questioner?
70.	Annie:	That was the question of the day.
71.	John:	Martina? That was a good question. No, Martina was word finder.

To make the transcript from John's class not any lengthier than necessary, I will summarize what occurred in lines 72 to 113 (approximately 5.5 minutes). In those few minutes, there is very little student talk about their ideas. After identifying which students had which role in this reciprocal reading cycle, the questioner asked, "What affect does adding heat energy have on the particles of a substance?" When a student responded with, "Makes them move faster," John acknowledged the student was correct and moved onto the word finder. The word finder asked about the word *particles.* After none of his students offered an explanation, John asked them if various objects in the room were particles. They responded no to each object John identified. Then one student said, "Fire is." After determining that no other student had anything to say on whether or not fire was a particle, John delivered a short lecture on particles. He explained that 1) particles usually meant molecules, which were so small one could not see them with the microscopes they had in their class; 2) molecules were the building blocks that made up macroscopic objects; 3) when one heats up an object, the molecules, or particles, in the object move faster, eventually leading to the object melting.

At the conclusion of this lecture, the class began the next reciprocal reading cycle by silently reading the next passage on heat and work. After the reading, new students were assigned roles by the participants from the previous cycle. Joshua, this cycle's summarizer, reported his summary to the class, which John recorded on the board.

114.Joshua:	Remember that something was moving for water to be boiling.
115.John:	OK, so (writing on the board). Um, OK what else?
116.Joshua:	Um (pause) When um, when water's boiling, water boiling it [???] energy, the heat is working [right?].
117.John:	OK, so. (12-second pause while John writes on the board) So this is an example. You said when water boils, heat is doing work. And you said something must move for work to be done. So with these two statements, what can we say about heat? What can we say about heat when we know that when water boils, um heat is
118.Student:	[kinetic?]
119.John:	Yeah it's, it's kinetic energy right, and we know that, that uh heat can do work. OK, does that make sense? Heat can move things. (walks over to the drawing on the board that represents the scenario in Annie's question) Do you think heat can move this top off the bottle?
120.Male Student:	Yeah.
121.Female Student:	Yes.
122.Male Student:	I mean when it gets hot.
123.John:	What do you think you have to do to, to make uh, uh the bottle top move off of a bottle?
124.Male student:	[shake it?]
125.Male Student:	oh yeah, [you/they?] did it on the [???]
126.John:	Well that was, they were using chemicals. They were using baking soda and vinegar. But here um do you think.
127.Student:	[???] pressure
128.John:	Do you think (draws on the board)
129.Student:	No.
130. John:	Do you think if you did this it would come off?
131. Several:	Yes, yeah.
132. Male Student:	Whoa, what do you mean?
133. John:	How many people would think it'd pop off if we heated it with the top on?
134. Male Students:	Yeah, because of the pressure.
135. John:	One, two.

136. Male Student 2: It'll pop because of the, you know how it gets hot on the other side [of the bottle?/the water?] [boiling?] [inaudible] so there's smoke
137. Male Student: There's no water in it though.
138. John: There's no
139. (multiple student voices)
140. Male Student: It's not going to dry it up
141. Male Student 2: It will smoke.
142. Student: It's going to pop because of the pressure.
143. John: Well, it's different if there's. Actually we'll have to find out if it's different when we do this. We'll have to find if it's different whether there's water or just air in there. You guys think that makes a difference?
144. Students: No. I don't know.
145. Eddie: I think it'll just cool it down. It'll just get it hot. [I think] it'll just hold the heat.
146. John: OK then the heat'll be trapped in here.
147. Eddie: I mean there's water in there, it'll hold the heat.
148. John: The wa-, the water. All right so Eddie's saying the water that were, that would be in the bottom would hold the heat (Eddie: yeah.) and keep it from getting real hot. Is that what you're saying?
149. Eddie: [there/yeah?] like when [inaudible]
150. John: It's, it's an OK thing to say. Is that what you're saying?
151. Eddie: Yeah.
152. John: OK. So he, he thinks that water will help cool down, um, but do you think we could boil that water in here if it's over a flame long enough?
153. Eddie: Yeah.
154. John: Yeah. Um, so the water could get hot, so but, but the, the water he's saying wouldn't get hot as fast as the air in there. And that's, that's an interesting thing. We, we'll have to find that out when we do, we should do an experiment for this next class.

For the duration of this lesson, the picture of Annie's question stayed on the board. After the class was over, John sketched all the questions they discussed during their reciprocal reading time on a sheet of paper and gave copies to the students for the next time they met. At the next meeting, he told the students that each student was to select a few ideas to investigate in an open-ended inquiry lab (John provided the materials). Using student questions from one lesson to generate another activity was not normal practice for John in this class. In the interviews, John repeatedly expressed excitement about the questions his students asked and the open-ended inquiry activity on those questions.

Evidence of attending to student ideas.

In these two episodes, I see evidence that John attended to his students' ideas, to the idea Annie asked about and to how his students thought about Annie's question. He worked with Annie to get a clear articulation of what she was thinking about in her question. At a later moment, he brought her question back into the class' conversation, even though the class had already moved to another reciprocal reading cycle. During the latter discussion, he tried to clarify, make sense of, and explore some of the ideas his students had. In the presentation of the evidence, I will break the discussion into three areas: John's attention to Annie's idea, John's attention to Eddie's idea, and John's attention to the two ideas his students argued about in lines 134 - 142.

Annie's idea.

At the beginning of the transcript, after the summarizer presented, Annie interjected with her question (line 37: "So what if we had a bottle and like we was heatin' it up and like we put the top on the bottle. Would the bottle, would the top fly off?"). For the next few turns, this question occupied John's interaction with Annie. He asked Annie for clarification, interpreted what she told him, and drew the class' attention to this question and the scenario she presented. Later in the lesson, during the summary of the third passage on heat and work, John used her question to talk about heat and motion.

Asked Annie for clarification.

In line 40, John tried to repeat Annie's question to the class but asked her to make clear what she was asking about (line 40: "What did you say, Annie?"). It is reasonable to expect that John might not have fully heard or understood what Annie asked. When Annie first asked her question, John was writing the summary on the board. Even though he was engaged in something else, he picked up enough of her question to be able to repeat a part of it (line 40: "If you heat up some, a bottle with…").

Interpreted what Annie said.

In line 42, John presented two plausible interpretations of what Annie said ("So, you're heating it up first and then putting the top or you're putting the top on and then heat it up?"). In the beginning, Annie had asked what would happen if they heated up a bottle and put the top on (line 37) and she had also said that the bottle would be heated with the top on (line 41). Attention to the details of her question could lead one to see the ambiguity that John highlighted.

Called the class' attention to Annie's question.

In lines 40-44, John drew his class' attention to Annie's question by asking them what they thought about the scenario Annie posed. It took a few lines for John to gain a clear sense of what Annie asked. Then, in line 44, when it seemed that John finally understood what Annie said, he presented his summary of it ("Oh, so you heat it up first and then put the top on") and asked the rest of the class about it. To provide an accurate summary of Annie's question, he needed to have attended to what she meant.

In directing his gaze away from Annie and to the rest of his students when he asked, “What do you think will happen?” he indicated that this question was meant for the rest of the class. Here, he opened the discussion up to the other students. At this point, other students entered into the conversation about Annie’s question. By inviting the rest of the class in on the discussion, John indicated he wanted to spend class time focused on Annie’s question.

Though John gives space for his students to say what they think near the end of the first episode, there is not enough evidence to clearly claim that John paid attention to the ideas they stated. It is possible that John paid attention to the idea Eddie stated in line 46. In the interview, John pointed out that Eddie was normally a student who infrequently participated in the academic discussions in his class, choosing to engage in conversations of a more social nature than of a scientific nature. When Eddie did participate in academic discussions, he was typically very spare with his words. John explained that he would often try to flesh out Eddie’s ideas out loud to try to understand what Eddie was saying. This was John’s way of attempting to pull more ideas out of Eddie and to also broadcast Eddie’s ideas to the class. However, the audio quality in this video is poor and I am not able to discern Eddie’s statements in line 46.

Returning to an idea at a later time.

Another piece of evidence that John attended to Annie’s idea comes from the discussion recorded in the second part of the transcript. Here, John brought the discussion back to the scenario Annie raised (lines 119 and 123). This question made enough of an impression on John that he was able to make a connection between it and the next passage on heat and work.

Eddie's idea.

During the discussion of Annie's question the second time, John spent a fair amount of time on Eddie's ideas about the heated bottle scenario. John interpreted and asked for clarification of what Eddie said. John also inquired about an implication of Eddie's idea. After Eddie confirmed John's interpretation, John relayed it to the rest of the class.

Interpreted Eddie's ideas and asked him for clarification.

Eddie told John why he thought the bottle would cool down (line 145: "It'll just get hot [I think] it'll just hold the heat. This John interpreted to mean the heat would get trapped (line 146: "OK, then the heat'll be trapped in here"). Though John seemed to have misinterpreted what Eddie said, it was a reasonable interpretation of Eddie's statement. There are similarities between holding something and trapping something.

In line 147, Eddie restated his point in more specific terms ("I mean there's water in there, it'll hold the heat."). John responded to this tightening of the argument by incorporating the actual phrases Eddie used (line 148: "Alright, so Eddie's saying that water that were, that would be in the bottom would hold the heat and keep it from getting real hot") into his new interpretation of what Eddie said.

In an interview, John explained that he saw Eddie as holding intuitive ideas about specific heat.

> John: He thinks of water as cooling things. Um, and it does take longer to heat up and the reason for that is the specific heat of water. Um, it's one of the, you know, great properties of water, it's a polar compound, you know, it takes a, it takes a long time heat it up and once it's hot it holds its heat, you

know, um. He doesn't know that but he sort of just has this feeling that, you know, that even if you're heatin' it up, water will sort of cool and keep the top from popping off. So, you know, it sort of begs the question if, you know, if you have a bottle with water in it and you have one with air, well then maybe he's he's making a argument, his argument is the one with th-, with air will pop off because the one with the water will cool it. (Interview, August 15, 2007)

It is not entirely clear what Eddie meant in line 145 with "it'll just cool it down", but based on the rest of what Eddie said, John interpreted it to mean that water helps to keep things cooler than things without water in it because water keeps in the heat. In the interview, John explained that he saw a connection to the concept of specific heat and the scientific understanding of the properties of water but recognized this was a connection Eddie did not necessarily make.

In this class, Eddie typically said very little in class discussions. John described in an interview how he often had to figure out what Eddie meant and help him elaborate on his statements (as can be seen in 148 and 150 when John offered an interpretation of Eddie's statements and checked with Eddie to see if that was what he meant).

John: With Eddie and Joshua, especially, you know, you can talk and they, you know, they sort of give you a little bit. And for Eddie, that's just a bit. That's about as much as you get out of Eddie in a, you know, all year he only says a few things. You know, other than fighting with other kids, arguing or talking about football. (I'm) trying to figure out his idea and make sure, um, yeah, his speech isn't great and, you know, there are other issues, but making sure that, you know his idea gets kind of heard. (Interview, August 15, 2007)

John saw his role with respect to Eddie as one that included helping Eddie clarify what he meant to say by interpreting out loud Eddie's statements and checking with Eddie to see if that was what he meant.

Explored Eddie's idea.

In line 152, John asks Eddie about whether or not he thought water would boil (line 152: "OK. So he, he thinks that water will help cool down, um, but do you think we could boil that water in here if it's over a flame long enough?"). Even though this was not part of what Eddie said, John thought this was a natural question to ask, given than Eddie said he thought water would hold the heat. In an interview, John described how this question came about.

> John: That one was just sort of me being part of the discussion. You know? Um, sort of being that active participant because he, he is right. And I don't, I don't use the term specific heat but he's right the specific heat of water is higher than, ah, uh, that of air. And, you know it will hold the heat a little longer, um.… Holding the heat, I don't know what that is but yeah, it's sort of a, a good description of what, what happens. Um, but, you know, I come up with the point, you know, it's an obvious point, it's not like I'm coming with something new, you know. I mean you can boil water, if it's over a flame.… So think about that. Yeah. Why does that happen? And, you know he could really stick to his idea. I mean he doesn't. Um, but he could really stick to his idea and say, "Well it takes a long time for the water to boil." And, that would be, that would be right also. (Interview, August 15, 2007)

John wondered about how Eddie thought about an implication of his argument that water held the heat. For John, this was not part of the curriculum or learning goals he had intended for his students but was simply an offshoot of pursuing Eddie's idea ("That one was just sort of me being part of the discussion.").

Other students' ideas: Noted differences in students' ideas.

In addition to the extended attention John paid to Annie's and Eddie's ideas, John also paid attention to the ideas other students offered. In lines 134-142, several students spoke out about what they thought. There were different ideas presented in rapid fire and student voices overlapped in that part of the video. In the class, John followed enough of the comments to note that students were not referring to the same things in their arguments. In line 143, John pointed out that his students were talking about two different scenarios ("We'll have to find if it's different whether there's water or just air in there.")

In an interview, John said he was worried that some of his students did not realize they were talking about two different scenarios.

> John: There are a couple people, who seem to be having differing ideas and it's fine that students have different, differing ideas and want to argue, or, you know, give reasoning for their ideas. However, I thought their, that their differing ideas may be based on, um, them thinking that there are two different scenarios. I didn't think everybody in the class was clear on what we were discussing. So, (143) is to clarify things and sort of move, you know, so that, so that we're discussing the same question. (5-second pause) 'Cause some people would, you know, one, one is talking about boiling, the other's

saying, ’no, there's only, you know, there's not water in it.’ And they seemed a little confused, so I just wanted them talking 'bout the same thing. (Interview, August 15, 2007)

He was concerned that his students would get confused if they kept arguing without recognizing they were referring to two different scenarios. He wanted to circumvent this potential problem by pointing out the differences he saw.

Comments on John’s case.

In these two episodes, we can see evidence of John’s attention to his students’ thinking. These two episodes show that John’s attention was locally contained. When Annie asked her question, John tried to understand what she asked about and to engage the rest of the class in an exchange about that question. When he moved the conversation back to the official reciprocal reading cycle, there is little evidence he paid attention to his students’ thoughts there. Even though there were very few student ideas presented, there were a couple of ideas presented (heat makes particles move and fire is a particle). After the class had moved onto the next reciprocal reading cycle, John used Annie’s question to explore how his students thought about heat and motion. Like Joanna’s episode, we cannot make blanket statements about whether or not John attended to his students’ ideas in his class. We can only talk about his attention in different moments of the class because his attention shifted.

Chapter Comments

In this chapter, I have presented evidence from each teacher that they can (and did!) pay attention to students’ ideas. In the different episodes, we can see that the teachers built on their students' ideas, asked their students to clarify their statements, interpreted or rephrased a student's idea, or found ways to get their students to continue talking about what they were thinking.

Some researchers have shown that it is difficult for teachers to pay attention to student thinking because there are pressures that pull teachers' attention away from student ideas such as institutional expectations (Levin, 2008; Rop, 2002). The data in this dissertation suggests there may be more to what makes it difficult for teachers to sustain attention on student thinking. A part of the difficulty may also be because it is not easy to hear, interpret, and respond to student thinking. For example, it was hard for Joanna to figure out what her students said. Initially, she could not see how anyone could think that the melted water on the ice would slow a person down.

> Joanna: And then he says slow down.… So I think there was a change in my tone. So I could tell from that, that there was a shift in what I [saw?]….I grew alarmed. "OK!" All of a sudden I felt like, "Where is this going?" (Interview, June 28, 2007)

Making sense of what her students said required the use of Joanna's skills and knowledge to manage this unexpected turn of events. In an interview, Joanna explained, "Like, I felt confident that we would get somewhere…. Like, it wasn't like all of a sudden we were going somewhere that I didn't think I could handle, intellectually," but it did create a challenge for Joanna (Interview, June 28, 2007). Given all the pressures and challenges, it is no wonder that attending to student ideas in the classroom does not always happen.

Chapter 4: Attention Directed Away From Students' Ideas

In Chapter Three, the teachers showed evidence of directing their attention toward student ideas. This chapter investigates episodes where the teachers' attention was directed away from student thinking. In other words, as discussed in Chapters One and Two, the point of this chapter is to look at moments when it is apparent that attending to what students mean is not a priority.

Consider the following clip from Joanna's class (the rest of the episode will be presented later in this chapter). This clip is from the class described in Chapter Three (the introduction to phase changes) and takes place at about 22 minutes into the lesson. On this day, Joanna initially wanted her students to engage in a short warm up discussion about a video clip of the U.S. Olympic Curling Team competing against the Canadian Olympic Curling Team. Joanna was surprised at the richness of the discussion and decided to let the warm up go on longer than she had anticipated.

By the time of the clip below, the class had discussed how the ratio of water depth to object size determined whether or not the object would slip and how the sweeping motion of the curling brushes helped melt the ice.

Joanna:	There's a little bit of air resistance, right? What is the property of objects that keeps them going?
Bette:	Kinetic energy.
Female student:	Their energy.
Joanna:	Well kinetic energy is related to the energy they have that makes them moving—
Female Student 2:	That law.

Joanna: What is that law? Objects in motion? Akeem, what is it?

Akeem and students: Inertia.

Joanna: (fortissimo) Inertia! Right? Inertia! (normal volume) What is inertia saying, Akeem?

Akeem: An object that is in motion will stay in motion unless [acted upon by?] another object.

Joanna: Or an outside force, right? So an object in motion stays in motion unless acted on by an outside force. Is there a force on this board somewhere?

Female Student : Friction!

In this clip, Joanna treated what her students said differently from the way she treated what they said in Chapter Three. To recapitulate the findings in Chapter Three, Joanna interpreted her students' ideas, asked them to clarify what they meant, and built on their thinking. When she did those things, I argued that the primary focus of her attention was on the substance of her students' ideas. Here, Joanna did not build on, interpret, explore, call the class' attention to, note differences in, nor reflect back any student ideas. Admittedly, the students said very little beyond scientific terms and formal definitions, but Joanna did not inquire about what her students meant by those. Here, her attention was mainly directed away from what her students talked about and toward the terms they used and the ideas she provided them.

Like Chapter Three, a presentation of the categories, the three teachers' cases, and the chapter's concluding comments will follow this introduction. As with the categories in Chapter Three, there may be overlap between the categories in this chapter. Again, the distinctions between the categories are not as important as the use of the evidence from these categories to argue where the attention is directed. It is also important to note that the evidence from this chapter, in conjunction with the evidence from chapter three, provides clear and concrete examples of teachers behaving in different ways with regard to student ideas, even though the nominal goal of the larger activity would have had the teachers' attention directed toward student ideas.

As we will discover in Chapter Five, by reorienting ourselves toward the data such that we look at the relationship between the attention and the interaction, we can see that though there is variability to the attention, there is logic to that variability. That in each situation, directing attention in that way made perfect sense because how the teacher framed that information helped organize the teacher's attention.

Categories of Evidence

As noted in Chapter Three, analysis of each teacher's attention relied heavily on classroom data; the interview data was used to explain motives and rationale to supplement this analysis. From the analyses of the three teachers, several categories of evidence emerged. The teacher's attention was directed away from student ideas, if in the responses to students, he or she: 1) did not allow students to say their ideas; 2) directed conversations away from what students said; 3) attributed ideas to students that were not warranted; 4) provided students with ideas with which to think; 5) focused on the terms rather than the substance of student ideas.

The same discussion points raised in Chapter Three about the overlap between the different categories of evidence of attention also apply here. The boundaries between the categories are not always clearly defined, but that is not critical to the arguments in this chapter. There are times when teachers may portray behavior that fits one (or more) of the categories described in this chapter. What matters more is that there is evidence that the teacher's attention was directed away from student ideas.

Formal analysis for this chapter was more complicated than the analysis conducted in Chapter Three. It is very difficult to identify an absence of attention. As a result, this chapter is as much about showing evidence that the teacher's attention was directed away from student thinking as it is about showing evidence that the teacher's attention was directed toward something else. In the presentation of the categories below, I will discuss how I identified where the attention was directed if it was not directed toward student ideas.

Does not allow students to express their ideas.

Not allowing a student to speak his ideas indicates the teacher's attention is directed away from the student's ideas. Some examples of this are: 1) a teacher delivering a traditional lecture that does not encourage student talk or 2) a teacher talking over or interrupting a student with statements or questions that clearly do not reference what any students have expressed thus far. If a student is not able to express his or her idea, it will be difficult for the teacher to attend to student thinking. What the teacher uses to fill the space can indicate where the teacher's attention is directed. For example, if a teacher keeps interrupting students with references to the vocabulary words from the unit, it is likely the teacher's attention is focused on the unit's scientific terms.

Directs conversation away from what students say.

By directing conversation away from what students say, the teacher communicates that the teacher does not want to focus on what students are thinking but rather on something else. What a teacher directs the conversation toward can indicate where the teacher's attention is focused. One clear example of a teacher directing the conversation away from what students say is when a teacher discounts a student's idea. Discounting an idea marks that idea as irrelevant and as not warranting further consideration. Two common ways to discount an idea are to disregard the idea by labeling it as wrong or as off-topic. This is different from arguing that an idea is wrong. In that case, making arguments about why an idea might be wrong requires understanding the idea; to challenge something effectively, one needs to have a good sense of what that thing is. In this case, this can be strong evidence that the teacher paid attention to that idea. For example, in Chapter Three, Joanna wanted to challenge the counterargument but she knew she needed to understand what her students were thinking before she could argue against it successfully.

Attributes ideas to students they did not say.

When a teacher attributes ideas to students that they clearly did not say, this is evidence the teacher's attention is not directed toward student thinking. Consider for example the following hypothetical discussion about sound in a high school physics class.

Student: I think that if I shake my maracas more, it will get more sound, louder.

Teacher: Oh, that's great! So you're saying that if you shake it faster, the pitch also changes. Then we can conclude that shaking it slower will make it a lower pitch. That's the concept of frequency folks! Write this down.

The teacher's statements are not an accurate portrayal of what the student said. The student was not speaking about pitch, but about loudness (or volume). Though it is unclear what the student meant by "shake my maracas more", she did indicate there was a relationship between shaking it and volume. The teacher's statement on the other hand is about quickness of shake, the pitch of sound and the concept of frequency. What the teacher said is not a reasonable interpretation of what the student said. Nor can what the teacher said be considered building on what the student meant. The reference for the teacher's points is not related to the student's idea.

In this hypothetical example, the teacher attributed ideas to the student the student did not exhibit, which is evidence the teacher did not attend to the student's idea. There is also evidence in this to indicate where the teacher's attention was directed. It seems that the teacher's attention might be directed toward the concept of frequency and the canonical understanding of that term. What a teacher attributes to his or her students can provide some evidence of the direction of the attention.

Provides students ideas with which to think.

When a teacher tells students to use ideas they have not expressed (or ideas that do not reference the substance of students' statements) and also tells students how they are expected to use those ideas, this is evidence the teacher's attention is directed away from students' ideas. One clear example of this is when a teacher, after asking her students a question, begins to provide the answer in the form of a "fill-in-the-blank" statement. In the clip from Joanna's class, presented earlier in this chapter, Joanna used a "fill-in-the-blank" statement with her students in line 147. There her half sentence, "Objects in motion," referenced a familiar statement her students were expected to have memorized. The appropriate response was for her students to complete that sentence with the appropriate terms and phrases about inertia. By supplying students with these fill-in-the-blank statements, the teacher constrains the conversation to a particular idea as well as to a specific presentation of that idea. There is no room for students to express what they mean. How the teacher constrains the conversation can indicate the focus of the teacher's attention. In Joanna's clip, she was focused on the canonical representation of inertia.

Focuses on the terms that students say.

When a teacher focuses on the terms that a student says rather than on the substance of the student's ideas, this is evidence the teacher's attention is directed away from the student's ideas. Another instantiation of this is when a teacher assumes the students use of a vocabulary term matches the canonical meaning, even when very little of the idea was articulated or what was stated was inconsistent with the canonical meaning. One might wonder how it is possible to not pay attention to the words people use; we do communicate with terms and words. It is not so much the issue of noticing or not noticing the words or forms students use. This category of evidence is more about whether or not the teacher noticed those terms in connection with how the students used them or what they meant by them. This is a particularly relevant issue in science classes where students may use scientific terminology in their classroom speech patterns without any sense of meaning.

An example of this can be seen in the episode from Heidi's class, presented at the beginning of this dissertation. Though the data is not conclusive, there is evidence to suggest that, at the end of the exchange, Heidi was more focused on word vibrates (and vibrations) than the meaning Marcus intended. At the end of the episode, Marcus and Heidi said:

Marcus:	Yeah, and it vibrates [in there?] (moves his hand back and forth).
Heidi:	(with greater emphasis and louder volume) Vibrations, I love it! Vibration, OK. (Writes the word vibrations on the KWL chart)

The word *vibrations* was what Heidi highlighted and recorded on the chart. Though it was not what Marcus said, it was on the list of vocabulary words associated with the sound unit. Marcus' point was that sound could come through the top of one's head and vibrate inside of it if one's ears did not work.

This category has some overlap with the "attributing ideas to students" category. Sometimes a teacher may hear a student say a word and attribute ideas to that student that the student may not hold. I made a decision to keep these two categories separate because there are occasions, as can be seen in Heidi's episode, where the attention is literally on the word and not on any meaning.

Section Comments.

From this dissertation data, a preliminary list of the types of evidence to indicate when a teacher's attention is directed away from student ideas has emerged. When a teacher: 1) does not allow students to speak their ideas; 2) directs conversation away from student ideas; 3) attributes ideas to students that they did not express; 4) provides students with ideas with which to think; 5) focuses on terms rather than on the substance of what students say, the teacher's attention is directed away from student thinking.

As noted in the introduction to this section, the formal analysis in this chapter was more challenging than in the previous chapter. In some interactions, a teacher may exhibit one (or more) of the above-mentioned moves in the service of attending to student thinking. Consider the following examples.

Example One: In Chapter Three, at the beginning of Joanna's episode, many students spoke out in response to her question about whether or not one could slip on ice. In line 24, Joanna interrupted that swell of voices and called attention to Abe. One could interpret Joanna's action as not allowing the other students to speak. But that move made it so the class and Joanna could hear one of the ideas. If Joanna did not do that, it would have been impossible to attend to any of the ideas.

Example Two: A teacher may direct conversations away from what students say or tell students what to think about in the service of attending to student thinking about a particular topic. Here is a hypothetical example.

1. Teacher: OK folks, let's stop for a minute and think about what Angie just said. Angie?

2. Angie: So would the top fly off if we heat the bottle up?

3. Teacher: That's a good question. Anyone got any ideas? What do you think? Ah, Thebo? Are you even paying attention?

4. Thebo: Um, yeah. I was just, ah, telling him that you know, there's no gravity in outer space. And, um, so if we went up there, the top, the top would just float off. (hands mimic an object floating)

5. Teacher: (laughter and smiles) Yeah, Thebo. Let's stay on Earth, OK? Sometimes I think your head is in outer space. Let's stick with Angie's question. Can someone tell me what they think will happen to the top when we heat up the bottle?

Here we see the teacher, in line 3, direct his students to a specific idea to consider (in this case it was Angie's question). In a sense, he is telling his students what ideas to think about. But he did so because he wanted to hear their thinking about the scenario Angie posed. He did not prescribe how his students should think about Angie's question. Then, in line 5, the teacher effectively directed the conversation away from what Thebo said. The teacher was interested in hearing what his students thought about what Angie asked, not just about any ideas they had. Thebo's statements were not related to the question at hand.

These examples illustrate the importance of considering the context in which the particular moves are displayed. In each of these examples, the purpose for those moves was to help the teacher learn more about what students thought about specific topics. They needed to establish boundaries, which cut out some ideas to create the space where students could articulate their thinking and stay on topic.

Dave: Attention Toward Acceptable Answers

This episode took place about a minute after Dave's interaction with George and Naveed (see Chapter Three). In this day's lesson, Dave wanted his students to work on the Galileo Worksheet questions (see Appendix B), a worksheet aimed at eliciting students' ideas on falling objects. Immediately after his interaction with George and Naveed, Dave walked to the front of the room, briefly checking on a handful of students along the way. When he reached the front row, Aisha called Dave over to her to discuss Question 2b on the worksheet.

> A bowling ball and a small rock are dropped from the same height at the same time. Which one lands first if this experiment is done
> **(a)** on the Earth?
> **(b)** on the Moon (which has no air)?
>
> Be sure to explain your reasoning and to answer both (a) and (b).

101.	Aisha:	Mr. H.
102.	Dave:	Yes.
103.	Aisha:	If you drop a bowling ball and a, a small rock on the moon, neither one of them would drop would it because there's no gravity up there.
104.	Dave:	So you don't think there's gravity on the moon?
105.	Aisha:	No, (pause)-
106.	Dave:	So-
107.	Aisha:	-because that's how space is.
108.	Dave:	OK, so if you're really far away from massive objects like the moon or the earth or the sun, then gravity is negligible, it's, it's like there's no gravity.
109.	Aisha:	(audible level) So it's…
110.	Dave:	But, if you're near. So, there is near, so there is gravity on the moon, yeah.
111.	Aisha:	(sotto voce) OK.

112.	Dave:	So things **do** fall on the moon. Do you think that, do you know if they fall faster or slower on the moon? (Aisha shakes her head no) They fall slower. Any idea why?
113.	Camille:	Because, uh, there's less gravity.
114.	Dave:	Right, so things accelerate slower on the moon because the moon is less massive than the earth.
115.	Aisha:	So a bowling ball would drop first right?
116.	Dave:	On where?
117.	Aisha:	On the moon.
118.	Dave:	(3-second pause) OK why?
119.	Aisha:	Heavy, [it's?] heavier.
120.	Dave:	Because it's heavier? So you think that heavier objects fall faster than lighter ones?
121.	Aisha:	(slight hesitant tone) On the moon, they drop slower
122.	Dave:	So, so, are you saying that on earth they would fall and hit the ground at the same time? (Aisha gives a very slight nod) But on the moon they wouldn't? (Aisha gives a slight nod) OK so what's the difference between the earth and the moon? (Aisha shrugs her right shoulder and chuckles) So (Dave's voice exhibits more inflection and changes in tone), so, why do you think that then?
123.	Aisha:	(smiling, looks at paper for 3 seconds, speaks loudly and with a quicker pace than line 121) Because it's outer space, (hesitant tone) it like, it's probably less gravity in outer space than it is on earth.
124.	Dave:	OK so gravity isn't as strong on the moon as it is on earth. That's true. But, so if gravity's weaker on the moon, I mean, things aren't gonna accelerate down as quickly on the moon, but why would, um, the fact that we're on the moon like, affects which one hit first? Like wouldn't they both (mimics two objects falling with his hands) just hit the ground at the same time just at a slower rate, (Aisha shrugs both shoulders and raises eyebrows) is that possible?
125.	Aisha:	(3-second pause) So they're gonna hit at the same time?
126.	Dave:	(5-second pause and rifles through stack of papers in his hand) That's what I want you to think about, that's what I want you to think about.
127.	Aisha:	(sotto voce) I'm gonna put down I don't know
128.	Dave:	(Stands by Aisha's desk watching the class as she writes. Glances at his watch. 15 seconds later announces to class while walking away from Aisha's desk) So you've got about 2 minutes. I'm collecting these at the end of the period so you need to make sure that you have them done. How's it going?

In this episode, Dave's attention was consistently pulled away from his student Aisha's ideas. It was directed toward the acceptable answer (as defined by Dave) to the worksheet question. During this bit of conversation, Dave directed the conversation away from Aisha's ideas, did not allow her to say what she thought, attributed an idea to her that she did not say, and provided her with the ideas to use in answering the worksheet question.

Directed conversation from what Aisha said.

In lines 110, 112, and 124, Dave directed the conversation away from what Aisha said by pointing out she was wrong. In these moments, Dave registered what Aisha said and responded by shifting the conversation away from the points she raised.

Aisha began the episode by claiming the objects would not fall on the moon because there was no gravity in space (and on the moon as well). Dave acknowledged it was reasonable to consider outer space as gravity-free (line 108: "then (in space) gravity is negligible…it's like there's no gravity") but told her, in lines 108 – 112, that she was wrong (line 110: "there is gravity on the moon" and line 112: "So things **do** fall on the moon"). In line 112, the empathic stress on the word "do" helped to underscore the point about gravity and the moon. By telling Aisha she was wrong about the situation on the moon, Dave moved the conversation away from her idea to the idea he proposed, that there is gravity on the moon. In the interview, he explained that he intentionally wanted Aisha to abandon her idea that the moon did not have gravity.

> Dave: With George and a couple of other students before, I think that in space, they think that there's no gravity and so like, the earth is the only thing that has gravity. So you know, she says it's not going to fall on the moon, she's thinking the moon is in space, if it's in space, there's no gravity therefore there's no gravity on the moon. Um, so I'm just trying to get them to realize that you know, if something has mass then it, you know, exerts a gravitational force on other objects around it…. And I'm trying to get her to realize that because the moon has less mass, things will have a lower acceleration or smaller acceleration on the moon. (Interview, July 6, 2007)

Since there was gravity on the moon, Aisha's original response that neither would fall was no longer a viable option.

At the end of the conversation, Dave also directed the dialogue away from Aisha's ideas. By this point, Aisha explained that since there was gravity on the moon, the heavier object would fall faster than the lighter object. She also tried to connect her answer to the point Dave raised about objects falling slower on the moon than on the Earth due to its reduced gravity. In response to Dave's question about whether or not she thought the heavier object would fall first, Aisha responded by stating, hesitantly (line 120), "On the moon, things drop slower." But it is unclear how she meant it.

Dave's response to Aisha's somewhat muddled points was to focus on the correct way to think about the situation on the moon. In line 124, he used his questions to propose the (correct) idea that, on the moon, both objects would hit the ground at the same time; they would just take longer than on Earth.

124. Dave: OK so gravity isn't as strong on the moon as it is on earth. That's true. But, so if gravity's weaker on the moon, I mean, things aren't gonna accelerate down as quickly on the moon, but why would, um, the fact that we're on the moon like, affects which one hit first? Like wouldn't they both (mimics two objects falling with his hands) just hit the ground at the same time just at a slower rate, (Aisha shrugs both shoulders and raises eyebrows) is that possible?

Dave's proposal did not reference Aisha's idea other than to indicate her conclusion was wrong. In line 125, Aisha seemed to have accepted Dave's bid to move the conversation away from her idea because she changed her response at the end to match what Dave said ("So they're gonna hit at the same time?").

Did not let Aisha speak her idea.

In this interaction, there are moments where Dave did not let Aisha articulate her idea by either talking over her or not asking her to clarify what she meant. Even though Aisha, in line 109, was loud enough to be heard clearly on the tape, Dave did not acknowledge she was speaking and had in fact started to speak over her at the end of line 109. At another point in this episode, Dave was able to pick up on what Aisha said even when her volume dropped to below this level. His response in line 110 ("But, if you're near. So, there is near, so there is gravity on the moon, yeah.")

indicates he was very interested in establishing the correct way of thinking about the moon.

It is possible that Dave did not hear Aisha but that is likely because his attention was not focused on her and not because she spoke too softly. It is also possible that Dave did hear her but had decided not to let Aisha speak because there was something more important he had to say. In either case, this is further evidence that Dave's attention was not on what Aisha was thinking, but on making sure she heard his explanation about the Moon. Dave said in an interview he was focused on helping her understand the Moon's gravity.

> Dave: I'm trying to get her to realize that because the moon has less mass, things will have a lower acceleration or smaller acceleration on the moon…. That's just me trying to explain the idea because I don't think that it's there, I don't think they've seen it before…(and) I'm trying to kind of explain it. (Interview, July 6, 2007)

Here, Dave's interview statement shows that his attention was on his explanation and not on Aisha's reasoning.

In line 111, Aisha also seemed to acknowledge that Dave's attention was not directed at her. Here, she dropped her voice down so that it was barely audible when she said "OK." Aisha was not typically a shy quiet student in this class. In other exchanges, she verbally challenged Dave and other students in the class when she did not agree. In dropping her voice down to a barely audible level, her utterance took on an insignificant role and effectively allowed Dave to continue to hold court. This suggests that Aisha agreed that the attention at the moment should be directed toward what Dave was saying.

Provided Aisha with ideas to use.

In addition to not allowing Aisha to articulate some of her ideas, he also provided her the ideas to use in answering Question 2b. In line 110 and 112, Dave essentially told Aisha what line of reasoning she should use in answering the question, that there was gravity on the moon and that things did fall on the lunar surface ("So there is gravity on the moon….So things **do** fall on the moon. Do you think that, do you know if they fall faster or slower on the moon? (Aisha shakes her head no) They fall slower."). From an interview, Dave explained that he needed to get Aisha to accept there was gravity in outer space, in particular on the moon, because "the question is about an object on the moon and we haven't really talked about gravitational forces on things or exerted by things other than on Earth" (Interview, July 6, 2007).

In line 115-119, Aisha had changed from her original answer (line 103: "neither of them would drop") to arguing that "a bowling ball would drop first…on the moon…(because it's) heavy, [it's?] heavier." This new argument was built off of what Dave had told her about the moon. Even when Aisha did try to incorporate Dave's points about gravity on the moon into her responses, Dave continued to supply her with ideas and ways to reason. In line 124, Dave tells her that objects on the moon would fall at the same rate, just a slower rate than on Earth. This line of reasoning directly challenged her new answer. If she accepted what Dave told her, she would have the canonically correct answer to Question 2b.

At this point, Dave was very concerned with getting Aisha to the correct conclusion about this worksheet question. In an interview, he explained his concern.

> Dave: I don't think she understands that (the two objects) would…both accelerate down at the same rate on the moon. So that's when I just…start explaining what happens because I don't think…she has enough background knowledge to be able…to make that conclusion. So that's just me trying to explain and fill in the gaps in her knowledge….I think she figures out (the right answer) because I'm trying to go through this long-winded explanation …(to explain) why it's not the case that they wouldn't hit at the same time…I don't think she necessarily understood the explanation I gave…but she senses that I'm trying to get her to conclude that they do hit at the same time. (Interview, July 6, 2007).

Dave wanted to provide Aisha with the knowledge needed to answer the worksheet question correctly. Though he may have heard what Aisha said, it was not relevant to answering the question. As a result, he tried to direct attention away from her points by providing her with the correct ideas to use.

Attributed an idea to Aisha that she did not say.

Though Aisha never mentioned what she thought would happen on Earth, Dave, in line 122, attributed the idea "on Earth, they would fall and hit the ground at the same time" to her. Data from the interviews suggests that Dave assumed Aisha had accepted the idea that objects on Earth, dropped from the same height, would hit the ground at the same time.

> Dave: What I think I've understood, in 122, when I respond back to her is that I think that she gets that if you're on the earth, they're both going to hit at the same time, but I think that she thinks that on the moon they're not going to hit at the same time. So I'm trying to get her to explain why she thinks there's a difference between the earth and the moon. So I ask her "What's the difference between the earth and the moon?" (Interview, July 6, 2007)

It is unclear why Dave would think that Aisha thought that objects on earth would hit at the same time. Aisha had not mentioned this in the conversation so far. The questions on the worksheet do not assume that students hold this idea. Additionally, Dave just came away from a conversation in which a student (George) did not hold such an idea.

On this worksheet, Question 2a asked about two objects falling on Earth. It is possible that Dave, who was standing about 2.5 feet to the front and right of Aisha, had glanced down at her paper, which was almost upside-down from Dave's vantage point, and read this from her written responses to Question 2a. To that question, she wrote, "They land at the same time, the air is slowing the (bowling) ball down to same them drop at the same time."

However, there was no indication from the data that Dave read anything off of Aisha's paper. It was not apparent that he glanced at her paper; he did not gesture to her paper in speaking line 122; there were no pauses in his speech to indicate he was trying to read text that was oriented away and situated a short distance from him. Lastly, if what Dave did in line 122 was draw connections in the interaction to Aisha's written answers, what Dave drew out was the phenomenon she identified and not the reasoning she used. Dave, in 124, provided her with the explanation about gravity on the moon and its comparison to gravity on earth. Here, he did not acknowledge the explanation that Aisha had put on her paper, which was that things land at the same time because air slows down heavier objects.

Comments on Dave's case.

There is evidence in this episode that Dave was at least aware of Aisha's thinking. He did act in response to what she meant. But awareness does not necessarily mean his attention was directed that way. He worked hard to push her ideas out of the conversation so the class did not have to focus on them. Attending to how Aisha was thinking about the moon and gravity was not a priority because her ideas were in error. Getting her to accept the correct reasoning was.

This is different from the hypothetical teacher, presented earlier in this chapter, who talked with her student about pitch and frequency. There, the teacher did not even seem to register what the student had said. To recapitulate that example: the student mentioned that shaking the maracas more resulted in a louder sound; the teacher summarized the student by saying she was talking about pitch and frequency. Dave at least heard Aisha's points and could identify what she talked about. But he did not want those ideas to be a part of her answer to the worksheet question.

I recognize that there may be different levels of attention. As a teacher, it is important to keep tabs on many things in the classroom. Consequently, a teacher's attention is likely organized in a hierarchical fashion. As I explained in Chapter Two, for the purposes of this study, I am interested in how students' ideas related to that hierarchy. Aisha's thinking was important to this interaction in so far as it provided her with the correct answer to Question 2b. Since she said the wrong things, he did not want attention directed toward her ideas.

Dave seemed to be listening just to see if Aisha was developing the right answer. If attending to Aisha's thinking was the primary focus, then one would have expected Dave to respond to Aisha's comment that heavier objects fell faster much in the same way that he responded to George, "I'm trying to get you to think about why that would happen. So that's what I want you to write down. Why do you think that would happen, why do you think heavier objects would fall faster than lighter objects." In Chapter Three's episode with George and Naveed, Dave was interested in how his students thought, regardless of whether or not they were correct. Though George incorrectly argued that air made things fall faster, especially heavier things, Dave's attention was firmly locked onto George's thinking and the reasoning behind his statements. He encouraged George to articulate and develop his ideas even though their experiment challenged it.

One wonders if this may simply be a case of "a teacher trying to keep a student on topic so he could find out her thinking about that topic." That is not so here. In line 115-121, Aisha began to develop her story of what would happen on the moon. In line 122 and 124, Dave responded by guiding her to the right way to consider what goes on up on the moon. As Dave said in an interview,

> I don't think she understands that (the two objects) would… both accelerate down at the same rate on the moon…. I don't think… she has enough background knowledge to be able to make that conclusion. So that's just me

trying to explain and fill in the gaps in her knowledge. (Interview, July 6, 2007)

He focused on making sure Aisha could reason about the moon in a very specific way and provided her with the ideas if she did not have them.

A better example of a teacher trying to find out about students' thinking on a specific topic would be Joanna's episode from Chapter Three where she directed her students to talk about the two arguments. There, she specifically asked her students to establish and explore both sides of the debate. When her students initially developed the two sides, she did not try to push them to any specific line of thinking but allowed them to develop the arguments as they saw fit.

Joanna: Attention Toward Scientific Terms

We now turn to the rest of the episode from Joanna's class, of which we caught a glimpse at the start of this chapter. This was from Joanna's class on phase changes that was described in Chapter Three. She planned to use a video of a curling competition to introduce the unit on phase changes. She intended to talk about energy and melting during this short warm up discussion. But events did not proceed as planned. The rich discussion was not a short, straightforward exploration of energy and melting ice. By the time of this episode, students had discussed the role of the melted water in moving the stone on ice as well as how brushing helped to melt the ice. Following the brushing discussion, Joanna asked her students about the property of the stone that made it hard to predict where the stone would end up.

113. Joanna: So it's kind of like, helpful because it gets stuck up on it and then it helps kind of melt the other stuff. (Yolanda nods and mouths "Right.") So it melts the ice and then you get the

		water kind of helping melt more ice farther because the water is warmer? Right? So the water helps melt the other part. OK, so what is it that keeps the whole thing going to begin with? What property of the stone—'cause the guy let it go at the beginning, it's not like he's pushing it the whole time. What property of the stone makes it so hard to predict where it's going to land?
114.	Student:	(inaudible)
115.	Joanna:	Right? I mean, he hit but then they have to use all these extra things to kind of make it go a certain distance. So, why, why, why, is it so hard? 'Cause it's not just the friction that's the issue here. That's part of it; you can direct it that way. What do you think AJ?
116.	AJ:	Because the entire bottom of the stone is the same smoothness.
117.	Joanna:	OK, so?
118.	AJ:	It can go wherever you want it to-
119.	Joanna:	mm hmm
120.	AJ:	-depending on the ice and where it have the friction, [the?/more?] ice [harder?/higher?] ice [versus/or?] [thinner?/smoother?] ice.
121.	Joanna:	Right.
122.	AJ:	So it can go anywhere.
123.	Joanna:	It can go anywhere depending on how smooth—how much friction there is. It's almost like friction is a traffic light, right? It kind of helps you go one way or another. Why—if—would it keep going straight forever? If there was the same friction everywhere?
124.	Female Student:	Yes.
125.	AJ:	No. It wouldn't.
126.	Joanna:	Would it start turning? What would happen? If it was just the same everywhere and there were no brushes and they just let it go. And the ice was completely the same smoothness everywhere.
127.	Female Student:	Yeah.
128.	Joanna:	What would happen?
129.	AJ:	The same, uh, is it balanced?
130.	Joanna:	It's perfectly balanced, perfectly flat ice…
131.	AJ:	It would stop.
132.	Joanna:	Why, why do you think it would eventually stop?
133.	AJ:	Nothing can go on forever.
134.	Joanna:	Well, what (several student voices) what keeps an object going, and what stops objects?
135.	Several students:	Friction.
136.	AJ:	Friction. It still has friction.

137. Joanna: There's still a little bit of friction on ice, right? So, friction will eventually stop it, but if there were no friction at all, what would happen to the stone?
138. Students: It would go on forever.
139. Joanna: Why?
140. AJ: Actually, no it wouldn't because the air would stop it.
141. Female student: Their-
142. Joanna: There's a little bit of air resistance, right? What is the property of objects that keeps them going?
143. Bette: Kinetic energy.
144. Female student: Their energy.
145. Joanna: Well kinetic energy is related to the energy they have that makes them moving—
146. Female Student 2: That law.
147. Joanna: What is that law? Objects in motion? Akeem, what is it?
148. Akeem & students: Inertia.
149. Joanna: (fortissimo) Inertia! Right? Inertia! (normal volume) What is inertia saying, Akeem?
150. Akeem: An object that is in motion will stay in motion unless [acted upon by?] another object.
151. Joanna: Or an outside force, right? So an object in motion stays in motion unless acted on by an outside force. Is there a force on this board somewhere?
152. Female Student : Friction!
153. Joanna: Friction. So anytime there's friction, it's going to slow it down, that's the outside force. But that's why it's so hard for him to direct it, right? If he pushes it a little too hard, it just keeps on going, even though there is a little bit of friction, it's not that much. So that's what makes it a sport. You know, you have to have some skill to do this. Just not every average person can go and throw them around. They probably go flying off the end of the curling board.

It should be noted that Joanna may have made a mistake about friction and inertia. In this discussion, she wanted her students to talk about inertia and ignore friction. Objects will travel in a straight direction forever if there is nothing to impede their path, including friction. If the ice has a uniform amount of friction, then AJ's point that everything would slow down eventually is correct. As long as there is friction, regardless of how evenly distributed, objects will slow down. Joanna later corrected this by saying, in 137, that there is no friction. Regardless of her correctness, the purpose of this chapter is not to explore Joanna's content understanding but to look at her attention. In this episode, Joanna's attention was pulled away from her students' thinking and toward scientific vocabulary words, in particular the term inertia. Joanna directed conversations away from a student's ideas and toward the concept of inertia, provided students with ideas with which to think and focused on the terms students were using rather than the substance of their ideas.

Directed conversation away from what AJ said.

For most of this episode, Joanna tried to direct the conversation away from the points AJ raised and toward the law of inertia. In several of her contributions to the dialogue, she made it clear that AJ's points about friction and what happened in the real world were not pertinent. Instead, she made the effort to get her students to focus on inertia.

Early in the conversation, in line 120, AJ said that where the stone ended up depended "on the ice and where it have friction." As the discussion continued, he expanded on this by saying the stone would eventually slow down and stop because there is always something to stop it, either friction or air resistance. His point was that eventually, everything comes to a stop. In response to AJ's line of reasoning, Joanna tried to define the situation such that friction was not a part of the picture (lines 123, 126, 130, and 137) and tried to divert discussions away from what AJ said (line 142).

After AJ made the point, in lines 118 and 120, that "it can wherever you want it to… depending on the ice and where it have friction," Joanna asked her students to consider a scenario where the surface was homogenous (line 123: "the same friction everywhere" and line 126: "the ice was completely the same smoothness everywhere"). This new situation nullified AJ's point that the unpredictability of the stone's motion was linked with the unevenness of the ice's surface.

Even though Joanna tried to define the scenario such that students would talk about how the stone could go on forever, AJ continued to claim that the stone must stop (line 133: "Nothing can go on forever"). Joanna responded to AJ's persistence by teasing apart what might cause the stone to stop (line 134: "Well…what keeps an object going and what stops objects?") and redefining the situation such that it removed the stop-inducing factor entirely (line 137: "So, friction will eventually stop it, but if there were no friction at all, what would happen to the stone?"). Removing friction as a factor allowed for discussions about an object's inertia; objects keep moving if there is nothing to slow them down.

Line 142 is an example of Joanna explicitly diverting the exchange away from what AJ said. AJ, in line 140, declared, "Actually, no it wouldn't (keep going forever) because the air would stop it." Joanna began by acknowledging his point: "there's a little bit of air resistance, right?" She, then, immediately followed with the question, "What is the property of objects that keeps them going?" Here, Joanna openly asked her students to think about objects that keep moving and not, as AJ's point would lead one to consider, objects that stop. Discussing Joanna's question would move the conversation away from AJ's point that everything comes to a stop.

In an interview, Joanna explained that, at the time, she was quite surprised that AJ said the stone would stop.

> Joanna: I said I think, "It's perfectly balanced and it's perfectly flat ice. What would happen?". And he goes, "It would stop." It would just stop. (laughing)….I'm sure I was like, "Oh!" 'Cause [that's?] not the sort of traditional scientific [line?].... Well, it would go on forever because there's no friction. (Interview, August 30, 2007)

Joanna had expected her students to say that in friction-free environments, objects would continue moving. When AJ told her that even on perfectly flat smooth ice, the stone would stop, Joanna's surprise indicated he was not reasoning as she anticipated ("'Cause [that's] not the sort of traditional scientific [line?]").

AJ's point did not fit because Joanna was focused on discussing the abstract situation in which one could easily see inertia at play. During an interview, Joanna reflected on AJ's statements and saw the validity in his thinking. She said, "But then, what he said in 133 was true. Nothing can go on forever in my experience…. I mean, the idea of a frictionless surface is just theoretical" (Interview, August 30, 2007).

Further evidence that Joanna's attention was primarily focused on the law of inertia comes from several of her questions. At the beginning of the episode, in lines 113 and 115, Joanna indicated she wanted the class to talk about the property of the stone that will "(keep) the whole thing going to begin with". She returned to this in line 142, when in response to AJ's point about air resistance, she asked, "What is the property of objects that keeps them going?" It was very likely that the property Joanna asked about was inertia. In lines 143-146, her students offer up the answer of energy or kinetic energy. This was not the property she wanted because in 147, she explicitly asked her students about a law and supplied them with a particular law to discuss ("What is that law? Objects in motion?"). Then, lastly, in line 149, her excited response when her students said the word inertia showed that her students had arrived at what she wanted ("Inertia! Right? Inertia!").

Focused on terms students used, rather than the substance of their ideas.

In this episode, Joanna also focused on the terms her students used, rather than the substance of their ideas. When her students said "Kinetic energy" and "Their energy" in lines 143 and 144, it is unclear what her students meant with those terms and how those terms related to the question Joanna asked. In line 145, she articulated a rationale for how those terms might relate to the question she posed ("Well kinetic energy is related to the energy they have that makes them moving").

This is different from when Joanna, in Chapter Three, picked up on what her students' said and added to their mechanistic explanation (line 34: "So it's kind of going deeper in the water right? So as it rolls in, it's actually sinking in and eventually the water is stopping it"). There, she had asked her students to articulate enough of the substance of their ideas such that there is a sense of where the ideas were going. In that earlier episode, she used their examples, contributed points in such a way as to preserve her students' arguments, and furthered the discussion along the way her students were exploring. This was not the case with line 145.

Lastly, in line 146, when the student said, "That law," it is unclear which law that student might have meant. Given the discussion, it is possible her student might have meant the law of conservation of momentum, the law of conservation of energy or the law of inertia, all of which have been studied by this point in time. By baiting her students with "Objects in motion" in line 147, Joanna selected the law they would talk about. In doing so, she focused attention on the law of inertia instead of focusing on whatever law her students might have meant.

In the interview, Joanna explained that she saw this exchange as an opportunity to focus on formal scientific vocabulary.

> Joanna: OK (long pause). Mmmmm (long pause). I think this is the part where I was trying to bring in kinda just standard scientific words, phrases, connections, using these established-because I think yes, there's certainly value in understanding things at the gut level away from scientific vocabulary. Scientific vocabulary is still important to be able to use. (Interview, August 30, 2007)

At this moment, she was interested in seeing her students use scientific language and canonically established connections, and move beyond talking about things just from the students' point of view.

At the end of the episode, Joanna brought friction back into the conversation. By correcting Akeem's phrasing of the law with "or another outside force, right?", she was able to set up the discussion so she would be able to talk about how friction fit into the discussion about the law of inertia (line 153: "So anytime there's friction, it's going to slow it down, that's the outside force"). Though she brought friction back, she did so on her terms and not on her students'. Joanna's arguments about friction were different from AJ's. Joanna used it as an outside force that works against the very nature of things (the tendency of things to maintain their current state of motion). AJ's description of friction is akin to saying it is part of the very nature of things — everything slows down eventually. She certainly did use AJ's words but used them to further the line of reasoning she wanted her students to hold about inertia.

Provided students with the idea with which to think.

At two different points in this episode, Joanna provided her students with ideas with which to think (lines 147 and 151). These moves helped her narrow the field of discussion to the topic of inertia.

In line 147 ("What is that law? Objects in motion? Akeem, what is it?"), Joanna used a fill-in-the-blank move described earlier in this chapter. Her half-sentence follow up ("Objects in motion?") indicated what answer she wanted. Her excited response to her students' one-word answer, "Inertia," is also quite telling. It indicated that her students supplied the right answer.

In line 151, Joanna added to Akeem's statement about the law of inertia with, "Or an outside force, right." Here it is not wholly clear how Akeem meant his statement in 150 ("An object that is in motion will stay in motion unless [acted upon by?] another object") and how he related it to the curling stone sliding on friction-free ice. He seemed to be reciting a textbook definition for inertia. Joanna's contribution was simply to complete the recitation. This move differed from the one she displayed in Chapter Three where she added to her students' arguments to further their line of thinking. There she listened to, processed, and understood the underlying mechanism for her students' ideas. That was a strong indication she paid attention to what they meant.

Section Comments

In some ways, this episode seems like Dave's episode from earlier in this chapter. Joanna did hear and respond to her student's points. She endeavored to direct the discussion away from what AJ said about friction because he was not talking about the intended topic in the right way. Instead, she wanted her students to talk about an idealized situation where inertia's connection to curling could easily be identified. When she did bring friction back into the conversation at the end of the episode, she did not bring back AJ's idea, just the term he used. There, Joanna continued to talk about friction as a separable force (line 153: "So anytime there's friction, it's going to slow it down, that's the outside force") and not as AJ described, as an inseparable part of reality (line 133 & 136: "Nothing can go on forever….Friction. It still has friction").

While it is true that Joanna wanted her students to focus on a specific topic, she was not focused on their thinking with respect to that topic. When Joanna was finally able to get her students to talk about inertia, she did not ask her students to explain their one-word replies or textbook-like definitions. There is very little sense of how they meant what they said or how they associated that with curling. As discussed earlier, Joanna's episode from Chapter Three would be a better example of a teacher trying to understand how students thought about a specific topic. Once Joanna got her students to focus on the two arguments, she was able to listen, process, and understand the underlying mechanism behind their ideas.

John: Attention Towards Canonical Ideas

John's episode below took place with the same students but one class meeting earlier than the one presented in Chapter Three. On this day, John was hoping to introduce and have students explore the topic of energy transfer. At the beginning of the class, John engaged the class in an approximately 20-minute warm-up discussion about when objects use up energy versus when energy is stored. In this conversation, they talked about how a pendulum has the most kinetic and potential energy and that a battery, which is filled with acid, can produce electrical energy.

After the warm-up, the class moved onto a few cycles of the reciprocal reading activity. They read about and discussed topics related to energy transformation. When they finished with the text, students worked for the remainder of the period on two worksheets on the topic of heat and energy transfer. On those worksheets, students were asked to identify the kind of energy and energy transfer presented in the pictures.

This episode is from the summary portion of the final cycle of the reciprocal reading for the day. The text was on the law of conservation of energy. The transcript begins with a student reading from the textbook on the law of conservation of energy and ends with the summary discussion.

120. John: We're on page, we're on page 48. Read that column on the left starting with conservation of energy.
121. Students: (student chatter and giggles)
122. John: Shhhh
123. Student 1: (reads from the textbook) You know that energy can change from one place to another
124. John: Shhhh
125. Student 1: (reads from the textbook) Energy can also move from one place to place. However energy can never be lost. Energy can

		never be made or destroyed. Energy can only be [take and formed?]. This is the law of con, what do
126.	Student 2:	(reads from the textbook) Conservation of energy.
127.	John:	Very good. Keep going. That bottom little paragraph.
128.	Student 1:	(reads from the textbook) A scientific theory, such as a law of conservation of energy is an idea supported by scientists over a period of time. Scientists have studied energy for many years. They have done many experiments, and made many observations about energy. As the result of these experime, experiments and observations scientists were able to state the law of conser, ahh, conservation of energy.
129.	John:	OK good, uhm. Alright that was good. You read two sections so let's, let's kinda put that together in the summary uh Jaquan, do the best you can.
130.	Jaquan:	It was mostly about how energy is formed.
131.	John:	OK, the whole thing is about, so conservation of energy is about how energy is formed?
132.	Jaquan:	(nods)
133.	John:	OK, well. What does the law of conservation of energy say? Does it say that energy is formed?
134.	Student 3:	No.
135.	Jaquan:	No it's like it says it's never, energy can never be made or destroyed.
136.	John:	OK so it can never be formed.
137.	Jaquan:	It can just change.
138.	John:	It can just change forms, right, exactly right. OK, so, this you have to memorize, this is really really important. Alright. I'll put a star next to it. Energy can't be created or destroyed it can only, if you don't write anything else down, write this down. Change forms, right. And when they say change forms they mean like we've been talking about from one of the five forms of energy to another.
139.	Annie:	It can't be destroyed, it can increase.
140.	John:	It can what?
141.	Annie:	It increases, it increases every time. I don't know.
142.	John:	No, it can't, it can't be created or destroyed so you can't increase it. You can have more of one type of energy than another. But you have to put something, some sort of energy into one type of energy to get more of it. Does that make sense?
143.	Student 5:	[inaudible]
144.	John:	If we wanted this battery (indicating a nearby battery) to be more powerful, what would we need to do?
145.	Student 6:	Put it in a generator
146.	Student 7:	Put another big one.
147.	John:	So you could recharge it.

148.	Student6:	The sun!
149.	Student7:	Put another big one in.
150.	John:	You could, yea, you could add more, what's inside of this?
151.	Jaquan:	Chemical battery acid.
152.	John:	Chemical energy, battery acid. So we could make a bigger battery with more acid alright. The battery, how big is the battery in your car?
153.	Student 8:	It's pretty big.
154.	Student 7:	It's like (makes hand motions to indicate size)
155.	John:	Yea it's like a big brick. So you know the more, if you want more energy you need more of a different type of energy. You need more of the chemical energy to have more electrical energy. Alright, uhm. In this uh, summary, is there anything else? Anything else Jaquan?
156.	Jaquan:	[inaudible]

Throughout this discussion, there is evidence that John's attention was pulled away from his students' ideas and toward a canonical understanding of the law of conservation of energy. He directed the discussion away from students' ideas. He also told his students how to think about the law. He was focused on the terms his students used. He also attributed an idea to his students that was not warranted. The analysis of this case was also more complicated than the other cases in this chapter. There is strong evidence that John was not focused on his students' ideas. There is also evidence that, at times, John was attentive to how well his students connected to the text, which suggests he did attend to their thinking. As John explained in the interview data, this was early in the year and he might not have been as adept at making space for his students to articulate their ideas.

Focused on the terms students used.

In this episode there are several instances where John focused only on the terms his students used and not really on how his students meant those terms. One common response from John here was to incorporate his students' words into explanations he provided. Whether or not those were the explanations his students had in mind is not clear.

It is not clear what Jaquan meant in his initial summary (line 130: “It was mostly about how energy is formed”). It is possible that when Jaquan said “how energy is formed” his interpretation of *formed* may have also included the idea that energy is formed when something else loses an equal amount of energy and gives it up to the thing that now has more energy. It is also possible that he just simply meant that energy is created. John responded by highlighting how Jaquan’s words did not match the text’s words. After John received confirmation from Jaquan that he heard the words correctly, John responded by asking his students to check the words from the textbook and compare it to Jaquan’s (line 133: “OK, well. What does the law of conservation of energy say? Does it say that energy is formed?”).

In an interview, John said that he heard Jaquan’s statement as an indication he did not understand the text.

> John: I think I was at the time, you know, probably surprised that he missed it that badly. And I was trying to figure out a way to sorta you know validate Jaquan, who’s a weaker student. And also get the real answer off somebody else. You know have the class sort of figure out the real answer and get it up there.… When there's a wrong answer and it’s associated with reading, you know in this group, you know you kinda wanna get an answer, a correct answer, but not you know completely discredit anybody. You just wanna sort of help them, you know, figure out what the real answer is. (Interview, March 18, 2007)

John heard what Jaquan said but he was concerned with finding a way to get the correct summary without making his student feel bad about being wrong.

According to John, Jaquan had missed the point of the text.

> John: I think what Jaquan was sort of thinking about, was he heard some terms there and heard about the law of conservation of energy…how energy can't be created or destroyed, uhm it can only change forms, from one form to another, and he used the word, you know, "that's talking about how energy is formed." … He heard a… word, and he's pulling things out of context, and trying to put them back together, and, and they're not equaling what the text is about. (Interview, March 18, 2007)

However, it is not entirely clear that John's interpretation was accurate because in line 135 and 137, Jaquan was able to appropriately answer John's question about the text ("energy can never be made or destroyed…it can just change"). Though "energy can never be made or destroyed" is repeating the text's words verbatim, "it can just change" is in Jaquan's own words. In an interview, John also noted, in retrospect, that his initial assessment of Jaquan might have been off. John said, "Oh, so he did know the correct answer.… I don't know why he said, just energy formed in the first place….'Cause you know later he says it can never be made or destroyed" (Interview, March 18, 2007).

Also during that interview, John reflected on this episode and commented that he is still not clear how Jaquan understood the words he correctly repeated in class.

> John: I think sometimes these students, use words and don't really understand the meaning or, what they're saying. They can sort of reiterate,

> they can read the text, and put some of the words together to make a sentence that makes sense, but they're not, I don't know that he completely understands what the means, that the energy can never be made or destroyed. But he said it. (Interview, March 18, 2007)

In the episode, the ambiguities of Jaquan's statements were not recognized in the dialogue. The textbook phrase Jaquan used in lines 135 and 137 were accepted and folded into John's presentation of his understanding of the text they read.

138.	John:	It can just change forms, right, exactly right. OK, so, this you have to memorize, this is really really important. Alright. I'll put a star next to it. Energy can't be created or destroyed it can only, if you don't write anything else down, write this down. Change forms, right. And when they say change forms they mean like we've been talking about from one of the five forms of energy to another.

At the end of the episode, John's students participate in the exchange by offering up fairly short answers in response to John's question of how to make a battery more powerful. His students said, "Put it in a generator" (line 145) and "Put another big one" (line 146). In line 147, John responded with "So you could recharge it."

It is not clear whether the student in line 145 meant that the generator would be used to recharge the battery. Using a generator might just simply mean to give the battery more of a boost. It is also unlikely that the student in line 146 meant that adding another battery would recharge the first one. It is possible that, for John, recharge here simply means adding more energy. This would align his response with his students' statements better.

> John: One of them said put it in a generator…. I don't think they completely understand that … they don't need to. That's a good answer….I don't think we have yet at this point, but we actually use a generator a little bit later to create electrical energy. And they know that a generator, uhm, is gonna create electrical energy so they, they figure you can recharge a battery using electrical energy, which you can. (Interview, March 18, 2007)

In any case, John explained in an interview that how his students thought about what they said did not matter as much as that they were able to identify different forms of energy and say that one could change into another.
At this point, it was enough that his students could identify examples that John could associate with different instances of energy transfers for his students.

Then finally, in lines 150-155, John led his students through a discussion about the connection between battery acid and the strength of a battery.

150.	John:	You could, yea, you could add more, what's inside of this?
151.	Jaquan:	Chemical battery acid.
152.	John:	Chemical energy, battery acid. So we could make a bigger battery with more acid alright. The battery, how big is the battery in your car?
153.	Student8:	It's pretty big.

154. Student7: It's like (makes hand motions to indicate size)

155. John: Yea it's like a big brick. So you know the more, if you want more energy you need more of a different type of energy. You need more of the chemical energy to have more electrical energy. Alright, uhm. In this uh, summary, is there anything else? Anything else Jaquan?

In line 150, John asked a fairly closed question ("What's inside of this?"). Considering the conversation during the warm-up, it had already been established in class that there was acid inside the battery. After Jaquan, in line 151, remarked that it was "Chemical battery acid," John used that to explain how one would need more battery acid (a form of chemical energy) to create a strong battery and get more electrical energy.

In the interview about this part of the episode, John said that he did not expect his students to have any idea about what was going on with the energy transfer. It was more important that they could identify the different forms so they could say the energy transfer happened.

> John: Uhm, and then, somebody says the sun. I don't know how that would work, but sure… it doesn't matter you know that they get all the details, exactly how it would happen. Just that, you know, energy can be transferred, but the best, the best answer, and the one that I was looking for at the time, was you know adding more chemical energy, or adding, you know, adding, if

> you were to make a battery more powerful, stronger batteries are bigger. They've got more chemicals in them…. More battery acid, so, you know, when a student says, you know, chemical battery acid, then that's, that was the answer. Uhm, you know, uhm, I'm probably talking a little too much, and not teasing out answers from them. (Interview, March 18, 2007)

John was looking for his students to use specific terms so he could use them to develop his explanation ("the one that I was looking for at the time, was… more chemical energy... stronger batteries are bigger. They've got more chemicals in them…. More battery acid"). It may be that line 150 ("what's inside of this?") was John's way of encouraging his students to say the words he needed.

Directed the conversation away from student ideas.

As noted in the previous section, John effectively told Jaquan his summary was wrong and needed to be replaced (lines 133 & 136: "OK, well. What does the law of conservation of energy say? Does it say that energy is formed?...OK so it can never be formed."). This was one instance where John drew attention away from what his student was thinking and toward the correct summary John had in mind. As John indicated in line 138, ("OK, so, this you have to memorize, this is really really important. Alright. I'll put a star next to it. Energy can't be created or destroyed it can only, if you don't write anything else down, write this down. Change forms, right."), it was critical for his students to get the correct summary for this piece of text.

In addition to this instance, John's response to Annie in line 142 is also an example of John drawing attention away from his students' ideas and toward his canonically correct ideas about the law of conservation of energy.

142. John: No, it can't, it can't be created or destroyed so you can't increase it. You can have more of one type of energy than another. But you have to put something, some sort of energy into one type of energy to get more of it. Does that make sense?

Here, John pointed out to Annie that she was wrong and then provided the right way to think about the law. Annie's wrong idea was no longer relevant to the text-summary discussion.

It is not clear whether or not Annie's idea was irrelevant because her statements, "It can't be destroyed…it increases every time" (line 140 & 142), are somewhat vague. Depending on how one defines the system of interest, energy for that system may increase as it receives energy from its environment. Additionally, it is uncertain what she meant by the increase happening every time. Did she mean every single moment in time or is it every time certain things happen, such as when energy of another form is added?

In an interview, John reflected on this episode and also noted the lack of clarity in Annie's statements.

> John: It sounds like Annie, Annie wants to say that it increases, every time. I don't even know what that means…. I could ask Annie what she means by "it increases, it increases every time, I don't know." But I don't even think she knows what "it increases" means. What, what is "it"? Energy? In what situation? When? (Interview, March 18, 2007)

As John pointed out, he could have "asked Annie what she meant." Instead, John's response to Annie in line 142 was to point out that she was wrong and provide the correct way to think about the law.

Provided his students with ideas.

In this episode, John guided how his students reasoned about the law of conservation of energy (lines 138, 142, 144, 152, and 155). In each of those turns, John told his students how to think about the phrase, "energy can only change forms." For example, in line 138, when he said to his students, "And when they say change forms, they mean, like we've been talking about from one of the five forms of energy to another," he defined for his students what forms of energy were allowed — the five forms discussed earlier in the unit.

Then in lines 142, 152, and 155, John explained to his students how to think about "it can't be created or destroyed" by telling them that "You have to put something, some sort of energy into one type of energy to get more of it… (such as making) a bigger battery with more acid…You need more of the chemical energy to have more electrical energy." His explanations and examples told his students how exactly to think about the law of conservation of energy.

In line 144, John initiated a shift in the conversation ("If we wanted this battery (indicating a nearby battery) to be more powerful, what would we need to do?") by asking his students about a battery in the front of the room. He moved the conversation away from the text to a more tangible object. In an interview, John explained that he thought his students were getting caught up in the abstract terminology and needed something concrete to discuss.

> John: So instead of… letting them talk about… this theoretical law (which is) sort of difficult to understand, especially for these kids, (I wanted to have them) being able to apply a law to, you know, situations… I want to get out of talking about the law,… I just sort of wanna get out of that and give them a situational thing to talk about, something that they know.…Because, you know, when you start, if none of it is tangible … they can't connect any of this knowledge to anything, they can't connect the laws to anything…You know, we’re not talking about a thing. We’re talking about a theorem, an idea. So you start getting into all sorts of pie-in-the-sky (stuff). It’s not even worth talking about…(I want to) try to get them looking at a…scenario where energy is involved instead of energy, sort of as this nebulous thing.
> (Interview, March 18, 2007)

John intended to use the battery as a way to show how energy went from a chemical form to some other form. As discussed earlier in this section on John’s data, he steered his students toward talking about the battery acid in the battery and its connection to electrical energy.

Comments on John’s case.

We can see evidence that John’s attention was directed away from the ideas his students had. Though he heard the words they said, he did not seem focused on what they meant. In fact, John tried to guide the conversation away from the incorrect statements he heard and toward the correct summary he wanted his students to have for the passage on the law of conservation of energy. If John had been focused on what his students were thinking, he might have responded differently to some of the more ambiguous student statements. For example, he could have asked Jaquan what he meant by "how energy is formed" or what Annie was thinking about when she said "It can't be destroyed, it can increase."

Like Joanna and Dave, John wanted his students to do something very specific. He wanted to make sure his students got the correct summary, which meant being able to identify situations in which energy was conserved even though the energy changed forms. Additionally, John wanted to make sure the class recorded an accurate summary statement of the text they read. But, there is very little sense of how his students understood this law.

John thought his students were having a difficult time understanding the law (they said the wrong things about the law). It was likely that his students did not understand the abstract idea of energy and the implications of it being a conserved quantity. John brought up the question about making the battery more powerful as a way to make this abstract discussion more tangible. His move to talk to them about the battery was motivated out of a desire to help his students connect with what he thought was an abstract idea. Even when he did move the discussion to a more tangible realm, his attention was still on the point he wanted to make — that to get more electrical energy, one would need more chemical energy. It was not on what his students thought about the conservation of energy.

Chapter Comments

To conclude this chapter, I will discuss some cross-case themes and issues. These episodes show examples of the teachers not paying attention to their students' ideas. I want to note, these episodes were not meant to paint the teachers in a bad light. Their attentions were directed elsewhere but their intentions were rooted in the desire to expose their students to new ideas they wanted their students to learn. Also, these same teachers showed evidence of paying close attention to how their students were thinking in Chapter Three. The pair of episodes from each teacher (episodes from Chapters Three and Four) shows one aspect of the complexity of teaching —that teachers' attention (especially to student ideas) may shift from one moment to the next.

Student ideas were not part of the intellectual work of the interaction.

In the episodes from this chapter, the teachers were aware of what students said. But the teachers' attentions were not focused on the students' thoughts. Dave's attention was focused on the right way to think about gravity on the moon. Joanna's was focused on the right way to talk about inertia and the curling stone's motion. In John's case, his attention was on whether or not his students had the right summary and could see that energy is always conserved. In these episodes, the teachers tried to concentrate the intellectual work of their interactions on ideas they had in mind (e.g., correct ideas about the moon) instead of on the ideas their students had. This was because those ideas were wrong for what the teachers wanted to do.

Teachers wanted to help students learn new ideas.

These examples may seem familiar to anyone who has taught before. Each teacher had an agenda they wanted to accomplish. Their students did not see a relationship or a concept that each teacher thought was critical to their agendas. To help their students along, they tried to guide students to the important connections that did not seem apparent to them. This is something many teachers face.

For example, in an interview about this chapter's episode, Joanna saw a "teachable moment" to review some vocabulary they had learned earlier and show how science is not a disjointed discipline.

> Joanna: I think this is the part where I was trying to bring in kinda just standard scientific words, phrases, connections…. There's certainly value in understanding things at the gut level away from scientific vocabulary. (But) scientific vocabulary is still important to be able to use….(I was trying) to connect to the first semester (with inertia). 'Cause they do physics the first semester [and chemistry?] the second semester" (Interview, August 30, 2007).

By insisting on talking about the law of inertia, Joanna was able to link an old topic from the physics unit (inertia) with their current discussion (sliding on ice) in their chemistry unit, and review vocabulary from the first semester. Since her students did not seem to understand what Joanna did, she took a stronger role in directing her students in the direction she wanted them to go.

How her students understood what they talked about is a different matter. With the exception of AJ, it is not clear what her students actually thought about friction, inertia, and motion. In the real world, these are complicated and entangled topics. AJ's statements exemplify how students' rich ideas about their real world experiences hit at the heart of how these theoretical ideas are enmeshed. It seemed that an opportunity to explore these relationships was missed. During an interview, Joanna reflected on this episode and noted that what she wanted them to talk about may not have connected well with the students

Joanna: What he said in 133 was true. Nothing can go on forever in my experience.... I mean, the idea of a frictionless surface is just theoretical… and how many people have an experience that even approximates that…. I mean on certain scientific environments maybe you can approximate it. But certainly not in experiences. (Interview, August 30, 2007)

In the episode in Chapter Three, she had originally thought that some of her students' ideas were wrong (that the melted water slowed down the curling stone) but gave them the space to develop those ideas anyway. By allowing her students to bring out their thinking and real-world experiences, Joanna and her class developed a deeper understanding of the relationship between water depth and object size in the phenomena of slipping and drag. This kind of deep exploration of inertia and friction did not take place in the episode from this chapter. A more detailed discussion of how the interactions in the different episodes might have impacted students' participation in science will be presented in Chapter Six. For now, I would like to point out that a strong focus on matters other than students' ideas seems to cloud one's ability to see what students might be thinking.

Teachers' attention exhibited variability.

In Chapter Three, we saw evidence that these three teachers were able to maintain attention on their students' thinking even when students said things the teacher thought were incorrect or did not make much sense. In the episodes from this chapter, we see these same teachers direct their attention away from student ideas even though the students insisted on making those ideas a part of the interaction.

John's episode is from a different activity on a different day. It may have been that during the summary part of the reciprocal reading, John did not see it as appropriate to focus attention on incorrect ideas regarding the text. He needed to help his students learn how to correctly comprehend the passages from the textbook about the law of conservation of energy. This may explain the shift in his attention.

In some ways, it is a bit surprising that Dave and Joanna would do that. Each teacher's episodes in both chapters took place in the same parts of their respective lessons. At the time, the overall activity was focused on getting students to talk about their thinking (e.g., Dave wanted his students to put down their ideas as answers to the worksheet questions). It seems that in spite of the activities, Dave's and Joanna's attentions were pulled away from their students' thinking. That is not to say that the activities structure and purposes did not influence the teachers' attentions. I am only saying that the activities are not the only thing.

Another factor noted in the literature that can constrain teachers' attention is institutional pressure. Levin (2008) and Rop (2002) found that these pressures can draw teachers' attention away from students' ideas. In Joanna's case, she felt very strong pressure from her department to follow a strict curricular schedule. But that did not stop her from spending time on how her students thought about the role of melted water in slipping, a topic marginally related to her lesson on phase changes. Additionally, her focus on getting her students to say the law of inertia was not related to her initial plans for this lesson nor department expectations of what should be taught in the phase changes unit. Her plans initially included connecting energy to phase changes. In Dave's case, there were no demands to maintain a curricular schedule. In fact, his entire day's lesson was a break from their current unit of study.

Lastly, it is possible that because Dave and Joanna were relatively new to teaching, they were exhibiting unstable practice. In other words, they could pay attention to students' ideas, but were unable to maintain it when they encountered unexpected ideas or novel situations. This is actually a reasonable explanation for some of what Dave did. George and Naveed talked about ideas he expected. With Aisha, Dave did not know what to do with her statement about the moon's lack of gravity. So, this led him to provide her with an explanation about how there is gravity on the moon. But, this does not explain why he seemed to be stuck in a mode of herding Aisha to the right answer even after she accepted his premise that there was gravity on the moon. Joanna was able to maintain her attention to her students' ideas in the episode in Chapter Three even when she had not expected, nor understood, what they meant. Also, when AJ talked about friction, though that was not the answer for which she was looking, this could not have been a novel idea to Joanna. As Joanna noted in an interview, friction is an integral part of everyone's experience.

These episodes suggest that there is something a bit more complicated going on than just inexperienced teachers or that the activity or institutional pressures constrained their attention in particular ways. In Chapter Five, I will explore how the teacher's framing of each interaction also played a part in organizing the teacher's attention in that particular moment.

Chapter 5: Teacher Framing Supports Attention

The previous chapters presented evidence of the teachers' attention. This chapter is about how to understand each of those instances of attention in relation to the interaction the teacher had with his or her student. The central argument of this chapter is that attention is a part of the teacher's framing of the activity. At times it may guide the frame, while at other times it is guided by the frame.

In this chapter, I will present a short discussion of John's episodes and a more detailed discussion of the episodes from Joanna's and Dave's classes. Joanna's and Dave's cases required more work than John's to establish what their framing of their interactions with students was. With Dave and Joanna, each teacher was working with students nominally in a single activity. Joanna's two episodes were from the warm-up to her lesson on phase changes. Dave's two episodes were from the part of the class where his students were working on the Galileo Questions worksheet before they had a whole class discussion about the answers. With both teachers, they each wanted their students to talk about their ideas during that time. Although Joanna and Dave each participated in a single larger activity (warm-up or seatwork to explore students' own ideas), Dave and Joanna framed their conversations with students in more than one way. John, on the other hand, changed his framing of the discussions with his students only when he moved to another activity (e.g., the questioning or the summarizing activities). Establishing his framing in each episode was a bit easier.

The purpose of this chapter is to explore the relationship between frames and attention. To do so, it will be necessary to articulate some of those categories of evidence of frames as well as determine how the frames are different from each other.

However, this chapter will not provide an exhaustive list of the types of frames and categories of evidence associated with those frames — that list could go on forever.

John: Framed as the Questioning Activity

In the set of episodes on Annie's question from Chapter Three, John's students were engaged in the reciprocal reading activity (please see Chapter Three for a full transcript). They first read about heat transfer and then read about heat and work. During the conclusion of the summary of the heat transfer paragraph, Annie interrupted class with her question (line 37), "So what if we had a bottle and like we was heatin' it up and like we put the top on the bottle. Would the bottle, would the top fly off?" After clarifying what Annie asked about (whether the bottle top was on before or after the bottle was heated), John asked his students for their ideas. They had a brief discussion and returned to the reciprocal reading activity. The official questioner's question ("What affect does adding heat energy have on the particles of a substance?") was answered with a direct reference to the material in the textbook. The word finder identified the word *particles* as a difficult word. Here, John ended up telling his students, in a short lecture, what particles meant. After the summary of the next passage, John brought his students' attention to Annie's question again and asked (line 119), "Do you think heat can move this top off the bottle?"

John treated Annie's question as if it was a questioner's question, even though that was not her role at the time. In the questioning part of the reciprocal reading activity, the goal was to discuss ideas students might have associated with what was asked and develop an answer to the questioner's question. There were specific goals, roles, and expectations John associated with this activity.

In his conception of the questioning portion of the reciprocal reading, John valued questions that pertained to what they read as well as had the potential to extend students' understanding of the topic. He also valued answers that showed students were processing the ideas and not just reiterating what was in the text. For example, in another reciprocal reading cycle, Diego, the questioner, asked why a pinwheel held over a light bulb would spin (there was a picture depicting this situation in the textbook). In an interview, John said that the initial answers to the questions were not sufficient because students did not say anything that added to the class' understanding of how heat affected the pinwheel (answers were: "Because of the heat"; "It's spinning because the heat around it makes it spin"). During that interview, John explained what he looked for in an answer to that question.

> John: I would have liked to have heard something about (the ideas of) convection or radiation…It might even have been better, you know, (if they said) all these particles are moving faster, so they're going up…and because they're going faster and up, they're hitting the pinwheel and making it go around….So they could (have explained) it by, you know, telling me what was going on….I (also) have no problem (with) there being something in the book and students questioning it. Saying, "Oh, well, maybe it's a trick question." Or you know, "Maybe they're just wrong. Maybe there's some other factor (like a little wind)." (Interview, August 15, 2007)

In an interview, John said he wanted his students to collaborate with each other on the answer to the question.

> John: I want 'em to go through the thought processes to try and figure out a question that's been posed.… I might have them sort of think about it and try and figure it out…. Maybe another student will have some sort of insight, but as, you know, as a group thinks about something …you know, different ideas can even spawn the person who asked the question into sort of, you know, figuring out, it out or having a new idea. So, it gets 'em, you know, it gets, it gets sort of an academic, more academic feel to the class than just the, you know, this is what it is because it is [or?] because I said so. (Interview, August 15, 2007).

John's role in this activity was to facilitate the development of the answer to the question.

> John: If a student comes up with a question, it's always open to the floor. … I don't give them a first answer…. Sometimes I'll follow it up with a question… then that'll get other students to think about it and they try to figure it out on their own. Um, and I usually try to lead 'em to (the answer)…. Some of (the questions), they can figure it out. Some of (the questions), no matter what they do, they won't be able to figure them out. Some of (the questions), I don't know…. You know, a question can be anything. (Interview, August 15, 2007).

These aspects of the questioning activity help direct John's attention to student ideas when he frames interactions as the questioning activity. First, he needs to make sure the rest of the class can see what is being asked. Then he needs to understand how his students are thinking to facilitate a discussion where his students can collaborate on an answer.

In the two episodes regarding Annie's question, we can see all these elements of the questioning activity come into play. Annie asked a question that was related to what they read and had the potential to help students connect the topic with a real-life scenario. In both episodes, when John asked his students about Annie's question, he opened up the discussion to the class (line 44: "Oh, so you heat it up first and then put the top on, what do you think will happen?" and line 123: "What do you think you have to do to, to make uh, uh the bottle top move off of a bottle?"). He encouraged student discussion by making sure the ideas could be heard (e.g., he worked with Eddie to make sure his idea was clearly presented to the class) and explicitly asked his students to comment on each other's ideas (line 51: "Um, anybody think anything different?" and "We'll have to find if it's different whether there's water or just air in there. You guys think that makes a difference?").

By framing the discussion of Annie's question in this way, John's attention needed to be directed to his students' thinking. He needed to understand what Annie asked and also how his students thought about what would happen with the bottle.

John: Framed as the Summarizing Activity

The summarizing portion of the reciprocal reading activity had a different goal, as well as roles and expectations than the questioning activity. It seems the goal for the summarizing activity was to make sure the students wrote down an accurate summary of the text's main idea in their science journals, or notebooks. In much of the reciprocal reading activities I have observed in John's class this was the case.

This was also confirmed in the interview statements John made about what they did during the summarization.

During an interview (Interview, March 17, 2008), John described the general pattern for the summarization activity. The summarizer is allowed the first attempt at presenting a complete and accurate summary of the main idea. Then other students are allowed to contribute to the summary if they have more to add. John explained in an interview, "(I may) have other kids, you know, add in and get a complete summary on the board so that everybody has a good complete summary (in their journals)." John's role was to ensure that an accurate summary was written up on the board. If students did not present an accurate summary, John would ask questions, provide hints, or guide students to the right summary (e.g., show them "where in a paragraph it's most likely to have the main idea"). For John, it was important "content-wise…and for reinforcement (of)…good reading strategy" for students to get the correct summary.

In John's view, he did not expect summarizing to be a place for students to make connections to other ideas they may have had. That would take place in other parts of the reciprocal reading activity. Here, he wanted his students to focus on what the text said.

> John: (Questioning) is a completely different thought process than the summarizer…. It's a higher level thinking skill than the summarizer…. (For example) you read over this (transcript) and you say, "Oh, your class was like this, and you know, doing that."… (In questioning), not only do you have to know what was going on… you have to be able to process that and sort of say,

> "Well, what other things are going on…What am I not seeing here?" And all sorts of higher level questions. (Interview, March 17, 2008)

These expectations, roles, and goals may have helped constrain John's attention in the episode from Chapter Four. There, his students were working on the summary for the passage on the law of conservation of energy. The summarizer, Jaquan, initially presented what John thought was an incorrect summary of the text (line 130: "It's mostly about how energy is formed"). John responded by directing his students to the text they just read (line 133: "What does the law of conservation of energy say? Does it say that energy is formed?"). Eventually, John provided his students with the correct summary. Annie added to the summary by claiming that energy (line139) "can't be destroyed, it can increase." John corrected Annie (line 142: "No, it can't, it can't be created or destroyed so you can't increase it") and then moved the discussion to his question: "If we wanted this battery to be more powerful, what would we need to do?" The subsequent discussion consisted of John leading his students to the conclusion that one needed to make the battery bigger in size because more chemical energy is needed to get more electrical energy from the battery. As we can see, each time his students talked about the ideas in the passage incorrectly, John stepped in and corrected them. His students presented ideas that would not lead to a complete and accurate summary, so John needed to push aside those ideas and focus attention on getting the right summary out.

Dave: Framed as Exploring Students' Ideas

Dave's plan for this day was to have his students complete the Galileo Worksheet. This worksheet was developed through discussions Dave had with his fellow teachers in a professional development project focused on helping teachers respond to student ideas in the classroom. The purpose of the worksheet was to elicit student thinking about falling objects by presenting them with various scenarios that focused on different factors that affected the fall. This episode took place during the portion of class where students were instructed to work at their seats, either individually or with a partner, on the worksheet questions. After this seatwork time, Dave held a whole class discussion about the answers students generated. Dave's intention with this day's lesson was to elicit his students' ideas so he could understand what misconceptions they had about falling objects. Once he understood what his students were thinking, he would be in a better position to help them correct their wrong ideas. In the episode below, Dave talked with his students, George and Naveed, about their thoughts on Question 1. In Question 1, a hypothetical student claimed if there was no air resistance, heavy objects would fall first.

In the episode with George and Naveed, Dave framed the interaction as, "exploring students' ideas about falling objects." The questions he asked and statements he made created the conversational space that allowed his students to develop their ideas. He rarely interfered with the articulation of those ideas. In the interviews, Dave explained that his intention was to help his students understand their own ideas more fully rather than introduce new ideas they might not hold. He saw this as a way to prepare his students for the whole class conversation about the correct ideas. If they understood their own thinking clearly, his students would be in a better position to understand the correct answer. Framed in this way, there were strong factors that encouraged Dave's attention to the substance of his students' ideas. Dave needed to do so to help his students explore and develop those thoughts. Additionally, Dave needed to understand his students' misconceptions so he could later help his students correct them.

Class data.

The following is a presentation of evidence from the class of how Dave framed this interaction as exploring student's ideas and how this framing supported his attention to student ideas.

53.	George:	If there wasn't no air the ball would be coming down very very slow.
54.	Dave:	If there was no air?
55.	George:	Yeah.
56.	Dave:	So you're saying it would come down slower if there was no air.
57.	George:	See like this (holds a book up and moves it down slowly) very slow. Like this, very slow, steady, because there isn't any air.
58.	Dave:	So you're saying air makes things fall faster.
59.	George:	Yeah. (turns to write on worksheet)
60.	Dave:	OK.
61.	George:	(8-second pause while writing) How high is this thing? Like if you dropped it, how high is it?
62.	Dave:	For which one.
63.	George:	For number one.
64.	Dave:	Number one, it doesn't matter, any height.
65.	George:	I mean, if you drop this from a certain height, it wouldn't, [the book?/they both?] wouldn't hit the ground.
66.	Dave:	Not at the same time?
67.	George:	Nah.
68.	Dave:	(pause) So are you saying the higher up that you drop something, like, the less likely they are gonna hit the ground at the same time?
69.	George:	Yup.
70.	Dave:	OK why?
71.	George:	Because it's heavier. Say look, say like, if I got, if I stand on top of this (slaps the top of the lab bench), right, and [we drop?] this (holds up a book), [along?] with this (reaches for another object) the binder's gonna drop first.
72.	Dave:	The, that one's (pointing to the book) gonna drop first?
73.	George:	No (slaps other object).

74. Dave: No this one. Why?
75. George: Because it's a lot heavier.
76. Dave: So, heavier, you're saying heavier objects fall faster than lighter objects.
77. George: Yup.
78. Naveed: That's not true.
79. Dave: You don't think that's true? Why not?
80. Naveed: On earth it's not true.
81. Dave: On earth it's not true?
82. Naveed: Air resistance.
83. Dave: So air resistance plays a role in how fast things fall? Like how. How does air resistance affect how things fall?
84. Naveed: Like if you drop this book and this pencil, they're gonna fall at the same time.
85. (George gets up to drop the binder and pencil
86. Dave: But…OK just be careful near the equipment, here do it over here.
87. George: Right here?
88. Dave: Actually, here, do it on that desk.
89. (George drops the objects and both hit the desk at the same time.)
90. Naveed: See, it didn't. That's why I got an A in this class.
91. Dave: So wait-do you still think that heavier objects fall faster?
92. George: (nods) I mean, for real though, if I stand up on top of here (pointing to the lab bench) and drop both of them (holding hands out at the same (height), this (places hand on binder) gonna land first, before that pen.
93. Dave: If you're, so you're saying if you were up a lot higher, it would be more clear that this one would fall faster than the pen.
94. George: Yup.
95. Dave: OK, why, why do you think that?
96. George: I don't know, I just know! It's gonna happen.
97. Dave: OK all right. I'm trying to get you to think about why that would happen. So that's what I want you to write down. Why do you think that would happen, why do you think heavier objects would fall faster than lighter objects.
98. George: Why?
99. Dave: Yeah. (to class) OK you've got about 5 minutes.

Created conversational space for students to speak.

Through his interactions with his students in this episode, Dave indicated that he wanted to attend to students' thinking. A basic word count shows that Dave generated 54 percent of the words in this exchange and his students, combined, contributed the remaining 46 percent. Of the 21 times Dave entered into the conversation, he generated 12 questions and four statements that directly referred to something a student said. But that analysis is done in broad strokes that do not provide much information about how he used what he said to create space for his students to speak.

His contributions frequently did not add to the content of the conversation. Instead they were usually restatements of what his students said or invitations for his students to expand on their words. In lines 54, 56, 72, 79, 81, 83 and 93, Dave restated much of what his students presented. By not adding anything new to the conversation, Dave effectively forced the conversation to focus on what his students told him. There was nothing else to talk about other than what his students were telling him. Some of these restatements were mere half statements that ended in a rising tone (lines 54, 81, and 83) which seemed to act as a request for his students to say more about what they were thinking. For example, in line 54 when Dave asked George, "If there was no air," George took this as a request for more information because he responded by explaining what he meant.

A noteworthy example where Dave created space for George to talk about his ideas is in line 91. Even though the result of his students' experiment seemed to refute George's initial ideas, Dave checked if George was still committed to his original argument. This helped open up the possibility of disagreeing with the experiment, which, as it turned out, George did. It seemed Dave did not want to assume he knew what his students were thinking because he allowed for the possibility that George might still hold his initial thoughts, even though the experiment's evidence suggested abandoning them. By making space for his students to generate their ideas, his students willingly provided Dave with more and deeper aspects of their thinking. With more and better ideas, there was simply more substance for Dave to attend. This provided a feedback loop that reinforced Dave's attention and supported this framing.

Even when he did add to the substance of the discussion (lines 58, 64, 66, and 68), his contributions were explicitly rooted in what his students said. For example, in line 58, Dave reflected back to George an implication of what George proposed. George had said that without air resistance, the two objects would fall very slowly. Dave responded by asking if George thought air was what made things fall faster.

Attention to the causal relationships behind students' ideas.

Dave's attention was not directed at just any aspect of his students' thinking. There were expectations about what was appropriate to pursue in this discussion. Dave was interested in having his students talk about the causal relationships between the observed (or proposed) phenomenon and the various factors in this situation in Question 1. To pursue this goal, Dave needed to pay close attention to how his students were thinking about falling objects.

Dave transformed some of his students' statements into more generalized or abstract forms to highlight or extend the students' logic. For example, in line 76, Dave said, "So heavier, you're saying heavier objects fall faster than lighter ones" in response to George's claim that the book would fall first because it was heavier. Here Dave emphasized the relationship George described in his example and applied it to more generalized categories (heavier versus lighter objects). In some other statements, Dave drew out the implications of what his students said. For example, after George explained that objects would fall very slowly in an airless situation, in line 58 Dave responded with a contrapositive of that account, “So you’re saying air makes things fall faster.” With regards to questions he asked, an example can be seen in line 83. After Naveed explained what he meant when he interjected, Dave pressed Naveed for an explanation of the mechanism behind his claim that heavier objects would not fall faster than lighter ones on Earth because of air resistance. Here, he asked Naveed specifically how air resistance affected how objects fell.

These statements and questions tended to bring to the fore the causal relationships between the observed (or proposed) phenomenon and the various factors in the situation. In this frame, exploration of his students’ ideas entailed finding out how his students thought about the mechanisms at play and how those ideas cohered with ideas they might have about related situations. Drawing attention to mechanistic explanations, abstracting his students’ statements into more generalized relationships and asking questions that led students to develop logically consistent arguments were some of the ways Dave helped his students explore their ideas. To do so required close attention to the meat of his students’ ideas.

Interview data.

The following is a presentation of evidence from the interviews that corroborates the evidence from the classroom data on how Dave framed this interaction. The interviews provide supporting details about how Dave seemed to interpret events.

Interpreted students as having substantive ideas.

In the interview, Dave explained that he felt George and Naveed were willing to express their thoughts and these thoughts were worthy of exploration. For example, he described George as being authentically engaged because he was talking about his own ideas. Dave said, "He's very sincere, like he's very honest in his explanation of what he thinks is happening" (Interview, June 14, 2006). It was important to Dave that his students were genuinely responding with their own thoughts to his questions. If he was to explore their thinking, he needed to trust that they would tell him what was on their minds.

> Dave: I don't want them to give me an answer that they think is correct, or that's what is correct according to Physics if they don't understand. I want them to give me what they actually think about the situation…I don't want them to fake their responses (because) only if I know what they're actually thinking, can I help them adjust what they're actually think to better understand what's correct. (Interview, June 14, 2006)

At the time, he felt that George, in lines 53-59, attempted to make connections between different ideas he had about space and gravity and Dave needed to support that.

> Dave: So he's thinking, "OK, if there's no air, it must be space, and if it's space, then things don't fall very quickly," so he's taking those ideas and bringing them together and then thinking that it's one idea when really it's two separate ideas… I want him to at least for the time being like (to) lock onto that idea and so maybe it's more firmly established for the time being even though it's wrong. (Interview, June 14, 2006)

For Dave, exploration of his students' thinking was also supported by the goal of helping his students learn and his belief that his students needed to examine their own thinking in order to learn. Regardless of whether or not George was correct, it was important in this interaction for his students to examine and develop *their* ideas. Even though mastery of the correct ideas was important, for now, Dave just wanted to understand what his students were thinking. Though it may seem trivial to state, it is important to note that Dave, in this framing, saw his students as having ideas worth exploring.

Other interpretations and expectations would fit with other frames. For example, he could have interpreted his students as not having any productive ideas about the situation in the worksheet because they were providing the incorrect answers or that they were rooted in something meaningless (e.g., making up answers). This interpretation would not have aligned well with framing the interaction as exploring students' ideas and would not have supported attending to the substance of his students' ideas. With those interpretations, there would be no ideas worth exploring.

In fact, in this class, Dave interpreted Naveed's statements about objects hitting the ground at the same time in two different ways. In this episode, he felt that Naveed had an idea about how height mattered with objects falling through air, "So Naveed, I guess, could identify like why, over a large height, one object will get to the bottom before another one and it's air resistance. So then I guess I'm just trying to elicit his idea" (Interview, June 14, 2006). However, right before this episode, Dave and Naveed had an interaction in which Dave interpreted and responded another way.

41.	Dave:	We're not talking about friction though. We're talking about free-falling objects.
42.	George:	[inaudible] I had this girl that played football and she fell. So-
43.	Naveed:	Her body and the ball fell at the same time.
44.	Dave:	Right.
45.	Naveed:	We were just discussing that. I mean, it was amazing how the world of physics can just take over my brain. (pause) It's just like (pause) oooh-
46.	Dave:	I'm glad you're much more aware of the world now. That's good, that's good. How the world works.

In an interview, Dave said Naveed was not engaging in the class authentically but instead was trying to sound smart. Dave explained, "Like I don't think he understands …where I'm going with this (worksheet) and he's just trying to throw stuff out there and sound smart…'Oh and they fell at the same time'…It's very insincere. He's blowing hot air" (Interview, June 14, 2006). Both in the interaction with George and Naveed and in this above snippet, Naveed essentially said the same thing—that he believed objects would fall and hit the ground at the same time. This snippet makes for an interesting case about framing. Here, the cue from Naveed suggested he was joking and possibly not taking the work they were doing seriously. Dave's sarcastic response acknowledged Naveed's joke and indicated that Dave did not take his student's point seriously here. In the snippet with George, Dave treated Naveed's statement more seriously. He saw Naveed as genuinely participating there.

> Dave: So Naveed I guess could identify like why, over a very large height one object will get to the bottom before another one and its air resistance. So then I guess I'm just trying to elicit his idea…. I think Byron has an understanding, or at least an intuition about the influence of air resistance, but he just hasn't identified it directly the way Naveed has. (Interview, June 14, 2006)

That is not to say that Naveed might not have been playing the "I can sound smart" game in the episode with George. In that episode, what Naveed said in line 90 ("See, that's why I got another A in this class) could be another example of Naveed playing the "I can sound smart" game. In the interview, when line 90 came up, Dave commented, "See that, that's another example of him just like goofing off, 'See, that's why I got another A in this class'" (Interview, June 14, 2006). Though this was Dave's interpretation of line 90 during the interview, this interpretation did not surface in his interaction with Naveed during the class. Until that line, both in the class and in the interview, he treated Naveed's ideas as authentic and attended to the substance of those ideas. In this frame, if there are student ideas present, Dave's job was to doggedly pursue those ideas.

Interpreted his role as helping students articulate their ideas.

To help his students explore their ideas, Dave needed to find ways to support his students' expression of their ideas. In this role, he encouraged his students to speak, tried to elicit the ideas that were hidden and not interfere with their articulation. He explained in the interviews that he wanted to help his students explore and understand their own ideas. Part of his role here was to not get in the way of his students speaking and developing their ideas.

Encouraging students to speak.

Dave was concerned that his students would withhold their ideas during this day's lesson. He explained in an interview, in the past, he had seen students shut down when he tried to probe their thinking.

> Dave: So like, if they started to go into a different direction, I would like push them in that direction and make them defend it…. Or if I thought they were being vague, I would try and get them to clarify. And a lot of them will like back off. Like as soon as you start pushing, they like, they run away… they feel overwhelmed and they run away…or they just get confused and they give up. (Interview, April 13, 2006)

For Dave, this worksheet activity was aimed at helping him gain insight into his students' thinking about falling objects. If students withheld their ideas, they would not be able to fulfill their task of completing the worksheet. It would also keep him from seeing what misconceptions his students held.

He tried not to tell students what he knew even when he thought they were wrong because that would interfere with his students' verbalization of their thinking. He explained in an interview, "I feel like in this part of the class, I'm actually denying them access to my understanding of physics so that more of their ideas will come to the surface, more will be articulated in the discussion" (Interview, June 14, 2006). For example, with George, Dave said, "…if I just interrupt him at this point or wait till he's done and then say, 'No. No. No. It's wrong, think about it this way', he might not think about it at all." Getting his students to the right way of thinking was not the point in this part of the class. Helping his students figure out what they were thinking was.

When he did interject his own ideas into the discussion, he was very conscious of not saying things in a threatening way that would stop his students' flow of ideas. For example, Dave explained in an interview, that in line 66, he purposefully presented the correction "not at the same time?" to George's statement as a question when George indicated, in line 65, he did not think the two objects would not hit the ground. Dave felt that George was veering away from the question but did not guide George back too forcefully. If he pushed too hard, George might assume Dave was telling him that his ideas were wrong and quit talking about them.

> Dave: I was thinking he's still thinking about the two objects being in space, far away, so…if there's no air, there's no gravity.…then if you drop something, it's never going to hit the ground, it's just going to float there. So … I try to redirect him back to the question by saying "not at the same time?" …Implying to him that they are going to hit the ground, but it's a question of whether or not they are going to hit the ground at the same time… that just because there's no air, that doesn't mean that there's no gravity. (pause)…the question is clearly asking about objects that are falling, so if he goes off talking about something that isn't falling, then he's not really… paying attention to what the question is asking about…. I try to just kind of like, indirectly, bring him back without threatening him. (Interview, June 14, 2006)

Since George's comment in line 65 opened up the possibility of going away from the focus of the worksheet question, Dave needed to guide the discussion back to where he thought they belonged. However, he did not want his students to see the discussion in a way that would not allow them to continue exploring their ideas. If they saw this as an exercise to get to the right answer, as opposed to exploring their thinking, his students might be more focused on fishing for the right answer from Dave.

Eliciting more student thinking.

Not only did he encourage his students to speak, he also needed to actively elicit their ideas. By directing attention back to the students whenever they spoke about their ideas, he was able to probe more deeply into their thinking. In an interview, he described how he tried to direct attention back to George in this episode.

> Dave: Basically I'm parroting what he's saying, kind of like reflecting it back to him.… All I'm doing is, he's giving me a thought, and then… he shines the spotlight on me to like get some kind of response back, and then I shine it back on him real briefly, and then he gives me some more thoughts and I just kind of like reflect back to him, and in this exchange I'm just, all I'm doing is trying to just like bring thoughts to the surface. I'm making him explain himself as completely as he possibly can. (Interview, June 14, 2006)

Dave explained that he also tried to dig more deeply into Naveed's thinking in lines 78-84. He said, in an interview, "So Naveed, I guess, could identify like why, over a large height, one object will get to the bottom before another one and its air resistance. So then I guess I'm just trying to elicit his idea" (Interview, June 14, 2006).

The elicitation was in service of exploring the meaning of those ideas. Dave explained in an interview that the question he asked in line 83 was not only to elicit Naveed's idea but to also explore how he thought air resistance played a role in falling. Dave also felt he took the same tack with George when he asked George why he thought the difference in falling times for differently weighted objects would be more prominent with larger heights.

> Dave: So I think there that he had an intuition about like, the higher up you are, the more air resistance plays a role in the, um, in the falling of an object…. He kind of has an intuition about it so there's something that glitters to me about air resistance and falling objects so… I say to him, 'OK, why?' So I shine the light back on him and then he feels compelled to explain to me why he thinks that. (Interview, June 14, 2006)

In this framing of the interaction, Dave's attention to the unexplored aspects of his students' thinking was a part of the frame "exploring his students' ideas." Dave looked for places where deeper ideas were hidden or aspects that needed clarification.

Helping to keep the intellectual momentum going.

In responding to his students the way he did, Dave also thought he was helping his students keep their intellectual momentum going.

> Dave: So I'm trying to get him to maintain whatever it is that he's thinking. Because sometimes… I really don't care what they're thinking so long as they're thinking because… there's some kind of mental mechanism or machinery that's like operating inside their brains at that point, and… part of

my goal is to keep that, that intellectual momentum going, even if it's wrong, because they're doing something that's making themselves smarter when they're doing that. (Interview, June 14, 2006)

For Dave, it did not matter whether George or Naveed had the correct answer during this part of the lesson. It was more important that they engaged in the process of exploring and fleshing out their own ideas. This would support their learning.

Dave used several methods to help his students continue thinking about the problem and the concepts. In an interview, Dave explained that he drew on his undergraduate philosophy major's experience to help his students. When, in line 58, Dave provided a contrapositive of George's idea (without air, objects would fall very slowly), Dave was engaging George in a logic-building game. This was a way to explore the implications of George's ideas.

> Dave: At that point, I'm just playing a logical game with him because he says um, if there wasn't no air, would the ball be coming down very, very slowly? So I say, so he's like, well if there's no air, it would go slowly, so then I say, oh OK, well if there was air, the opposite situation, then it would go down faster and he says yes, because it's the opposite. So he tells me one thing, I then reflect back the opposite, and then he gives me the opposite consequence so there, I mean he's showing me that he can think logically, like just in an exchange, but even though he does, even though the concept isn't right…. Because I'm trying to get him to realize the logical implication of what he's saying…. It's just for coherence of thought, like developing coherence and of thought. (Interview, June 14, 2006)

When it became clear to Dave that George was struggling to explain himself at the end of the episode, Dave decided to ask George to switch to another mode of exploring by writing out his ideas. Dave hoped that by writing, George would be forced to figure out what he was thinking in ways that verbalizing did not allow.

> Dave: (In line ninety-six), OK. So if, yeah, here he doesn't answer my question, he just kind of, he just goes to, and I mean that's fine because I think he's sincerely struggling to illustrate his point. Like, he realizes I'm questioning him and so he feels compelled to clarify what his idea is, hoping that whatever that clarification is, that it'll answer my question, even though in this exchange I don't think he answers that question, but he's trying to do that, and that's what I'm really trying to encourage. Whatever I can do or say, however indirect it is, if it gets them thinking about stuff, then great. It doesn't have to be a perfect logical exchange…(I want to) force him to write his ideas concisely and when he writes it down you're more likely to remember it. You've decided that this is what you believe, write it down. Articulate it on paper concisely. (Interview, June 14, 2006)

For Dave, it did not matter if George answered his specific question or even if he came up with the right answer to the worksheet question. It was more important for George to engage in this thinking game. Helping his students maintain their intellectual momentum was a way to maintain the activity of exploring his students' ideas. In order to keep that intellectual momentum going, Dave needed to pick up on and respond to the ideas his students presented in an encouraging way.

Understanding when students were struggling to explain themselves and what aspects of those ideas they struggled with required attention to those ideas.

Comments

Both the classroom and interview data show evidence that Dave was focused on exploring his students' thinking. Dave's goals, actions, and interpretations strongly encouraged attention on his students' ideas. To help his students develop their thoughts, he created conversational space for them to express themselves. He saw his students as not only capable of expressing their ideas but that they had ideas that were relevant and productive for the learning task at hand. Lastly, he envisioned his role as assisting his students in the formation of their conception of the situation, by encouraging them to speak and to build on their ideas. These together helped create a context where Dave's attention to his students' ideas was strongly supported.

It is worth noting that his attention on his students' ideas in this context seemed to form a feedback loop with his students' contribution to the conversation. Dave concentrated on and encouraged his students' thinking. This encouraged his students to present more of their thoughts. This in turn provided more for Dave to attend and reinforced his interpretations of his students, which further promoted verbalization of student ideas and deeper exploration of what was in their minds. This feedback loop was a part of the frame and reinforced his attention. A deeper discussion of this issue will occur in Chapter Six.

Dave: Framed as Getting to the Right Understanding

This next episode took place a few minutes after the episode with George and Naveed, during the seatwork time. After Dave walked away from the boys, Aisha called Dave to her desk to check her answer for worksheet Question 2. Worksheet Question 2 was:

> A bowling ball and a small rock are dropped from the same height at the same time. Which one lands first if this experiment is done
> **(a)** on the Earth?
> **(b)** on the Moon (which has no air)?
>
> Be sure to explain your reasoning and to answer both (a) and (b).

101.	Aisha:	Mr. H.
102.	Dave:	Yes.
103.	Aisha:	If you drop a bowling ball and a, a small rock on the moon, neither one of them would drop would it because there's no gravity up there.
104.	Dave:	So you don't think there's gravity on the moon?
105.	Aisha:	No, (pause)-
106.	Dave:	So-
107.	Aisha:	-because that's how space is.
108.	Dave:	OK, so if you're really far away from massive objects like the moon or the earth or the sun, then gravity is negligible, it's, it's like there's no gravity.
109.	Aisha:	(audible level) So it's…
110.	Dave:	But, if you're near. So, there is near, so there is gravity on the moon, yeah.
111.	Aisha:	(sotto voce) OK.
112.	Dave:	So things **do** fall on the moon. Do you think that, do you know if they fall faster or slower on the moon? (Aisha shakes her head no) They fall slower. Any idea why?
113.	Camille:	Because, uh, there's less gravity.
114.	Dave:	Right, so things accelerate slower on the moon because the moon is less massive than the earth.
115.	Aisha:	So a bowling ball would drop first right?
116.	Dave:	On where?
117.	Aisha:	On the moon.
118.	Dave:	(3-second pause) OK why?
119.	Aisha:	Heavy, [it's?] heavier.

120. Dave: Because it's heavier? So you think that heavier objects fall faster than lighter ones?

121. Aisha: (slight hesitant tone) On the moon, they drop slower

122. Dave: So, so, are you saying that on earth they would fall and hit the ground at the same time? (Aisha gives a very slight nod) But on the moon they wouldn't? (Aisha gives a slight nod) OK so what's the difference between the earth and the moon? (Aisha shrugs her right shoulder and chuckles) So (Dave's voice exhibits more inflection and changes in tone), so, why do you think that then?

123. Aisha: (smiling, looks at paper for 3 seconds, speaks loudly and with a quicker pace than line 121) Because it's outer space, (hesitant tone) it like, it's probably less gravity in outer space than it is on earth.

124. Dave: OK so gravity isn't as strong on the moon as it is on earth. That's true. But, so if gravity's weaker on the moon, I mean, things aren't gonna accelerate down as quickly on the moon, but why would, um, the fact that we're on the moon like, affects which one hit first? Like wouldn't they both (mimics two objects falling with his hands) just hit the ground at the same time just at a slower rate, (Aisha shrugs both shoulders and raises eyebrows) is that possible?

125. Aisha: (3-second pause) So they're gonna hit at the same time?

126. Dave: (5-second pause and rifles through stack of papers in his hand) That's what I want you to think about, that's what I want you to think about.

127. Aisha: (sotto voce) I'm gonna put down I don't know.

128. Dave: (Stands by Aisha's desk watching the class as she writes. Glances at his watch. 15 seconds later announces to class while walking away from Aisha's desk) So you've got about 2 minutes. I'm collecting these at the end of the period so you need to make sure that you have them done. How's it going?

Dave ended up framing his interaction with Aisha and Camille differently from his interaction with George and Naveed. This frame, labeled "getting to the right understanding", incorporated different conversational moves, attention and interpretations. Here, Dave contributed a lot to the content of the conversation, attended to and directed his students' attention to what was correct, and interpreted the meaning and relevance of student ideas in terms of how well they would help his students accept the correct way of thinking about the moon. In this frame, having the correct understanding about gravity on the moon meant also developing the correct answer to Question 2b. All of these aspects of the frame helped direct Dave's attention away from the substance of his students' ideas and toward the canonical understanding about gravity on the moon.

Contributed correct content to the conversation.

Dave contributed to the content of the conversation much more than he did in the episode with George and Naveed (lines 108, 110, 112, 114, and 124). Additionally, the content he contributed was the canonical (or correct) content that was associated with Question 2b on the worksheet, as opposed to implications of his students' ideas. For example, in line108, after Aisha explained how she thought there was no gravity in outer space, Dave proceeded to tell her that there is gravity in outer space, though a negligible amount, and that there was definitely gravity on the moon. Dave continued by explaining that gravity is lower on the moon and that meant things would fall more slowly than on Earth (line 112 and 114). None of his contributions could be inferred from what Aisha said.

Some of Dave's questions acted as vehicles for delivering content. For example, the question in line 124 ("Like wouldn't they both just hit the ground at the same time, just at a slower rate, is that possible?") provided the correct answer to the worksheet question. Just prior to this question, Dave effectively told Aisha that her idea that heavier objects on the moon would fall faster than lighter objects was incorrect. His leading question at the end of line 124 helped replace Aisha's wrong answer with the correct one (objects on the moon fall at the same rate) and directed Aisha's attention to the correct answer to Question 2b.

Dave also attributed ideas to his students they did not say, such as in line 122, which also served to introduce more content into the conversation. Here Dave said, "…are you saying that on earth they would fall and hit the ground at the same time? But on the moon they wouldn't?" It is not clear that was what Aisha meant in line 121, in any of the lines prior to this point, nor in her hesitant, gestured responses to Dave in line 122.[8]

Adding in scientifically accurate information communicated that accepted ideas and answers were an important feature of this discussion. This helped to direct the conversation's focus on the correct ideas rather than on his student's ideas. Participating in the interaction in this way was markedly different than with George and Naveed. There, not only did he refrain from introducing new content into that discussion, he did not indicate if any of the ideas were right or wrong. His

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8 It is possible that Dave, who was standing about 2.5 feet to the front and right of Aisha, had glanced down at her paper, which was oriented away from Dave, and read this from her written responses. Her response to 2a, a question about the two objects falling on Earth, stated, "They land at the same time, the air is slowing the (bowling) ball down to same them drop at the same time."

However, there was no indication from the data that Dave read anything off of Aisha's paper. It was not apparent that he glanced at her paper; he did not gesture to her paper in speaking line 122; there were no pauses in his speech to indicate he was trying to read text that was oriented away and sat a short distance from him. Additionally, if what Dave was doing in line 122 was drawing connections in the interaction to Aisha's written answers, what Dave drew out was the phenomenon she identified and not the reasoning that she used. Dave, in 124, provided her with the explanation about gravity on the moon and its comparison to gravity on the earth. This line of reasoning did not acknowledge the reasoning that Aisha had put on her paper.

Dave attributed to Aisha the idea that objects fall at the same rate because gravity causes equal acceleration, independent of the object's heaviness. What Aisha wrote indicated she thought the heaviness of an object would result in different accelerations, and air resistance is what slows down the heavy ball so it will fall at the same rate as the rock. For Aisha, the equal rates of falling were the result of air resistance compensating for the effect of gravity and not the result of either air resistance or gravity alone. This is the same incorrect argument the hypothetical student in Question 1 proposed. If Dave had read Aisha's paper, he would have noted that and would have questioned whether or not she thought what happened on Earth would also happen on the Moon, which had nearly no air on its surface.

Another possibility was simply that Dave did not read Aisha's worksheet and assumed she thought that objects on Earth would fall at the same rate. By this point in the year, the class had already discussed gravity and related topics. As stated earlier, it is not clear that was what Aisha was thinking about at the time and thus it is not clear if Dave was accurate in this assumption. Regardless of which situation it was, in line 122, Dave's contribution served to correct Aisha, assigning an idea to her that she might not have held, and introduced new material into the conversation.

contributions here suggested that the conversation was about the correct way to think about the moon and not what his students thought about the situation proposed.

Students needed correct information to reason appropriately.

Interview data shows that Dave found it critical to get Aisha to accept the canonical understanding of gravity on the moon. In this frame, making progress on the worksheet question meant developing the correct understanding about the situation on the moon. This reinforced attention on canonical ideas rather than his students' thinking. Dave saw this question as helping students come to the conclusion that objects on the moon would hit the ground at the same rate, just as they would on Earth, but at a slower rate than on Earth. To come to this line of reasoning, he needed to make sure Aisha was working with accurate information about the moon. If she was not, then he needed to provide it.

> Dave: The question is about an object on the moon and we haven't really talked about gravitational forces on things or exerted by things other than the earth…. I don't think that they've been exposed to the idea that as long as you have mass then you exert a gravitational force on other things that have mass... if they don't know it, then I just end up explaining it. (Interview, July 6, 2006)

Evaluations of Aisha's statements were related to how well they matched canonical ways of reasoning. Though Aisha used the idea that there is gravity on the moon to reason in her responses, Dave was not satisfied with Aisha's answer. Because she could not reach the right conclusion, Dave was not convinced Aisha knew what the idea meant.

> Dave: I don't think she knows which direction to take in answering that question. Um, that on the earth they would fall on the ground and hit the earth at the same time….I don't think she understands that they would be both accelerate down at the same rate on the moon. Um, just at a slower rate than they would on earth. So that's when I just start explaining what happens because I don't think she has enough background knowledge to be able to jump, to make that conclusion. So that's just me trying to explain and fill in the gaps in her knowledge. (Interview, July 6, 2006)

He attributed her inability to a lack of knowledge that he needed to provide. Implicit is the belief that his students could understand this idea only if someone told them the information or provided them with direct experience with the phenomenon. Since Aisha was not thinking about the moon in the right way and he could not take her out to the moon to show her, he needed to tell her what would happen. The expectation was if he explained the ideas properly, then Aisha would comprehend the situation.

Learning progress here was closely linked with how well he could explain the ideas as opposed to how well Aisha could articulate her own ideas.

> Dave: (In line 124) I don't think I've put it in student talk so to speak, so in (line 125) I think that's her kind of like fishing for the answer that I've already given hidden amongst all of these other explanations…. And I don't think she necessarily understood the explanation I gave in (124), but she senses that I'm trying to get her to conclude that they do hit at the same time. So I don't think my explanation was very effective in (124). (Interview, July 6, 2006)

Aisha's questions at the end of the episode were seen as "fishing for the answer," which indicated to Dave she did not understand what he tried to explain to her. In an interview, he said that since his explanation was not effective and he had given her all the pieces to reason with (the correct reasoning, the correct answer to the worksheet question, and the correct information about the moon), he hoped that by leaving her to think about things on her own, she would understand what he was telling her.

This way of seeing his student's ideas and his role in assisting his students' progress is very different from how he saw things in the previous episode. In the previous episode, development of canonical ways of reasoning was not the focus of the interaction and his role was to support the development of his students' lines of reasoning, irrespective of correctness. In this episode, the canonical ideas took priority and his role was more like a transmitter of information than a facilitator of student thinking.

Constrained attention to correct ideas.

Dave guided discussions toward what he considered acceptable topics with respect to the worksheet question. Not only did Dave inject correct ideas into the discussion, some of Dave's conversational moves also served to constrain the topic of the conversation to the correct answer or the correct content associated with the question. In the episode with George and Naveed, what Dave said and asked about also served to constrain the topic of the conversation. There, however, he tried to constrain the conversation to his students' ideas about the worksheet question, whereas, here, he constrained it to the canonical ideas associated with the worksheet question and not his students' ideas.

Dave worried that, at the beginning, Aisha was moving away from the point of the question and he needed to bring her back. Dave said, "I'm just trying to get them to realize that you know, if something has mass, then it, you know, exerts a gravitational force on other objects around it" because "the question is about an object on the moon and we haven't really talked about gravitational forces on things or exerted by things other than the Earth" (Interview July 6, 2006). For Dave, this question was aimed at developing an accurate understanding of how objects fell without the presence of air resistance (Interview June 19, 2007) because the moon had gravity but no air.

For Dave, the appropriate response to Question 2b would be built from the premise that gravity on the moon behaved in the same way as gravity on Earth, just to a lesser extent. If Aisha did not talk about the moon in this way, then it was Dave's responsibility to get her to do that. As Dave stated in the interview, "I'm trying to get her to realize that because the moon has less mass (than Earth) things will have a lower acceleration or smaller acceleration on the moon" (Interview July 6, 2006). In this interaction, how Aisha actually thought about gravity on the moon was less salient than the correctness of her statements about the moon. In fact, since her ideas were wrong, they needed to be put aside.

Statements and questions focused the conversation on the points Dave raised.

From the class data, there is evidence that Dave tried to limit the conversation to the correct ideas associated with the worksheet question. In this conversation, Dave asked questions that were about the ideas he raised (lines 112, 122 and 124). For example, in line 112, after Dave told Aisha that things do fall on the moon, just at a slower rate than on the earth, he asked her to explain why that might be the case. Here Dave asked Aisha to talk about the idea he presented to her. This idea could not be construed as an offshoot of Aisha's idea. Prior to 112, Aisha had only said she did not think things on the moon (or in outer space) would fall at all.

In line 114, after Camille stated that there is less gravity on the moon, he acknowledged what she said by indicating it was correct. Then he proceeded to talk about how things accelerated more slowly on the moon than on Earth because the moon had less mass. To a physicist, saying an object has less gravitational pull than another object is equivalent to saying the first object has less mass than the second. However, it is not clear if this is the same understanding Camille had of the situation. Though he said equivalent things to a physicist, they may not have been equivalent to Camille. Additionally, he did not follow with a restatement of Camille's idea to check if that was what she meant. By only highlighting the fact that she was correct and then proceeding to provide the reasoning for those statements, Dave indicated that what mattered was whether or not what students said was correct. In this frame, how Camille might have thought about her idea was not brought into the discussion. What was important was establishing the acceptable way to think about the situation, which, in this case, was aligned with the physicists' understanding of the situation.

At the end of the conversation, in line 124, when Dave provided the correct answer to 2b in the form of a Socratic Question, he, again, limited the discussion to the ideas he provided.

124. Dave: OK, so gravity isn't as strong on the moon as it is on earth. That's true. But, so if gravity's weaker on the moon, I mean,

> things aren't going to accelerate down as quickly on the moon, but why would, um, the fact that we're on the moon like, affects which one hit first? Like wouldn't they both (mimics two objects falling) just hit the ground at the same time just at a slower rate, (Aisha shrugs both shoulders and raises her eyebrows) is that possible?

To respond to the question of whether or not it was possible, Aisha would need to reason about the scenario he posed and, at least temporarily, put aside her idea that heavier things would fall first on the moon.

In the conversation with George and Naveed, he constrained the conversation to his students' ideas about the worksheet question. Even when George clung to his idea in spite of the experiment they did, Dave did not try to get George to think differently (namely in the correct way). Instead, Dave asked George to stick with his idea and flesh it out. In this episode, Dave tried to get Aisha to reason about the (correct) ideas he provided and reason with them in a particular (correct) way. When Aisha persisted, he endeavored to help her change the way she thought.

Comments.

The kinds of contributions Dave made to this interaction contained references to the right ways of thinking with regard to Question 2b. Interview evidence shows that he evaluated Aisha's ideas in relation to how much they agreed with the scientifically accepted ways of thinking and how much correct knowledge he needed to provide her. His statements, questions, and interpretations of the situation served to constrain the conversation and the attention to the correct ideas, and not to his students' ideas. These behaviors point to a framing of the interaction that was markedly different from the framing of the interaction with George and Naveed. Here, Dave behaved as if the activity they were engaged in was to determine the correct answer to the worksheet question and to develop the correct explanation for that answer. This type of frame encourages attention to the correct ideas and away from student ideas.

It is worth noting that in trying to get Aisha to come up with the right way to answer this question, Dave may have inadvertently shot himself in the foot. In leading Aisha through what happens on the moon and why it happens that way, she stopped trying to develop her own explanations but instead came to rely on Dave to approve answers she was picking up from his explanations. She did not come up with the right answers on her own. Articulating the correct explanation without his aid would have indicated to Dave that she understood what he was saying. But, analysis of Aisha's moves to get Dave to affirm her answer choice, at the end, indicated that she did not understand what she was saying and confirmed Dave's interpretation that she was just fishing for the answers. More of this will be explored in Chapter Six.

Breaking from telling her information was Dave's attempt to get Aisha to stop relying on him for the answers. Though Aisha seemed to accept this as the end of the conversation, this did not seem to end how she thought about the worksheet question. Her response from this break in the conversation was quite telling. Though she did have different ideas about the situation on the moon, she muttered "I'm gonna put down I don't know" and in fact wrote down "I don't know" as her answer. It seems since she was not able to get Dave to affirm her answer choices, she declined to put any of them down.

In a separate paper, Elby, Lau, Hammer & Hovan (in preparation) argued that Dave displayed two very different sets of epistemological beliefs in the two episodes from this class. With George and Naveed, having students articulate their ideas, regardless of correctness, was important for their learning. In this episode, it seems that students needed to have the correct ideas and correct ways to reason to make learning progress. Elby, et al have argued that in each context, there are locally coherent clusters of cognitive resources that are activated and are a part of the frame. Some of these clusters exhibit qualities that would lead one to identify them as beliefs (other such clusters may be an element of knowledge). Further development of this argument will proceed in Chapter Six.

From the classroom data, it is not entirely clear if Dave began this conversation by focusing his attention on the right understanding and framing or "getting to the right understanding." It seems that Dave did attend to Aisha at the beginning.

101.	Aisha:	Mr. H.
102.	Dave:	Yes.
103.	Aisha:	If you drop a bowling ball and a, a small rock on the moon, neither one of them would drop would it because there's no gravity up there.
104.	Dave:	So you don't think there's gravity on the moon?
105.	Aisha:	No, (pause)

In line 104, his question highlighted Aisha's reasoning — that there is no gravity on the moon. One possibility is that Aisha's idea caught Dave's attention. But, pursuit of this idea would lead Aisha away from the purpose of this worksheet.

Joanna: Shifts in Framing

In this episode, Joanna planned to use a discussion about a video of the American Olympic Curling Team competing against the Canadian Olympic Curling Team as an introduction to the new unit on phase changes. After showing her students the video, Joanna asked them, "What science makes this Olympic sport possible?" After an initial brainstorm session of what science topics they could connect with the video, a disagreement arose between her students about whether the players were brushing the ice to generate more water to help the stone slip or to move the melted water out of the way so the stone's path would not be impeded. Joanna was surprised that her students thought the melted water would slow the stone down. As a result, she decided to ask her students about whether or not one could slip on water. In response, students erupted into discussion of what they thought. Partly to quell the tumult, Joanna selected one student, Abe, to present his idea to the class.

22. Joanna: You do slip on ice. But can you slip on water?
23. Students talk at the same time: "I mean water…" "The reason why you slip on ice is because there is water on it." "Like if it was pure ice…"
24. Joanna: Ok, so here's Abe's idea, say it again.
25. Abe: It—the reason why it's slippery on ice is cause there's a little water. If you have ice, with no water, with no melted water, then you'll probably [wouldn't slip on it].
26. Joanna: So you think that the melted—the little—(draws on the board) you're basically saying here's our ice and that there's like a little, little, little, tiny thing of water right there and

that's what makes it super slippery. (Abe: Yeah) Is what you're saying. So someone who thinks that it makes it, slows it down, tell me why you think it slows it down, 'cause that's our counterargument, right? So, so why do you think Melissa?

27. Melissa: Well I'm not sure, but like, maybe if it's like water then it's like just more stuff to go over.

28. Joanna: Oh, so you're kind of thinking like (Melissa: I don't know)…like what would be an example of that?

29. Melissa: Umm…I'm not sure. (students speak up) Like a puddle?

30. Joanna: Like a puddle? How would a puddle slow it down—like, what do you mean? Like what's an example of that?

31. Tiffany: Going into the water, you know, just like-

32. Joanna: Like if something is kind of like—

33. Rhonda: Well if you're doing a marble across a table or something it would probably go slower in the water 'cause it has more stuff that it's going through.

34. Joanna: So it's kind of going deeper in the water right? So as it rolls in, it's actually sinking in and eventually the water is stopping it. OK. So what do you think Bette?

35. Bette: Also, like, molecules move slower—like, there's this thing where um, where molecules move fastest like air, solid, liquid, gas, and umm, gas, because it's less compact, everything is less compact, that things move slower.

36. Joanna: mmhmm.

37. Bette: Like, they move slower in water, they move the slowest through a solid, slower in water and fastest through gas 'cause gas is really separated. Maybe, so I'm not sure that it makes sense [but?/that?] it would go faster

38. Joanna: OK.

39. Bette: The slower because the water molecules are…

40. Joanna: Let's take that idea.

41. Bette: These are cold molecules too.

42. Joanna: So let's take this marble idea, right? Of it going from on the ground and all of a sudden it hits a water puddle. Was it going—when it was just rolling, right here, was it going through air or was it going through the ground?

43. Class: Air. Through air.

44. Joanna: Through air, right? So it was going through air. Air has like a lot less resistance right? Like, what you're saying. So, Bette was saying that in the air all the molecules are farther apart. And, so it's easier for things to go through that.

45. Bette: And you can't just jump over that little—that little water, like, blockade almost, you can't just jump over that. (inaudible) get stop by that.

46.	Joanna:	(draws on the board) Right, it's kinda going through that. So by the time it gets here—here's our marble—it's going from air into some of the water. So, if there's a lot of water here, let's say the water was like…kinda high compared to the marble 'cause usually, a puddle is pretty deep. So, there'd be a difference between it going in the air and going on the water.
47.	Tiffany:	'Cause like, there's still, there's a hole in the ice now and there's water there.
48.	Joanna:	mmhmm.
49.	Tiffany:	[So there's ice and water?] (inaudible) And it's probably going to go in.
50.	Joanna:	So if the water is really thick on the ice, it will probably slow you down. So, if there's like—when there's big patches of water in ice, that's not desirable right? You're not going to try to skate into a big puddle of water if you're a hockey player. So, if there were big puddles like that, I agree with you, I think it would slow it down. But what if there was just umm…pretend you're driving. Oh yeah, Aisling, you have an idea?
51.	Aisling:	But wouldn't the water be a thin layer so wouldn't it make it faster? If it was on top of ice it would be, the [whole, like?] slippery?
52.	Joanna:	So it's different 'cause it's really thin. You're exactly right, 'cause here when we use our water puddle idea, the water is pretty deep. It's not that, like, microscopically thin layer that's on ice. So it's slightly different. So you're right that a puddle would slow something down, but I think you're also right that if it's a thin layer, like—here's our thin layer of water and here's the ice—that would be different somehow because if you're a car, right? Has anyone ever hydroplaned in a car?
53.	Bette:	My sister. (Students: Yeah.)

The analysis for the first episode from Joanna's class was not as straightforward as the other episodes in this dissertation because her frame shifted, her attention remained fairly constant on her students' ideas, and the delineation between the frames was not always clear. In this episode, her role, participation in the discussion, as well as interpretations and goals changed as a result of her attending to the ideas her students presented. Joanna went from guiding her students to the right answer, to participating in the discussion as a learner, back to guiding her students to the right answer, though the answer, at this point, had changed. Each role was associated with a different frame: 1) debating the two sides; 2) searching for a mechanistic explanation; 3) reconciling the two ideas.

From her interview statements, it is clear that Joanna's understanding of the interaction changed. Initially, Joanna's concern was to help her students examine what she considered the incorrect argument and eventually guide them to see how melted water helped objects slip. In exploring what her students thought about the counterargument, Joanna became convinced this argument had merit, which helped her make a new connection in her own content understanding. However, since she saw both sides as correct, she could no longer pursue her original goal of showing how the counterargument was incorrect. To manage this problem, Joanna changed the way she thought about the purpose of the discussion. It was no longer a debate between two opposing sides as she had first envisioned but a reconciliation of two ideas.

Framed as "Debating the two sides".

By the end of line 26, Joanna's conversational moves established the discussion as a debate about whether water did or did not help objects slip on ice. In line 22, she identified the question under consideration ("can you slip on water"). After Abe, in line 25, presented one idea, Joanna asked her students for the counterargument, presumably to the one Abe stated. This was an explicit request for the other side of a debate.

In the interviews, Joanna explained that she had several reasons for holding the debate. At the time, she could not fathom how students could think that one did not slip on melted water.

> Joanna: I was like, uh oh. Half of them think it slowed down half of them think it speeded up…. Some of our basic experiences and how we're applying our basic experiences — like from other things outside in the world — differ.…We didn't all think that melted ice causes things to speed up….For some reason I felt like we can't get to where I'd like to get if we don't address the fact that some people think that water on ice slows you down. (Interview, June 28, 2007)

Joanna was concerned that some of her students might have thought about the world in a completely different (and possibly incorrect) way. She felt that this had the potential to interfere with her initial goal of exploring the connection between energy and phase changes.

Although Joanna was pleased that the correct idea was presented at the beginning of the discussion in this episode, this was not where Joanna wanted to stop the discussion. Addressing the incorrect idea here meant exposing her students' thinking and ultimately showing them why they were wrong.

> Joanna: I was happy with Abe's idea, but because I knew that the class was already split before…I want people to be, sort of be able to look at counterarguments. And then you can more definitively come up with an idea or wipe out, like knock out a counterargument. (Interview, June 28, 2007)

She wanted her students to have the opportunity to examine the arguments for the incorrect answer. Even though Joanna expected to ultimately declare the counterargument as incorrect, it was still important to understand what those arguments were.

> Joanna: (I asked them) "someone who thinks it slows down, tell me why you think it slows down. 'Cause that's our counterargument"…Like I-I'm sure I used that phrase, our counterargument, very explicitly. Y'know, I was just trying to get them to think about yes, we're in a discussion but there are different sides. Like, to kind of cue them that we're doing something specific in our discussion. (Interview, June 28, 2007)

In this part of the discussion, Joanna took on particular roles. Here, she was a moderator, ensuring that both sides of the debate were articulated, and a teacher guiding her students to the correct answer. As the moderator, Joanna created space for both sides of the debate to articulate their arguments. In line 24, she quieted the class down and drew their attention to Abe so he could present his idea ("the reason why it is slippery on ice is 'cause there's a little water"). She followed this by reflecting back an exaggerated version of what Abe said that highlighted the reason behind his proposal ("there's, like, a little, little, little, tiny thing of water right here and that's what makes it super slippery"). She also checked with Abe to make sure she represented his idea well.

Joanna wanted her students to participate in specific ways. As she said in the interview, "We're in a discussion but there are different sides… (I wanted to) cue them that we're doing something specific in our discussion" (Interview, June 28, 2007). Airing the other side of the debate was an action that also meshed well with her role as a teacher guiding her students to the right answer. In this role, Joanna needed to help her students bring out their incorrect thinking so it could be examined. Through this examination, she could guide her students to see why the counterargument was wrong. But she could not do that unless they told her what they were thinking.

Prior to this episode, Joanna led a brainstorming session on what science her students saw in the sport of curling. The intention was to warm-up her class and jump into the new unit on phase changes. Joanna had not expected her students to be split about the role of melted water in the curling stone's motion. Holding a debate was a consequence of Joanna attending to her students' thinking; she wanted to hear what her students meant. She saw the class as split between slipping on the melted water and not slipping on the melted water. Since a good portion of the class agreed with the incorrect side, Joanna could not ignore it. A debate lent itself nicely to what had emerged in the class. This kind of discussion would allow the class to compare the two ideas. She wanted them to see what was wrong with the counterargument and why it was correct to think of water as facilitating the stone's motion. In this debate, there was an expectation that the one she saw as correct would win the debate, be developed into the explanation for why objects slip on wet ice, and help students determine how the counterargument misrepresented the situation. At this point, her role was to both moderate the debate and guide her students to the right way of thinking.

Framed as “Search for a mechanistic explanation”.

At some point after the class began to discuss the counterargument, Joanna’s frame shifted. From both the class and interview data, it is clear that Joanna did not intentionally try to change frames, as she did in the beginning of the episode when she made explicit moves to set up a debate. This shift came about as a result of Joanna closely attending to what her students thought. The evidence shows that Joanna’s participation in the discussion and understanding of her role and the interpretation of what her students said changed. Additionally, her attention to her students’ ideas contributed to her learning new content knowledge.

Here, Joanna participated in a search for the mechanistic explanation for the counterargument. A mechanistic explanation for any phenomenon includes identifying the relevant entities, their applicable properties, their location in relation to each other, as well as the pertinent activities in which the entities engage to give rise to the phenomenon of interest (Russ, Scherr, Hammer, & Mikeska, 2008; Russ, 2006; Machamer, Darden, & Craver, 2000). In lines 26, 30, 34, 44, and 46, Joanna specifically asked for and highlighted the mechanistic reasoning for the counterargument. For example, after Melissa said that the water would be “more stuff to go over,” Joanna, in lines 28 and 30, pressed her for an example of what she meant and how that scenario worked.

Shifting how she framed her conversation meant her role changed as well. She was still a facilitator but she was now also a participant in the development of the mechanistic explanation for the counterargument. As a facilitator, she still needed to make sure her students were able to express their ideas clearly. This may explain why she pressed Melissa to explain what she meant even though Melissa seemed to have a difficult time with it. As a participant, she contributed to the content of the argument and, as she explained in the interview, learned new ways to see the water on ice scenario alongside her students.

When Joanna watched Melissa present the counterargument in the video, Joanna explained that she had no idea what Melissa meant. She said during class she wondered whether or not water could slow down the stone. She needed her students help in understanding what they were thinking.

> Joanna: I had no idea what they were talking about…. because I would have thought [???] made it go slower.... I hadn't even thought about the counterargument (before). So they needed to sort of explain that to me. I hadn't anticipated what that would be. So it took from line 27 to 40, for that to be clearly explained to me." (Interview, June 28, 2007)

She wanted to push Melissa to provide an example of what she meant, as she did in lines 27 and 30. Understanding Melissa's idea was important because Joanna needed to know what Melissa meant if she was to try to prove how that was a misunderstanding of the situation.

Following on the heels of this request for more information about the mechanism, Joanna and her students constructed a mechanistic explanation for why there would be more water and how that would slow the stone down.

31. Tiffany: Going into the water, I don't know, just like (gestures hand sliding across and down; voice trails off)

32. Joanna: Like if something is kind of like—

33. Rhonda: Well if you're doing a marble across a table or something it would probably go slower in the water 'cause it has more stuff that it's going through.

34. Joanna: So it's kind of going deeper in the water right? So as it rolls in, it's actually sinking in and eventually the water is stopping it. OK. So what do you think Bette?

Here, each person's contribution built on the previous person's statements. Tiffany explained what the stone would do when it encountered the puddle Melissa described. Rhonda provided a real-world example of the scenario to root the discussion and linked the slowing down of the marble with the "more stuff that it's going through" in the water. Joanna added the process of how the marble would go into the water ("sinks into the water") and the point that the water acted like a breaking mechanism ("the water is stopping it"). As we can see in the interview statement below, contributing in this way may have supported her sense that she was a student too.

> Joanna: I remember feeling like I was having a fairly sophisticated discussion with them. Y'know, one where I-if you were together with five other sort of scientists slash educated people… discussing some phenomenon you found interesting… that you all start convincing each other of different things. And you come up with new ideas yourself. Like I kind of felt like I was the one-I mean, it felt like I was the teacher, but I really felt like-kind of a student too…. But, the fact that I was being convinced of things, um, when I

say things later on which will [???] I get excited; “Oh! That's right! You're right!” (laughing)... that, that is-it's not really a show…. It's my conveying something to them naturally. (Interview, June 28, 2007)

In sum, by paying close attention to what her students meant, Joanna’s frame shifted. Joanna had originally expected to hear out the counterargument so she could prove it wrong (Interview, June 28, 2007): “And I want people to be, sort of, be able to look at counterarguments. And then you can more definitively come up with an idea, or wipe out, like knock out a counterargument”). Joanna had not expected to see those ideas as right and to participate by building support for the side that she thought was wrong. As a result of trying to understand what her students were thinking, Joanna gained information that violated her expectations. Violations of expectations can lead to frame shifts (Goffman, 1974). Here, we see that Joanna did change her framing of the interaction. In this new frame, Joanna engaged as a learner alongside her students and made new connections in her own content understanding. When she understood the counterargument, she no longer saw the two sides in the same way— they were now both correct. This new way of seeing the two sides of the debate contributed to yet another shift in Joanna’s framing, which will be discussed in the following section.

Framed as “Reconciling the two sides”.

In the latter part of the episode, Joanna’s frame shifted again. Now that she had figured out a new correct answer, she needed a new way to wrap-up the conversation. The class data shows that Joanna did not ask her students about their thinking as much as earlier in the episode. Instead, she spoke more about the points she wanted to make and took up more conversational space. In this frame, she returned to her earlier role of guiding her students to the correct answer but with a different correct explanation. In the class, Joanna summarized the points the two sides made and explained how they were both correct, but talked about different phenomena. The interview data shows that Joanna was caught off guard by the counterargument's explanation and had to reconsider how she thought the discussion would end. Her conversational moves and interview statements paint a picture of a teacher trying to wrap-up the debate by reconciling the two sides.

After Bette spoke about the phases of matter, Joanna took on a much stronger role in directing the content of the discussion. She used up much more of the conversational space than her students. Of the last 16 conversational turns in this episode, there were five turns where Joanna spoke at least twice as long as the student to which she was responding, as measured by a basic word count of the different turns. Additionally, she closed off conversational space by interrupting her student Bette, in line 40. In an interview, Joanna explained that she had a purpose for interrupting Bette.

> Joanna: I was trying to find a clear articulation of the counterargument. But I really wasn't interested in the solid-liquid-gas thing….I just didn't think that would be helpful…. So that's why I interrupted her, in 40, even though she didn't really want me to interrupt her. So I said let's take that idea, what I really need is the water. (Interview, June 28, 2007).

Even though Bette's statements were ultimately more in-line with the direction Joanna meant to be going at the beginning of the lesson (Joanna intended this lesson to be an introduction to phase changes), at the moment, Joanna was more interested in developing the ideas around the role of water in slipping versus slowing down. As she said, "what I really need is water" and not everything Bette said about the phases of matter.

Several of Joanna's questions (lines 42, 44, and 50) seemed to be rhetorical moves to direct students' attention to the points she made. For example, in line 50, Joanna asked, "So, if there's like-when there's big patches of water in ice, that's not desirable, right?" Ending the statement with a rising inflection on the term "right" implies a question about whether or not the listener agrees. Since Joanna provided relatively little time for her students to respond, this question did not require an answer. Instead, this question helped argue the point that the puddle scenario could not describe what happened with the curling stone.

Joanna's statements were focused on summarizing the earlier parts of the discussion. She was interested in showing how the two sides were correct but spoke about slightly different phenomena and how to explain slipping on ice. If student statements were directly related to what Joanna talked about, she acknowledged their correctness and utilized them to forward her points.

For example, in lines 47-52, Tiffany and Aisling made two separate points about water's role in moving objects along the surface of ice.

47. Tiffany: 'Cause like, there's still, there's a hole in the ice now and there's water there.

48. Joanna: mmhmm.

49. Tiffany: [So there's ice and water?] (inaudible) And it's probably going to go in.

50. Joanna: So if the water is really thick on the ice, it will probably slow you down. So, if there's like—when there's big patches of water in ice, that's not desirable right? You're not going to try to skate into a big puddle of water if you're a hockey player. So, if there were big puddles like that, I agree with you, I think it would slow it down. But what if there was just umm…pretend you're driving. Oh yeah, Aisling, you have an idea?

51. Aisling: But wouldn't the water be a thin layer so wouldn't it make it faster? If it was on top of ice it would be, the [whole, like?] slippery?

52. Joanna: So it's different 'cause it's really thin. You're exactly right, 'cause here when we use our water puddle idea, the water is pretty deep. It's not that, like, microscopically thin layer that's on ice. So it's slightly different. So you're right that a puddle would slow something down, but I think you're also right that if it's a thin layer, like—here's our thin layer of water and here's the ice—that would be different

somehow because if you're a car, right? Has anyone ever hydroplaned in a car?

Joanna's response to each student was to acknowledge that they were correct and to move on to her summary and explanation points. In line 52, after she tells Aisling she was "exactly right," she proceeded to show how both ideas were correct and related but referred to slightly different conditions ("when we use our water puddle idea, the water is pretty deep. It's not that, like, microscopically thin layer that's on ice. So it's slightly different. So you're right that a puddle would slow something down, but I think you're also right that if it's a thin layer, like—here's our thin layer of water and here's the ice—that would be different somehow").

Another difference between how she responded to her students here and earlier in the episode can be seen in how Joanna manages Aisling's comment. Joanna did not ask Aisling how she thought the thin layer of water would make things go faster and slip on ice. With respect to the counterargument, an argument Joanna did not originally understand, she asked her students how they thought water would slow objects down and to describe what kind of scenario they envisioned. Here, Joanna accepted Aisling's statement without further explanation and even started to provide a scenario for her students ("Has anyone ever hydroplaned in a car").

Further evidence that Joanna was focused on delivering a wrap-up of the discussion comes from the data that follows this episode. Immediately after this episode, there was a brief exchange between Joanna and Bette about her experiences hydroplaning and then a lecture from Joanna on how hydroplaning works and why objects on top of ice slip.

53.	Bette:	My sister. (Multiple students: Yeah.)
54.	Joanna:	What is hydroplaning like?
55.	Bette:	Oh, well she was on her way to school, here, two years ago, and it was raining outside. The roads were really slippery because it was wet so I guess things do kind of make sense. She like spun around and her car, it like spun around.
56.	Joanna:	So this is the car wheel, right? So basically, when you hydroplane on a rainy day, you hit a puddle like this. But in that case, your wheel is pretty big compared to the puddle, right? Because the puddle is really thin, whereas our marble idea, it was pretty much the same size as the puddle. So, as soon as your wheels hit the—hit the water right here, it starts spinning the car around, so it actually becomes less friction. If you have a really, really, really, really thin layer of water. If it's a big old puddle, it's going to slow your car down. If you drive into a big deep puddle, your car will probably slow down. But if it's a really thin, thin layer, then it actually kind of slides you along. It's almost like the water here is kind of like a really fast conveyor belt. There's nothing resisting you, the water's just kind of sliding around.

And so it can actually make your wheels keep going even faster than they were before. So, I think you could argue it depends on how thick the water is. If the water is really thick compared to the thing that's sliding on top of it, like the marble, it might slow it down. But if the thing that's on top of it is really big, compared to that little layer of water, it might help to actually speed it up. So how does that make sense with our brushing? If when the guys are brushing it and, ah, Conrad's idea was that it melted the ice a little tiny bit and made it into water-

57. Bette: Then it's going to slow it down.

58. Joanna: Well, but the stone is quite big compared to that little thin layer of water, right?

59. Bette: So you're making more water then.

60. Joanna: So if this is your big stone, it's kind of, you know, pretty big, we'll zoom in on it sideways. And it's sliding this way and then it hits this little layer of water, right here, and that's pretty small, compared to the size of the wheel, or the size of the stone. Is it possible that that makes it like a little conveyor belt that goes, like, really fast?

In her closing summary, Joanna presented a detailed argument for how objects slip (and travel faster) on surfaces with a little bit of water, but when the depth of water, as compared to the object, is high, the object will slow down.

In the latter part of the episode, Joanna moved into a different frame. Her conversational moves at the end and her interview statements paint a picture of a teacher trying to wrap-up the debate by reconciling the two sides. She directed most of the exchange at the end of the episode. Joanna summarized the points from both sides of the debate, as well as developed explanations for why both arguments were correct. She paid less attention to her students' thinking. Joanna did not explore what Bette meant in line 57 ("Then it's going to slow it down") and 59 ("So you're making more water then") but pressed on with her summary explanation (line 58 and 60: "the stone is quite big compared to that little layer of water… it hits this little layer of water…. That's pretty small, compared to the size of the wheel… Is it possible that that makes it like a little conveyor belt that goes, like, really fast?"). She also showed her students how the two sides addressed different phenomena (the same materials but different conditions).

In helping her students reconcile the two sides, Joanna returned to the role of guiding her students to the correct answer. She was able to meet part of her original goal of showing her students how the melted water on the surface of the ice helped the curling stone go faster. However, she had to modify that goal to include a discussion of how the counterargument was also correct—something she had not anticipated. To adjust for that new understanding, she had to reconsider how she thought the debate would end.

Comments.

Analysis of this episode was difficult for two reasons. First, Joanna's frame changed and the changes were not always clearly marked. Second, the relationship between the attention and the frame is not a simple one. This episode shows how a teacher's attention and frame mutually influence each other. It was Joanna's close attention to her students' ideas that contributed to the initial frame (the debate frame) and the shift to the next frame (the search for mechanistic explanation frame). At the end of the episode (and even slightly past it), Joanna's frame of reconciling the ideas shifted her focus to wrapping up the discussion. Though she acknowledged her students' ideas when they raised them, those ideas were not the primary focus. But, by this point in time, the "debate" was over and Joanna had reached a verdict. Here, she used what her students said to help her reconcile the fact that the debate had two correct sides and to wrap-up the discussion. They point to the notion that one's framing of social interactions is a continuous, adaptive, responsive process. Though I have tried to delineate the changes in Joanna's framing with discrete categories for discussion purposes, the evidence from the data does not support considering the boundaries between the different frames as necessarily distinct.

Joanna: Framed as Reviewing a Concept

This episode occurred later in the lesson, about 22 minutes after the start of the period. Prior to this conversation, students established that the friction between the brush and the ice played a role in the melting of the ice. After that discussion ended, Joanna proceeded to ask about what property of the stone made it hard to predict where the stone was going to stop once it started moving. In this episode, Joanna leads her students to a review of the concept of inertia.

113.	Joanna:	So it's kind of like, helpful because it gets stuck up on it and then it helps kind of melt the other stuff. (Yolanda nods and mouths "Right.") So it melts the ice and then you get the water kind of helping melt more ice farther because the water is warmer? Right? So the water helps melt the other part. OK, so what is it that keeps the whole thing going to begin with? What property of the stone—'cause the guy let it go at the beginning, it's not like he's pushing it the whole time. What property of the stone makes it so hard to predict where it's going to land?
114.	Student:	(inaudible)
115.	Joanna:	Right? I mean, he hit but then they have to use all these extra things to kind of make it go a certain distance. So, why, why, why, is it so hard? 'Cause it's not just the friction that's the issue here. That's part of it; you can direct it that way. What do you think AJ?
116.	AJ:	Because the entire bottom of the stone is the same smoothness.
117.	Joanna:	OK, so?
118.	AJ:	It can go wherever you want it to-
119.	Joanna:	mm hmm
120.	AJ:	-depending on the ice and where it have the friction, [the?/more?] ice [harder?/higher?] ice [versus/or?] [thinner?/smoother?] ice.
121.	Joanna:	Right.
122.	AJ:	So it can go anywhere.
123.	Joanna:	It can go anywhere depending on how smooth—how much friction there is. It's almost like friction is a traffic light, right? It kind of helps you go one way or another. Why—if—would it keep going straight forever? If there was the same friction everywhere?
124.	Female Student:	Yes.
125.	AJ:	No. It wouldn't.
126.	Joanna:	Would it start turning? What would happen? If it was just the same everywhere and there were no brushes and they just let it go. And the ice was completely the same smoothness everywhere.
127.	Female Student:	Yeah.
128.	Joanna:	What would happen?
129.	AJ:	The same, uh, is it balanced?
130.	Joanna:	It's perfectly balanced, perfectly flat ice…
131.	AJ:	It would stop.

132.	Joanna:	Why, why do you think it would eventually stop?
133.	AJ:	Nothing can go on forever.
134.	Joanna:	Well, what (several student voices) what keeps an object going, and what stops objects?
135.	Several students:	Friction.
136.	AJ:	Friction. It still has friction.
137.	Joanna:	There's still a little bit of friction on ice, right? So, friction will eventually stop it, but if there were no friction at all, what would happen to the stone?
138.	Students:	It would go on forever.
139.	Joanna:	Why?
140.	AJ:	Actually, no it wouldn't because the air would stop it.
141.	Female student:	Their-
142.	Joanna:	There's a little bit of air resistance, right? What is the property of objects that keeps them going?
143.	Bette:	Kinetic energy.
144.	Female student:	Their energy.
145.	Joanna:	Well kinetic energy is related to the energy they have that makes them moving—
146.	Female Student 2:	That law.
147.	Joanna:	What is that law? Objects in motion? Akeem, what is it?
148.	Akeem & students:	Inertia.
149.	Joanna:	(fortissimo) Inertia! Right? Inertia! (normal volume) What is inertia saying, Akeem?
150.	Akeem:	An object that is in motion will stay in motion unless [acted upon by?] another object.
151.	Joanna:	Or an outside force, right? So an object in motion stays in motion unless acted on by an outside force. Is there a force on this board somewhere?
152.	Female Student :	Friction!
153.	Joanna:	Friction. So anytime there's friction, it's going to slow it down, that's the outside force. But that's why it's so hard for him to direct it, right? If he pushes it a little too hard, it just keeps on going, even though there is a little bit of friction, it's not that much. So that's what makes it a sport. You know, you have to have some skill to do this. Just not every average person can go and throw them around. They probably go flying off the end of the curling board.

This episode from Joanna's class was more straightforward than the previous episode. Joanna's frame did not change and it helped direct her attention. I will show in the evidence that follows that Joanna tried to frame this interaction as "reviewing a concept". In contrast with the earlier episode from the lesson, within this frame, it was not necessary to direct her attention to the students' thinking only to confirm the presence of the concept of inertia. In this episode, the evidence shows Joanna repeatedly communicated to her students that she wanted them to talk about inertia, a concept they had explored earlier in the year. Though her student AJ raised valid points about friction, Joanna tried to restrict conversations such that friction would be ignored. Instead of friction, Joanna wanted her students to review what they remembered of inertia and apply it to curling. In the interviews, Joanna explained that she saw this as an opportunity to make connections between the physics and chemistry portions of the class.

Within this context, Joanna's attention was directed toward her students' articulation of the canonical representation of the concept of inertia. It was not that Joanna made a conscious decision to ignore her students' ideas. She simply wanted them to say, aloud, what she thought they already learned about inertia. Since this was an old topic for the class, Joanna expected her students to understand the concept and only needed a reminder of the vocabulary work and a brief statement of the law to refresh their memories and strengthen their connection to that concept.

Marked friction as irrelevant to this discussion.

In lines 123, 126, 130, and 137, Joanna established that the ice was to be considered a homogeneous frictionless surface. In so doing, Joanna helped to mark points raised about friction's influence on the curling stone's motion as irrelevant to this part of the discussion.

Joanna's response in lines 123 and 126 to AJ eliminated a key element in his idea—the stone's direction depended on the roughness or smoothness of the ice's surface (stated in line 120). According to AJ, the surface variation was what made it difficult to predict where the stone would end up. In lines 123 and 126, Joanna's response redefined the circumstances so as to effectively remove the heterogeneous surface features of the ice from the discussion. She described the ice's surface as "the same smoothness everywhere" and that it was "perfectly balanced, perfectly flat ice", in other words, a homogeneous surface free of friction. After AJ indicated he still did not think the stone could travel forever (lines 125, 131 and 133), Joanna unambiguously asked her students to consider what would happen if friction did not exist (line 137).

Joanna recalled being surprised when AJ stated that he expected the stone to stop even on perfectly flat ice. This was not the answer she had expected.

> Joanna: So, in 130, I said, I think, "It's perfectly balanced and it's perfectly flat ice. What would happen?" And he goes, "It would stop." It would just stop (laughing)… like I don't know. It's hard to distinguish [between?] what I remember and what I watch… but I'm sure I was like, "Oh!" 'Cause [that's?] not the sort of traditional scientific [line?]. Well it would go on forever because there's no friction. (Interview, August 30, 2007)

Though Joanna was candid that there may have been some reconstruction of her recollections, she thought it was likely she was surprised by AJ's response. Given what had happened so far, she expected herself to be attuned to how AJ's answer did not match with her understanding of what the canonical answer would be in this situation. With her attention focused on inertia, she could not see how it was reasonable for AJ to focus on friction. It seems that by characterizing the ice as perfectly flat, Joanna meant to indicate to her students that there was no friction on the ice's surface, and hence no reason for the stone to stop. To a scientist, if there is a frictionless situation and the net force acting on the object is zero, the object will maintain its velocity.

It is not that Joanna did not understand the physics of objects sliding on real-world surfaces. There are very few situations in the world that come near to a friction-free situation. For the vast majority of objects in motion, objects do come to a stop eventually, even on surfaces that seem perfectly flat and smooth to the human eye. In an interview about this episode, Joanna noted the validity in AJ's idea.

> Joanna: But then what he said in 133 was true. Nothing can go on forever in my experience…. I mean, the idea of a frictionless surface is just theoretical… and how many people even have an experience that even approximates that?… I mean on certain scientific [environments?] maybe you can approximate it. But certainly not in experiences. (Interview, August 30, 2007)

AJ's answer was simply not what she wanted. In Joanna's eyes, the class had already explored the topic of inertia and she just wanted to bring up what she thought they knew. Joanna stated in an interview,

> I think that's where I was going…to connect to the first semester, 'cause they do physics the first semester [and chemistry?] the second semester… (I brought up inertia because) I really think it was just to connect with [???] the first semester" (Interview, August 30, 2007)

AJ's ideas about friction were beside the point and therefore did not warrant attention to its meaning. Like the counterargument in the earlier episode, AJ's idea was an unexpected wrong idea. However, Joanna did not attend to what AJ meant as she did with the students who argued for the counterargument. Here, her framing of the discussion made reviewing an old topic more important than exploring an unexpected idea. What mattered here was a discussion about the law of inertia and not how her students thought about what happened in real life.

Narrowed discussion to the term inertia.

By trimming out the points raised about surface variations and friction, Joanna tried to define the problem in such a way that her students would not talk about friction's effects on the stone's motion but about inertia (lines 113, 123, 134, 142, 145, 149). In lines 113, Joanna explicitly asked her students what was the property of the stone that allowed it to keep going forever. Some possible valid answers to that question are: 1) the stone's inertia; 2) the stone's kinetic energy; 3) the stone's momentum; or 4) nothing keeps the stone moving because the stone *is* moving (everything's natural state is to stay the way it is).

Inertia was the property that Joanna was after. When the student in line 144 said, "That law," Joanna picked up on that statement by asking what that law was. She then quickly followed with a very leading question, "Objects in motion?" This partial sentence would have had no meaning to the students unless they had heard it before. In fact, their responses indicated they knew exactly what Joanna was asking. Many students responded quickly and loudly to that question with the term inertia. Their responses had a ritualized cadence.

At this point, Joanna's response is quite telling. When her students called out inertia, there was a marked change in her volume and pacing that indicated she was excited about what they said. Here, Joanna rapidly shouted out inertia as soon as her students said it. This was not how Joanna responded to Bette in 145 when Bette brought up kinetic energy. Joanna's response to Bette was more even in tone and volume, much like how she had been responding to AJ and other students thus far. From her excited response to the word inertia, it is clear that Joanna was happy with what was said. The word inertia was a proxy for understanding here. Joanna assumed she knew what her students meant when they called out the word and when Akeem recited, "An object that is in motion will stay in motion unless [acted upon by?] another object."

With regard to the content of this exchange, the laws of conservation of energy or momentum were as appropriate as the law of inertia for exploring why objects on a surface without friction would continue their motion. On a friction-free uniformly level surface, an object will maintain its kinetic energy or momentum and continue traveling forever because there is nothing to change that energy or momentum.

In an interview, Joanna explained that at the end of this episode, she was explicitly reviewing what they had covered on inertia in the first semester.

> Joanna: I think this is where I was trying to bring in kinda just standard scientific phrases, connections, using these established (phrases) —because I think yes, there's certainly value in understanding things at the gut level away from scientific vocabulary. Scientific vocabulary is still important to be able to use. Though, I think that's where I was going…to connect to the first semester, 'cause they do physics the first semester [and chemistry?] the

> second semester… (I brought up inertia because) I really think it was just to connect with [???] the first semester. Then again, it's part of the sport….[It?] helps explain something about the [stone?] and why it keeps going. (Interview, August 30, 2007)

Here Joanna saw herself as overtly drawing her students' attention to scientific formalism. This was a good opportunity to review an old term and make connections to a new topic. In reviewing the old concepts, Joanna valued the use of formal vocabulary and descriptions. Though she expected that there could be some "gut level" ways of understanding this concept, the class had moved beyond that point and needed to practice using the more formal ways of representing the concept ("I was just trying to bring in kinda just standard scientific phrases, connections, using these established (phrases)…Scientific vocabulary is still important to be able to use"). This matches the evidence in the classroom data, where Joanna provided her students with the fill-in-the-blank question indicating that she wanted her students to talk about the law of inertia. In this frame, the focus on the formalism, specifically on a term they had learned in the previous semester, provided sufficient pull on Joanna's attention so that it was directed away from her students' reasoning about the situation.

Comments.

Joanna saw an opportunity to make a connection to previously covered material and review the concept of inertia. Review of inertia entailed using a theoretical scenario to correctly demonstrate the standard formal description of inertia, that on a perfectly flat smooth surface, an object, undisturbed, would maintain its velocity. In class, Joanna attempted to guide discussions away from topics (such as friction) that would not lead to this conclusion, which meant that the conversation needed to be drawn away from what AJ said about the real-world game of curling (where there is friction). At that moment in class, his idea was labeled wrong and inappropriate or irrelevant for pursuit because it would not lead to the traditional school science answer representation of inertia. She even went as far as baiting her students with a phrase to jog their memory about the law of inertia. This way of attending to her student's ideas is in contrast to the attention she paid to both the right and wrong ideas in the earlier episode. In that episode, how she framed the interaction supported exploration of student ideas about the real world and not necessarily on scientific formalism.

There is also some evidence to suggest that Joanna could not see AJ's idea because her mind was focused on reviewing inertia. In the interview, she mentioned she was surprised that he stuck with the idea that the stone would slow down. This was not what she had expected her students to say and, in class, she could not understand why he would say that. In the first episode, when Joanna's expectations were challenged, she shifted how she framed the conversation. Here, Joanna tried to actively maintain her frame by insisting that AJ's points were not relevant to what she asked. In her framing of the "review" in this episode, there was no reason to explore what her students meant, only what her students could recall.

Chapter Comments

There is a dynamic between attention (what the teacher is focused on) and framing (what the teacher thinks is going on). How a teacher frames an interaction can influence how that teacher attends to student thinking. When Dave's interaction was framed as "exploring students' ideas", attending to the substance of students' ideas was necessary because that was what was to be explored. However, when the interaction was framed as "getting to the right answer", what mattered most was that his student, Aisha, could produce the right account of what happened on the moon. When Joanna framed the interaction with her students as "reviewing a concept", what students thought about real-life situations was not as important as what they could recall about the term inertia. In fact, Joanna made explicit moves to direct the discussion away from what AJ argued and recalled being perplexed by why he would talk about friction when the answer to her question was inertia. In framing the discussion with his students as the questioning part of the reciprocal reading cycle, John needed to pay attention to what his students thought because he wanted to help them use their ideas to collaborate on an answer to the question. When the discussion is framed as the summarization part of the reciprocal reading cycle, John only needed to pay attention to when his students correctly spoke about the main idea in the text.

However, that is not all. A teacher's attention may also influence how that teacher frames classroom interactions. This is seen most clearly in two of the episodes from Joanna and Dave. In the first episode from Joanna, her attention to her students' thoughts led her to change her frame. As she made sense of what her students were thinking, she got more involved in the discussion, even engaging in it as a learner. There is also some evidence to suggest that this was the case in Dave's episode with Aisha. It may be that, in the beginning, her idea caught his attention because it was the wrong kind of wrong idea. Since this could pose a problem for

Aisha in terms of completing the worksheet, Dave needed to help her explore the appropriate ideas for the worksheet problem. Once he moved into the frame of "getting to the right understanding", his attention was now constrained by the new frame.

In the literature I presented in Chapter One, evidence of variability is typically presented at a much larger scale such that what the teacher does in the classroom is typically presented as being fairly consistent (Jones & Carter, 2007). There may be differences between what the teacher states in the interviews and what that teacher does in the classroom (Bryan, 2003; King, Shumow, & Lietz, 2001; Tobin & McRobbie, 1997). There may be differences from one kind of activity to another (e.g., Kang and Wallace, 2005). Or, variability is the result of instabilities inherent in novice teachers' practice (Richardson, Anders, Tidwell, & Lloyd, 1991). The cases presented here challenge some of these common notions about variability in teachers' practice.

In these cases, the variability is not between interview and classroom settings because the interview data coheres with the classroom data. The variability is also not between different classroom activities because the variabilities exhibited in this chapter each occurred within one section of a lesson for each teacher. In fact, for Dave and Joanna, the changes in frames and attention occurred within a few minutes of each other. The variability is at the level of the interaction.

On the last issue of novice practice, Dave and Joanna were new teachers (less than 3 years) at the time. But closer analysis can make possible a method for making sense of the particular ways in which they shift frames. At times, they were each able to maintain their attention on their students' ideas and frame the discussion so they could help their students expose and develop those ideas. At other times, some aspect of what students said caught their attention and led them to reconsider or unconsciously shift how they interacted with their students and where they placed their attention. What a teacher attends to is influenced by and has influence on how the teacher frames the situation. In helping teachers develop, we would like to support the development of frames that involve attention to student thinking. Understanding the contextual dynamics of framing and attention can help us make sense of how some frames become stable.

Chapter 6: Discussion and Implications

I argued in Chapters One and Two that some previous work on teacher attention and teacher cognition were insufficient in helping us analyze and explain episodes like Heidi's (presented in Chapter One) or the ones in this dissertation. The coding schemes for identifying teacher attention were either developed for professional development work (and not for analyzing classroom teaching) or were not able to parse out the data at a fine enough level for us to reliably identify shifts in attention (as was the case with Ainley & Luntley's (2007) coding scheme). Additionally, explanations for what teachers did (and attended to) in the classroom that relied heavily on a unitary model of cognition (e.g., a teacher's classroom practice is driven by one coherent core set of beliefs and knowledge) insufficiently accounted for the variability we saw in this study in the attention teachers paid to their students' ideas.

In this chapter, I will present some closing comments and implications of this study. One contribution of this work to the field of research on teaching is methodological in nature. I developed categories that can be used to identify when a teacher is or is not attending to student ideas. Another contribution is more theoretical in nature. Specifically, this dissertation adds to our research understanding of that attention. I will discuss how a teacher's framing of an interaction can help explain the attention the teacher pays to student ideas. This study directly contributes to work that takes a more context-dependent, locally situated view of teacher cognition (see Aguirre & Speer, 2000; Kang & Wallace, 2005; Tabak & Rieser, 1999), by showing how a teacher attends to student ideas and is situated in his or her framing of the interaction with students. Lastly, I will end with a discussion of the implications for teacher education. This work highlights the need for a more nuanced approach in providing feedback that supports teacher development.

<u>Identifying whether or not a teacher attended to student ideas</u>

My first research question was: What do we see as evidence of whether or not a teacher is attending to student ideas? The literature I reviewed in Chapter One discussed some of the work on teacher attention to student ideas. Much of the work that looked explicitly at teacher attention was focused on teacher attention to student ideas in professional development settings. There, researchers developed coding schemes for identifying how a teacher notices student ideas when reflecting on records from the classroom (e.g., videos of classroom activities or copies of student work). While these coding schemes provided some indication of how one might identify when a teacher is or is not attending to student ideas in the classroom, they are not directly applicable for use with data from the classroom setting. Much of the coding scheme references the kinds of reflections a teacher may make in the luxury of the professional development environment, where videos may be paused, student work may be closely analyzed, and researchers and other teachers may draw attention to particular aspects of classroom events.

Most of the work that looked at how teachers attended to student ideas in the classroom did not articulate how one could identify when a teacher was or was not attending to student ideas. Ainley & Luntley's (2007) work on teacher attention has the most well-developed coding scheme for identifying teacher attention, though they did not focus solely on teacher attention to student ideas. The aspects of their coding scheme associated with teacher attention to ideas were the dimensions labeled affective/cognitive (attention to student feelings or to concepts and ideas) and noting/interrogating (the teacher noted a student's thinking but did not do anything or the teacher interrogated the student to try to find a way to move the student along the conceptual direction the teacher wanted). One of the difficulties I noted in Chapter One with using Ainley and Luntley's coding scheme is that it would have difficulty characterizing the teacher's attention if it shifted within an episode (see my discussion of the episode from Heidi's class in Chapter One). There is yet another difficulty with their coding scheme. The categories are not designed to help identify when a teacher is attending to *student* ideas specifically, and not just to ideas in general (e.g., ideas the teacher has).

Consider Joanna's two episodes. According to Ainley & Luntley's coding scheme, both episodes would be labeled in the same way, cognitive and interrogating. In both episodes, Joanna was more focused on ideas than on how her students felt. Additionally, Joanna asked many questions in the two episodes and the questions served to help move the discussion (and presumably student thinking) along the direction she wanted to go. In the first episode, it was toward a resolution to the debate. As I showed in Chapter Three, Joanna did attend to her students' ideas about the role of water in slipping. In the second episode, Joanna tried to move the conversation toward a review of the concept of inertia, which entailed a recitation of its definition. As I showed in Chapter Four, Joanna did not attend to her student's ideas about friction. Instead, Joanna seemed to be attending to whether or not her students were talking about inertia in the right way. In using Ainley and Luntley's coding scheme, we would miss seeing these differences. In one episode she did attend to her students' ideas and in another she did not.

To address the question of how we can identify whether or not a teacher attended to student ideas, I developed categories of evidence for identifying when a teacher's attention, during a classroom interaction, was directed at student thinking. If a teacher built on student ideas, asked for clarification of what the student said, interpreted what a student uttered, explored aspects of what students articulated, reflected student ideas back to them, drew the class' attention to what a student said, returned to the ideas a student presented at a later time, or noted differences between what students talked about, there was evidence to suggest that a teacher attended to student ideas.

On the other hand, if a teacher did not allow students to state their thinking, directed conversation away from the ideas students presented, attributed ideas to students that the evidence did not warrant, provided students with ideas to use and think, and focused on the terms students used rather than the meaning the students intended, then the evidence suggests that the teacher did not attend to student thinking. In such moments, what the teacher highlighted or focused on indicated where the attention was directed.

While it was not necessary to have the entire set of categories (for either attending or not) represented in any one episode, it was also not the case that any one category was necessary or sufficient for showing whether the teacher did or did not attend to student thinking. In Dave, Joanna, and John's episodes, it was the accumulation of different pieces of evidence that showed whether the teacher did or did not attend to student ideas. By looking at the nuances of what happened in the interaction, we may be able to identify when a teacher's attention was on student ideas and when there were shifts in that attention.

Two areas regarding identifying teacher attention that need further development.

Though this study brings us closer to identifying and understanding teacher's attention to student ideas, there is still more work to be done. I see two areas that need further exploration (and development): 1) a teacher might ignore some ideas to attend to others and 2) there may be levels of attention. In conducting the analysis, I realized that my initial conceptualization of attention (and attending) contained an implicit assumption that became problematic. I originally thought of teacher attention to student ideas as either an on or off phenomenon; the teacher either was or was not paying attention to student ideas. Joanna's first episode (see Chapter Three) illustrates some of the problems with this dichotomy.

In that episode, Joanna facilitated a debate in her class about the role of water in slipping on ice. She worked with both sides of the debate to help her students present their arguments clearly. It was important that everyone in the class, including Joanna, had access to and understood the ideas so they could participate. In an interview, Joanna said she did not think Bette's comments about the phases of matter were relevant to the debate.

> Joanna: I was trying to find a clear articulation of the counterargument. But I really wasn't interested in the solid-liquid-gas thing…. I knew that—I just didn't think that would be helpful….So that's why I interrupted her, in 40,

> even though she didn't really want me to interrupt her. So I said let's take that idea, what I really need is the water. (Interview, June 28, 2007)

To stay on topic, Joanna ignored what Bette said about phases of matter. Later in this interview, Joanna acknowledged that she disregarded the ideas Bette presented. Given that the class could only focus its discussion on a finite amount of things at a time, it was necessary to prioritize and put aside ideas that were not directly relevant to the discussion at hand.

This brings us to the second issue: there may be levels of attention. Joanna seemed to have paid some attention to what Bette said—enough to determine she did not want to spend class time on it. In an earlier part of the interview presented above, Joanna explained that Bette seemed to need to talk out loud to sort out her own ideas. Bette's contributions were sometimes difficult to follow and did not directly contribute to the conversation.

> Joanna: I kind of just let her talk about that. Because I knew with her, she has to talk about things to make sense of it. I had actually talked to her about that before…. You know how where, some people have to say it, and while they're saying, they're understanding what they're saying…. Like, they can't just think of the words in their head…. And I knew that she was like that so (pause) [???] she would eventually get somewhere…. (So I was like) "Mmmhmm. Keep on going." Bette needs to almost dump it all out and then kind of make sense of it. (Interview, June 28, 2007)

While Bette verbally sorted out her ideas, Joanna listened for how her comments could connect to their debate about water. Joanna explained in this interview, "I was trying to find a clear articulation of the counterargument… what I really need is water." Joanna also said that she did not want to continue with the phases of matter discussion, or at least in the way Bette was headed, because it was not helpful to reiterate what everyone in the class already knew. She expected all her students to already grasp those concepts.

> Joanna: I think the actual phases of matter they understand well. Like, most of them have, it's an easy concept for them. Molecules closer, farther apart, farthest apart…. By the time they're in high school, even 9th grade, they have a pretty clear sense of that. They've been learning that for a while…. That's sort of just too simple. Like, we don't have to spend time on that…. I mean maybe that's why I ignored it there,… her solid-liquid-gas thing. "OK, got it. We all understand it." (Interview, June 28, 2007)

Joanna listened closely enough to what Bette said to decide that her comments were too simple to warrant further discussion and were not relevant to the debate. This would imply that Joanna paid some attention to the ideas that Bette presented but decided it was not necessary to attend to those ideas in the class discussion.

As I mentioned earlier, I initially considered attention to be an on/off phenomenon—either the teacher's attention was on student ideas or not. This example suggests there may be levels of attention. In this case, Joanna acknowledged the idea but decided not to follow-up on Bette's statements. This would fit into the noticing category from Ainley and Luntley's (2007) study, which may indicate a low level of attention. When a teacher attends to student ideas during class discussions, not necessarily with the intention of moving student thinking forward in a particular direction but simply to understand it, this may indicate a high level of attention to those particular ideas. This dissertation furthers research understanding of teacher attention by developing a coding scheme that looks specifically at teacher attention to student ideas and developing a more refined coding scheme than previous work (see Ainley & Luntley, 2007) for identifying when teachers do or do not attend to student ideas.

On this matter of levels of attention, several researchers on teacher noticing in professional development developed coding schemes to characterize different levels of attention to student ideas (see Chapter One). Sherin and her colleagues (see for example Sherin & Han, 2004 or van Es & Sherin, 2006) developed coding schemes for identifying levels of noticing. Low level noticing would be a simple restatement of what a student said. A high level would entail a synthesis of student thinking or establishing a connection between a student idea and broader issues or ideas. The work in this dissertation shows that these coding schemes are not appropriate for studying how teachers attend to student ideas in the classroom. For example, restatement of student ideas or comments in the classroom may actually indicate close attention to those ideas because the teacher may be attending to what that student is thinking (see for example, John's efforts to understand Annie's question and present it to his class for discussion).

More work is needed to help our field develop ways of studying teacher attention. In particular, we may need a more refined way to characterize the levels of attention a teacher pays toward student ideas beyond noticing and interrogating. I would argue that framing theory may hold the key here. By understanding how a teacher frames an interaction, we can see what is relevant to the task at hand and what is not. A teacher may be likely to notice ideas that seem to have potential relevance (e.g., ideas that seem tangentially related). When it is determined that an idea is highly relevant to the task at hand, the teacher may consider that idea more and attend to it in the discussion.

A teacher's frame influences the teacher's attention

In Chapter One, I discussed some of the influences on teacher attention that have been explored in research on teaching practice. It is widely accepted that a teacher's cognition will have an impact on what ideas teachers notice, how they make sense of what they notice, and how they choose to respond to that in the classroom (see Ackerson, Flick, & Lederman, 2000; Brickhouse, 1990; Hammer, 1995). In particular, a teacher's perception of the type of activity (see Kang & Wallace, 2005), the curricular expectations (see Tabak & Reiser, 1999), and the institutional demands or demands placed on the teacher from a source external to the class (see Rop, 2002) may impact how a teacher attends to student ideas during classroom interactions.

The work in this study does not challenge those findings. How a teacher thinks does have an impact on what the teacher attends. We can see this in each teacher's work presented in this dissertation. Joanna, during an interview, explained that in the first episode, she felt she could manage the conversation because she was comfortable with the pedagogical and conceptual terrain, even though she was not sure how it would end.

> Joanna: I felt confident that we would get somewhere…. Because I knew I was able to respond, like it wasn't like all of a sudden we were going

> somewhere that I didn't think I couldn't handle, intellectually …. But I could see if it were a different unit. That perhaps I never taught before. I think it would be harder to do that. Like, this year when I was teaching chemistry and I taught electron configuration for the first time and having learned it on my own 10 years ago-it had been 10 years since I had even looked at the subject,… I don't think I would've been as willing. (Interview, June 28, 2007)

This comfort with the material allowed her to open up the class discussion so they could explore students' ideas about water's role in slipping.

In John's two episodes, we can see the influence of activity type on his attention. John had a particular way of considering the Questioning and the Summarizing portions of the reciprocal reading activity. These had an impact on how he attended to his students' thinking. With the Questioning part, his students were expected to try to jointly figure out the answer on their own ("I want 'em to go through the thought processes to try and figure out a question that's been posed.… Maybe another student will have some sort of insight, but as, you know, as a group thinks about something …you know, different ideas can even spawn the person who asked the question into sort of, you know, figuring out, it out or having a new idea.") (Interview, August 15, 2007). Summarizing was meant as an activity to reinforce good reading skills, such as gleaning the correct information about the text's main ideas.

Lastly, we can see the influence of external pressures on Dave's work. With Dave, the pressures came from the Mod Squad Project instead of from his department. By the time of this lesson, the Mod Squad Project was explicitly focused on examining student ideas from each teacher's class. During this lesson, there were several factors that amplified the project's goal. First, the worksheet Dave used was created during a cohort meeting for the expressed purpose of eliciting student ideas about gravity. Second, I was there to tape the class' work on this worksheet with the intent that we would view the video at a cohort meeting to talk about what ideas students had about falling objects. This may help explain why Dave put so much effort into eliciting his students' ideas, not just in the first episode but throughout that lesson.

These factors did have an impact on how the teacher attended to student ideas—as the literature would suggest. What this study challenges is how we can understand the impact of those factors. This work suggests that these factors (beliefs, knowledge, pressures from sources external to the classroom) did not necessarily exhibit uniform influence over the teachers' work, even within what was nominally the same activity. This was apparent in the episodes from Dave and Joanna's lessons. As the teacher's framing of the immediate activity evolved the definition of interaction—what cognitive resources were used, the relative importance of various expectations, and the goals and purposes pursued (at least at the local level) —changed as well. This study builds on work that takes a locally situated, context-sensitive view of teacher cognition, such as Aguirre and Speer (2000), by providing an explanatory framework that can account for why teachers may fluently use certain cognitive resources or respond to certain pressures in one moment but not so in another.

The influence of various factors on a teacher's attention depended on how the teacher framed the interaction.

In Joanna's second episode, she did not attend to her student AJ's ideas on inertia, even though AJ tried repeatedly to assert that friction could not be ignored. She was a bit surprised that AJ would insist on talking about an object slowing down when what she wanted them to talk about was why an object would keep moving on a friction-free surface. Joanna did this not because she lacked the knowledge and ability to handle the pedagogical situation. Nor was it strictly a matter of external demands that pressured Joanna to do this. It seemed that, in this episode, only certain cognitive resources were active and particular external pressures were relevant given how the interaction was framed.

Several pieces of evidence show that Joanna had a good understanding of friction's effect on moving objects in the real world and that she likely knew, at that time, what AJ meant and how friction related to inertia. During the discussion, Joanna endeavored to create scenarios that removed friction and allowed inertia to be seen unambiguously. The data from this lesson (see for example the first episode), the interviews, and the cohort meetings showed that Joanna also had knowledge of some ways in which students thought about friction and real world motion (e.g., that all moving objects would eventually come to a stop). Lastly, Joanna also showed that she had the pedagogical knowledge to effectively manage discussions aimed at eliciting and developing students' ideas even when she was not wholly sure of what her students would say or the outcome of the conversation (e.g, the first episode). Though she had the knowledge to support attention to AJ's thinking about friction and inertia, she did not use it. I would argue that those cognitive resources did not seem appropriate for what she wanted to do with her students at that time; she wanted her students to bring up what they covered in the first semester regarding inertia, not talk about friction and real world phenomena. In framing things as "reviewing a concept," she likely drew on other more appropriate resources to support her work, possibly resources that included routines for helping students use scientific formalism in canonically appropriate ways.

Pressures from external sources, such as the curriculum or the science department of her high school, created some tension for Joanna. But that does not effectively explain why Joanna was so focused on reviewing inertia. She was expected to give the unit test on the same day as all the other Matter & Energy teachers in her high school. This typically meant she needed to maintain the same pace through the curriculum as the other teachers. Joanna explained in the follow-up interview, though she valued the rich discussion the class had, it created some tension for her.

> Joanna: I wasn't planning for this (warm-up) discussion to go as long as it did. It was supposed to be an engagement. I was trying to do the 5 E's… (If I did not stay on the same schedule as the other M & E teachers) I would be in trouble at the end…If I got behind, for some reason (like if I was) two days behind or something, I'd still have to give the test on the same day (as the other teachers). (Interview, April 21, 2006).

As it turned out, Joanna ended up behind schedule. She tried to quickly deliver her notes on phase changes at the end of the lesson and took a portion of the next day's lesson to deliver the rest of those notes.

Though this pressure was likely in the background throughout this lesson, it seemed that these more immediate curricular expectations were not the ones that had the most influence during this episode. Talking with her students about inertia would seem counter to her plans and the department's schedule. At this point in the lesson, the class had already spent quite a bit of time on Joanna's opening question: "What science makes this Olympic sport possible?" Additionally, in the Matter & Energy curriculum, inertia was a first semester topic, connected with the class' work in Physics. It was not part of the phase changes unit. Exploring this tangent would make it more likely that Joanna's class would be behind schedule. The demands of the current curricular schedule did not seem a high priority during this episode. Instead, getting her students to think about Newton's Third Law (the law of inertia), a first semester topic, was.

The cognitive resources that were a part of Joanna's framing helped to create a context in which she saw a good opportunity to link the conversation to inertia. She explained in an interview, she was simply trying to continue their exploration of what was going on in curling. She said, "The first thing they said was friction, so I think that I was going with this to try and help explain, well, what scientific things make this sport possible…trying to explore that and part of what makes it possible is the ability to turn" (Interview, August 3, 2007). For Joanna, talking about the stone's inertia was a natural extension of talking about the stone's motion. For Joanna, inertia helped explain why the stone turned.

Joanna said she came up with this connection because of her work with her other classes. Joanna also taught an 11th/12th grade physics course. At this time, those students were studying light refraction.

> Joanna: I was teaching (11th/12th grade) physics concurrently…. I was teaching them about the bending of light, as it enters, you know, when it refracts, when it goes through a different medium…. I had used the conceptual physics worksheet that showed these carts. And when the carts were going on the sidewalk, they just go straight. But what if they kind of come in at an angle and they hit the grass? They kind of turn in the direction of the grass…. I remember that being in my mind, sort of concurrently. This idea of turning…. I do think that what you teach concurrently affects what you're doing in other classes. (Interview, August 3, 2007)

Lastly, pursuing inertia aligned well with one of her overarching teaching goals. Joanna wanted to help students make connections between the different topics in science. This probably seemed like a good teachable moment to bring up a connection to the Physics part of this class while they were learning about the Chemistry topics.

The cognitive resources that are a part of a teacher's framing of an interaction help the teacher determine the meaning of events or cues that may trigger decisions, and the relative importance of certain goals or expectations. Here, we can see the department pressure to maintain curricular pace was downplayed while her overarching goal of helping students make connections between science concepts was promoted. Also, we can see Joanna drawing on some cognitive resources (to guide a review of an old topic) but not on others (to see why a student might think talking about friction was a sensible thing to do in response to her question).

Changes in how a teacher frames a situation may mean changes in the cognitive resources the teacher draws on and the kinds of decisions a teacher may make. This can also be seen in the episodes from Dave's lesson. In the next section, I will use his two episodes to continue exploring the implications of this study on research on teacher cognition (and decision-making). In particular, I will use his episodes to talk about the TMG model of teacher decision-making. In Chapter One, I explained that this was the most well-articulated unitary model of teacher cognition that was focused on understanding the teacher in interaction with students. As such, this had the most potential for explaining the examples in this dissertation.

Context independent or dependent models of teacher cognition.

Context independent models or unitary models of teacher cognition assume that each teacher has a stable, fairly robust system of beliefs and knowledge that control their practice. Though a teacher may exhibit varied behaviors, analysis of these behaviors will show that they are actually consistent with the teacher's core set of beliefs and knowledge. Researchers in the TMG looked at the connection between the local context (e.g., the interaction between a teacher and his or her students), teacher cognition, and teaching behaviors (Schoenfeld, 1998; Schoenfeld, 2000; Schoenfeld, Minstrell, & van Zee, 2000; Zimmerlin & Nelson, 2000). I will focus on this model as an exemplar of work that follows the unitary view of teacher cognition.

They provided a very rational account of teaching. Their main argument was that variations observed in a teacher's practice were the result of a core set of cognitive elements (beliefs and knowledge) responding to changes in the situation to pursue the particular goals the teacher had at that moment.

The TMG model of interactive teaching seemed a likely candidate for explaining the kind of episodes in this dissertation. In particular, the model's reliance on routines as a way to explain teacher decision-making may help explain some of the episodes in this dissertation. In short, routines are cognitive decision-making structures that teachers call upon to address the various things that come up during a lesson, such as a mistake a student made (please see Schoenfeld (2002) for a more detailed discussion of routines). The term routines implies scripted pieces of behavior, which is similar to the routines Leinhardt and Steele (2005) described. However, for Leinhardt and Steele, routines are "small socially shared, scripted pieces of behavior…(that) evolve over time and are jointly built by teachers and students" (Leinhardt & Steele, 2005, p. 92). In the TMG model, routines are cognitive structures that the teacher develops and holds.

The TMG model can explain John's data from Chapter Three quite well. In the discussions of Annie's question, his routine for handling the Questioner's question turned on. At the time, John was recording the summary of the text the class had just read. Annie interrupted with her question about the bottle cap and heated bottle. Though she was not the official questioner for this cycle of the reciprocal reading activity, she asked a question that related the text they just read with a situation students would likely encounter in their daily lives. In John's eyes, this was a good question for the class to explore. Additionally, the timing of Annie's question was just right —it came when John was almost finished with recording the summary on the board. John's routine for handling an official Questioner's question was activated. A rough sketch of this routine is as follows:

Step 1: Is there a clear articulation of the question? If yes proceed to step 2. If no, enact subroutine for gaining clarity about what the student means.

Step 2: Ask the class to comment on the question. If students are reticent, proceed to step 3. If students are forthcoming, proceed to step 4.

Step 3: Rephrase the question. If students are still reticent, proceed to step 3b. If students are forthcoming, return to step 2.

Step 3b: Provide students with suggestions on a related but different question to think about and return to step 2.

Step 4: Are student responses unclear? If yes, probe student responses and repeat step 4. If no, proceed to step 5.

Step 5: Ask other students if they have anything else to add to the discussion. If yes, repeat step 4 until there is nothing more to say. If there is nothing more to say, move to step 6.

Step 6: End routine and move to the next activity. There are several options for ending this routine. One option for ending the routine is by commenting on the quality of the question and responses. Another is to summarize what was said.

This routine served as a way for John to pursue his goal of helping his students learn to answer each other's questions and develop their critical thinking skills. I developed this description based on my other observations of what John did during the questioning portion of the reciprocal reading activity.

The questioning activity is a well-structured activity that John had used many times. He had a nicely compiled script, or routine, to follow for this activity. Though Annie's question was a break from the official pattern (she was not called on and did not have a role in the current cycle), there were aspects of her question that fit easily into the reciprocal reading cycle (she asked it after the summarizer had given his summary and it connected the science content with a real scenario students could understand). In framing the discussion of Annie's question as a questioner's question, the routine guided John's behaviors in the conversations.

But, the TMG model had difficulty explaining why a teacher might commit to a set of actions that were contrary to the teacher's plans, stated beliefs, and goals for a specific activity. Dave's case serves as a nice focal point for discussion of these issues.

Student in the wrong problem space: a routine for redirecting George.

In the two episodes from Dave's class, both of his students, George and Aisha, moved into the wrong problem space with respect to the worksheet question. They thought about the scenario in the question in the wrong way (e.g., the objects would not fall). There was the potential that his students would not explore the kinds of ideas the questions were aimed at eliciting —ideas about how objects fell. To mediate this difficulty, Dave saw his role as making sure his students considered the questions properly. Given the similarities between the two situations with Dave's students, we should expect to see Dave enact the routine for dealing with students working in the wrong problem space.

In the episode with George, we can see in lines 65-68, when George initially said the objects would not hit the ground, he was not talking about what the question asked.

65.	George:	I mean, if you drop this from a certain height, it wouldn't, [the book?/they both?] wouldn't hit the ground.
66.	Dave:	Not at the same time?
67.	George:	Nah.
68.	Dave:	(pause) So are you saying the higher up that you drop something, like, the less likely they are gonna hit the ground at the same time?

Dave explained in an interview, he wanted to help gently guide George to the point of the question.

> Dave: I was thinking that he's still thinking about the two objects being in space, far away…If there's no air, there's no gravity. This is his line of reasoning. So if there's no gravity, then if you drop something, it's never going to hit the ground. It's just going to float there. So that's what I'm thinking he's thinking, so then I ask him, I kind of, I try to redirect him back to the question by saying "not at the same time." Like, kind of implying to him that they are going to hit the ground, but it's a question of whether or not they are going to hit the ground at the same time.… I'm trying to get him to see that

> just because there's no air, that doesn't mean that there's no gravity. (pause) So that's an example of me kind of indirectly nudging him back to the question. (Interview, June 14, 2006)

As noted in Chapters Three and Five, Dave did not want to come off too heavy-handed in his guidance. In the past, when he guided or questioned too much, his students frequently stopped participating and deferred to his authority in answering questions. He wanted to send the message to his students that the intent of this day's activities was to jot down their ideas, not necessarily what the teacher thought was correct.

The interview about this episode showed that Dave's decision-making could be distilled into the following pattern:

> Step 1: Is the student thinking about the question in the right way? If yes, proceed to step 3. If no, proceed to step 2;
>
> Step 2: Help the student think about the question in the right way (e.g., gently provide correct information) then return to step 1;
>
> Step 3: Return to the lesson agenda (in this case, return to eliciting student ideas).

According to Dave, George was not thinking about the question properly. This triggered the plan to help George work on what the question was asking.

> Dave: I think (George's line of reasoning) would be a problem because that's not what the question is asking. The question is clearly asking about objects that are falling. So if he, if he goes off talking about something that

isn't falling, then he's not really… paying attention to what the question is asking him. (Interview, June 14, 2006)

George's point that they "wouldn't hit the ground" put George into the wrong problem space for answering the question. Dave needed to help George move into the right space of ideas, the kind of ideas associated with objects falling.

> Dave: I try to redirect him back to the question by saying "not at the same time." Like, kind of implying to him that they are going to hit the ground, but it's a question of whether or not they are going to hit the ground at the same time…. But (doing so) without criticizing him, indirectly or directly. Without being like, "you're not answering the question." I try to just, kind of like, indirectly bring him back without threatening him. (Interview, June 14, 2006)

Evidence from the class data supports this. After George said that the objects would not hit the ground at the same time (line 65: "I mean, if you drop this from a certain height, it wouldn't, [the book?/they both?] wouldn't hit the ground."), Dave responded by injecting the missing information that would make George's statement fit with the question (line 66: "Not at the same time?"). George seamlessly folded Dave's point into his subsequent response. According to the routine described, this meant that Dave had successfully redirected George. Dave could now return to his original plan of eliciting student ideas, which he did in line 68 ("So are you saying the higher up that you drop something, like, the less likely they are gonna hit the ground at the same time?").

After Dave and I watched George incorporate Dave's suggestion into his statements in an interview, Dave said he saw an aspect of George's thinking that needed development. Dave stated, "(In lines 70-80) I'm just trying to get (George) to explore…. Because I think George has an understanding, or at least an intuition about the influence of air resistance, but he just hasn't identified it directly the way Naveed has" (Interview, June 14, 2006). Once George moved into the right space of ideas, Dave no longer needed to push him to talk about certain things, moved to step 3 of the routine, and returned to asking George about his thoughts.

In following the TMG model, we can develop a characterization of Dave's work with students when his students are not doing what the question asked. George's statement that the objects would not land had put him in the wrong problem space for the question. Dave switched out of the plans associated with his original lesson agenda (eliciting student ideas) to redirect his student. When George talked about the kinds of ideas associated with the question, Dave stopped redirecting George and switched back to his original plans (elicit student ideas). If we assume a unitary model of cognition (e.g., Dave has a core set of beliefs and knowledge that drive most of his teaching), then when Dave encounters a similar situation, where a student (or students) is not working in the right space of ideas, he should enact the same routine. In the episode with Aisha, she too was not thinking about what Dave thought the question asked. We would expect Dave to enact the same routine he used with George ―redirect Aisha and when she considers the question appropriately, return to eliciting her thinking.

Student in the wrong problem space: a routine for redirecting Aisha?

In the second episode, Aisha said the objects on the Moon would not fall. Dave corrected her by declaring that there was gravity in outer space, including the Moon.

103.	Aisha:	If you drop a bowling ball and a, a small rock on the moon, neither one of them would drop would it because there's no gravity up there.
104.	Dave:	So you don't think there's gravity on the moon?
105.	Aisha:	No, (pause)-
106.	Dave:	So-
107.	Aisha:	-because that's how space is.
108.	Dave:	OK, so if you're really far away from massive objects like the moon or the earth or the sun, then gravity is negligible, it's, it's like there's no gravity.
109.	Aisha:	(audible level) So it's…
110.	Dave:	But, if you're near. So, there is near, so there is gravity on the moon, yeah.
111.	Aisha:	(sotto voce) OK.
112.	Dave:	So things **do** fall on the moon. Do you think that, do you know if they fall faster or slower on the moon? (Aisha shakes her head no) They fall slower. Any idea why?
113.		Camille: Because, uh, there's less gravity.

114. Dave: Right, so things accelerate slower on the moon because the moon is less massive than the earth.

As Dave explained in an interview, Aisha's original idea would get in the way of her answering the question.

> Dave: I don't think that they understand yet that if you have less mass you exert a weaker gravitational force on other things, so I'm trying to kind of push them in that direction… because the question is about an object on the moon and we haven't really talked about gravitational forces on things or exerted by things other than the earth…. Right so, her idea, like George's is that if you are in space there is no gravity, it doesn't matter if you're on the sun or on the moon or on Jupiter or wherever. If you are in outer space, there is no gravity…. I just end up explaining it. Like in line (108), I just try to explain it to them. (Interview, July 6, 2006)

Dave saw Aisha as thinking the same kind of wrong idea as George. By claiming that the objects in the questions would not fall, the two students were seen as not answering their respective questions. In both situations, Dave needed to help steer his students back to the right range of ideas (ideas about objects that fell) to explore. He did so by adding correct information about the scenarios into the dialogue. In this episode with Aisha, Dave told her that the objects on the moon will fall, though at a slower rate than on Earth because it is less massive (lines 108, 112, and 114). This is similar to Dave's move in line 66 to tell George that the two objects in the first question would hit the ground (line 66: "not at the same time").

One noticeable difference between the two episodes is that Dave provided considerably more information to Aisha than to George. He wanted Aisha to reason with the idea that the objects will fall on the Moon and that the Moon has less gravity than on Earth. Since Aisha's statements unambiguously placed her very far away from these ideas ("line 103: "…neither one of them would drop, would it, because there's no gravity up there"), Dave could not gently suggest that the object would drop as he did with George.

After Dave established that there was gravity on the Moon, albeit less than on Earth, Aisha accepted the premise and reasoned with it.

115.	Aisha:	So a bowling ball would drop first right?
116.	Dave:	On where?
117.	Aisha:	On the moon.
118.	Dave:	(3-second pause) OK why?
119.	Aisha:	Heavy, [it's?] heavier.
120.	Dave:	Because it's heavier? So you think that heavier objects fall faster than lighter ones?

So far, Dave seemed to be enacting the same routine he used in the first episode. Once Aisha talked about falling objects, Dave proceeded to ask her about what she thought (lines 116 and 118), as he did with George. But, Dave did not elicit Aisha's ideas for long. When Aisha hesitantly mentioned that things drop slower on the moon, Dave switched to leading Aisha down specific lines of reasoning, e.g., comparing the earth to the moon, rather than asking her about her thinking about heavier objects falling faster.

121. Aisha: (slightly hesitant tone) On the moon, they drop slower

122. Dave: So, so, are you saying that on earth they would fall and hit the ground at the same time? (Aisha gives a very slight nod) But on the moon they wouldn't? (Aisha gives a slight nod) OK so what's the difference between the earth and the moon? (Aisha shrugs her right shoulder and chuckles) So (Dave's voice exhibits more inflection and changes in tone), so, why do you think that then?

123. Aisha: (smiling, looks at paper for 3 seconds, spoken loudly and with a quicker pace than line 121) Because its outer space, (more hesitant tone) it like, it's probably less gravity in outer space than it is on earth.

124. Dave: OK so gravity isn't as strong on the moon as it is on earth. That's true. But, so if gravity's weaker on the moon, I mean, things aren't gonna accelerate down as quickly on the moon, but why would, um, the fact that we're on the moon like, affects which one hit first? Like wouldn't they both (mimics two objects falling) just hit the ground at the same time just at a slower rate, (Aisha shrugs both shoulders and raises and lowers eyebrows) is that possible?

125. Aisha: (3-second pause) So they're gonna hit at the same time?

126. Dave: (5-second pause and rifles through stack of papers in his hand) That's what I want you to think about, that's what I want you to think about.

Here we see Dave leading Aisha toward the conclusion that the two objects would hit the lunar surface at the same time, assuming they are dropped from the same height. The TMG model provides very little to help explain why a teacher would do one thing in one moment and a different thing in another, analogous moment. George presented a very similar idea to Aisha's (heavier objects fall faster than lighter ones). George was sure about his ideas even though their experiment challenged it. Aisha also seemed fairly confident that the heavier object would fall first. Even when Dave challenged her by pointing out an inconsistency in her logic (line 122: "are you saying that on earth they would fall and hit the ground at the same time? But on the moon they wouldn't?), she stuck with her line of reasoning. When Aisha implied that objects could behave differently on the Moon "because it's outer space" (line 123), her tone, volume and pacing indicated a fair amount of conviction behind that statement. She said it without hesitation and loud enough to be heard clearly. What Aisha seemed uncertain about was how Dave's claims about the moon having weaker gravity than the earth fit with her arguments (line 121: (hesitant tone) "On the moon, they drop slower"). Nonetheless, in the latter part of line 123, she was able to continue with her idea and linked Dave's point back to her line of reasoning;

the Moon and the Earth are different because the Moon is in outer space and it has less gravity.

If we assume that Dave acts rationally and in accordance with the beliefs and knowledge he stably exhibited in episode one, we would expect Dave to return to elicitation of Aisha's ideas once she started to reason with the premise that lunar gravity existed. But he did not do that. Even though Aisha was committed to her thinking and began to talk about objects falling on the moon, Dave continued to supply her with ideas. This violated the routine he used with George. In that routine, Dave provided guidance to help students get into the right problem space. Once George accepted his gentle guidance, Dave backed down from telling him any more information and returned to eliciting George's thinking. In fact, Dave encouraged him to flesh out his wrong idea in writing, even after their experiment contradicted it, because exploring his own thinking would ultimately help George understand the canonical line of reasoning.

Exploring Aisha's incorrect ideas here did not seem the thing to do. With Aisha, Dave continued to supply her with ideas even when she began to talk about objects falling on the moon. Dave told her what to think and how to use it in answering question 2b because he did not "think she has enough background knowledge to be able to like, to jump, to make that conclusion (that objects on the moon should fall at the same rate). So that's just me trying to explain and fill in the gaps in her knowledge" (Interview, July 6, 2006). Here, fleshing out Aisha's incorrect ideas would not help her get to the right understanding.

Though the TMG model is able to explain John's work, it has difficulty accounting for Dave's episodes. Aisha, like George, presented an idea that put her in the wrong space of ideas for question 2b. As he did with George, Dave tried to help Aisha get into the right problem space by suggesting that the objects in the scenario would fall. With the TMG model, one would expect Dave to go back to eliciting student ideas once Aisha began talking about the right scenario. Instead, he continued to lead her to the right answer, even though she did try to reason with the premise that there was gravity on the moon.

The TMG model also has no explanation for why two similar student cues would be interpreted in such dissimilar ways. Once Aisha started to talk about objects falling on the moon (line 115-119: "So a bowling ball would drop first right?... On the moon…. (because it's) Heavy, [it's?] heavier"), Dave did not see Aisha's work in the same way as he saw George's work. Her incorrect answer would hinder her learning because it would not lead her to the correct conclusion. With George, his incorrect idea could help his learning if George understood that idea better (and possibly see how incorrect it was). By leading Aisha to the right answer, Dave went directly against his goals for the seatwork portion of this lesson (having students explore and write down their thinking irrespective of their correctness).

It may be that there are other aspects of Dave's central system of beliefs and knowledge that led to this decision. One possibility could be that Dave held beliefs about male and female students that led to gender-bias treatment of students. I have not done a systematic search for bias but there is some data that suggests this may not be the case. For example, during the whole class discussion of question 4:

Two identical plastic soda bottles, one of them full of soda and the other completely empty, are dropped from the roof of this school at the same time. A student, when asked which object lands first, answers as follows:

STUDENT: “We learned from those Galileo experiments that objects of different mass all fall at the same rate. So the full and empty bottle land at the same time.”

Do you agree? Disagree? Explain your reasoning.

Dave asked his student, Patrice, about the details of her ideas. His approach was similar to what he used with George.

312.	Dave:	We’ve got one soda bottle that’s full and one that’s empty. So—
313.	Patrice:	I think the lighter one gonna fall first.
314.	Dave:	OK, why?
315.	Patrice:	I don’t know.
316.	Dave:	So you’re just guessing?
317.	Patrice:	Why don’t you drink some soda here and you show us. You, you show us these things, you need to start showing us stuff so we could see the proof of it, because-
318.	Dave:	OK. I don’t have any soda bottles on me right now. But I want you to think what would happen if you did that. So why, why do you think the lighter soda bottle would fall first?
319.	Patrice:	Because it is lighter, so it has less stuff to hold while it’s falling.

320. Dave: Less stuff to hold while it's falling.

321. Patrice: Yeah, it got less stuff, for you know what I'm saying, like, say like, [???] all right, this is lighter right? So watch this. (she drops two objects. Sounds of objects bouncing on the ground). That hit first. I mean that hit first. 'Cuz it don't have as much stuff in it to hold while it's falling.

322. Dave: OK so if you…

323. Patrice: It don't have as much stuff to take down with it.

324. Girl: (laughs)

325. Dave: So, you're saying that if something has more stuff to hold, then it's going to fall slower.

326. Patrice: Yeah.

327. Dave: --than something that isn't holding as much stuff. OK. Camille.

Patrice is not correct in arguing that the lighter one would fall first because it has less stuff to hold. If air resistance were not an issue, the empty and full bottles would hit the ground at the same time. If air resistance were an issue, the empty bottle would hit its terminal velocity first and take more time to reach the ground than the full (heavier) bottle. Though she was incorrect, Dave pressed Patrice to explain her thinking.

Just prior to this clip, Camille had presented a canonically correct analysis of the situation (the heavier bottle would fall faster because it had more mass to counteract the air resistance it faced as it fell). In what follows from this clip, Camille argued against Patrice by reiterating her "more mass" account. Dave ended the discussion by telling his students, "I want you to respond to these questions with your own reasoning. Why you think certain things are going to happen and then backing those, those responses up." Here, Dave explicitly asked Camille and Patrice (as well as the entire class) to answer the questions by developing their ideas, just as he did with George.

Another possibility may be that Dave's knowledge was not well-developed enough to allow him to support the elicitation of Aisha's ideas. Dave was a new teacher at the time. Like Mr. Nelson, the new teacher from the TMG study (Zimmerlin and Nelson, 2000), Dave might not have had sufficient knowledge and skills to pursue his goals. In the TMG model, a teacher's behavior is determined by the goals the teacher has and the beliefs and knowledge that will allow a teacher to pursue those goals. A challenge to this argument is that Dave seemed to have had this knowledge and skill when working with his students in the first episode, the episode with Patrice and Camille, and in other interactions with his students during this lesson. But in the episode with Aisha, this knowledge and skill seemed to have turned off, or at least was unstably activated. The TMG model is not able to comment on why it seemed this knowledge was weakly activated in one moment but stably activated in another moment of the *same* activity. In fact, the two episodes occurred within minutes of each other.

It may simply be that Dave thought of question 2b as different from all the other questions on the worksheet. In that case, another routine, along with a new goal, was more appropriate than the one he used with George and Naveed. With this question, Dave's goal was to get his students to the right answer first, then make sure they had the right explanation to back up that answer. If they did not, then he would supply it. There is some support for this in the data from the whole class meeting regarding the worksheet questions. When they reached question 2b, Dave began by surveying how many students thought there was gravity on the moon (some said there was no gravity on the moon). He then continued by telling his students that there was gravity, albeit weak gravity, and no air resistance on the moon, which meant that the two objects would hit the ground at the same time.

200.	Dave:	So on the moon gravity does pull things down to its surface. But not as quickly as on earth. On earth things fall at about, at 9.83 seconds squared, right? But on the moon it's only about 1.6 or 1.7. So instead of falling like that on the moon things would accelerate much slower on the moon. So there is gravity on the moon. But the moon is very different from the earth in that it doesn't have a whole lot of air on it, right? There's not a lot of air in the atmosphere. So, if you were to drop the bowling ball and the rock on the moon, would they still both land at the same time? When there's very little air?
201.	Students:	Yes. Yes.
202.	Dave:	Yes. OK why?

203. Boy: Because, gravity would pull both of them together. Like, if there is no air, there is no air resisting. And they would pull at the same time.

204. Dave: OK, all right. So, good. OK so, as we're going through these questions, if there's stuff that you want to add to your responses, make sure you're filling that in. Um, OK let's look at number three. Can I get a volunteer? Warren, go ahead.

Once his students seemed to accept his premise, Dave responded by asking why his students thought that. Since the male student in line 203 provided the correct explanation, Dave did not need to provide any more explanation and was able to move on to the next question.

What Dave did here was markedly unlike what he did with the discussion of the other problems. During the class discussion time, Dave typically asked students to present their answers first and comment on each other's answers before he made his comments, if he had comments to make (see the example with Patrice and Camille). Though arguing that Dave simply had a separate routine for 2b does make matters more complicated (e.g., he had planned on pursuing a subgoal for 2b that was at odds with his goals for the rest of the activity), it does provide a reasonable explanation of what happened. What is lacking here is how it came to be that Dave considered this question as different from all the other questions on the worksheet. Analysis of Dave's frame may shed some insight into this issue. This will be discussed in the next section.

Another possibility was that Dave was simply pressed for time at the end of his interaction with Aisha. This new constraint (not present in the episode with George and Naveed) led to the decision to tell the answer to the worksheet question. Because Dave was rushed, he activated the routine for telling answers. Dave may have felt pressure to move along. Just prior to this episode, he told the class they had only 5 minutes left before they had a discussion. But, that does not explain why Dave did not end the conversation earlier, when Aisha talked about objects falling. Dave left George to ponder the same wrong idea Aisha stated. It is not clear why he needed to rush her to the correct answer and not just to the ideas about falling the question was aimed at eliciting. This data challenges the assumption this was a rational decision based on a context-independent core set of beliefs and knowledge that Dave had.

One last possibility is that Dave had beliefs about Aisha in particular that may explain the difference in his actions. While I am not able to definitively rule out this possibility, I have not noticed this in any of my observations of and interviews with Dave. I could continue to explore possible beliefs or knowledge-based explanations in hopes that something would rescue the unitary explanation of Dave's work with Aisha. But that discussion could go on for quite a while and I do not believe it would redeem the unitary explanation of inconsistent teacher behavior.

In this section, I focused on the TMG model because it was the unitary model of teacher cognition that had the most potential for explaining the examples in this study. In summary, the TMG model is quite effective at explaining a lot of a teacher's work when he or she acts consistently with his or her goals and beliefs.

However, it could not provide an effective explanation for the contradictions in what Dave did in this lesson, such as when Dave continued to tell Aisha information even though it was contrary to his lesson agenda, overall goal for this portion of his class, and his belief that heavy-handed teacher explanations were not helpful for student learning. Unitary models cannot explain why the same cue in one setting may trigger one set of decisions but in another a different set of decisions. I would argue that the meaning of those cues may depend on the context, and a frame analysis may help us see that.

Framing theory can explain Dave's apparent inconsistencies.

Understanding Dave's framing of this interaction may help explain why Dave acted as he did with Aisha. In this view, it may not have been a well-rationed decision to tell Aisha the answer to the worksheet question. It may simply have been that once Dave had proceeded far enough down the path of framing the interaction as a discussion to get Aisha to the right way of thinking far enough, he got stuck in this way of doing things.

In the situation with George, it was fairly easy for Dave to guide George to the right kinds of wrong ideas and to talk about the scenario in the expected way. George seamlessly merged what Dave interjected with his answer and there was nothing more for Dave to do. In Aisha's situation, Dave had to do more work establishing the correct scenario and could not subtly suggest as he did with George. The more he told her, the more the frame "getting to the right understanding" became established and even seemed to take on a life of its own. Sawyer (2003) argued that as frames become more established, the frames exert a certain amount of control over the participants' actions that may be beyond the control of any individual participant. Nudging his students into the right problem space evolved into simply making sure Aisha had the right idea.

It is likely that this well-developed way of framing was triggered without him noticing. "Getting students to the right understanding" is a fairly common way of framing classroom discussions for Dave. There were well-established routines, roles, and goals associated with this way of framing. In much of the data from Dave's classes, he could be seen using demonstrations, lectures, and calculation problems to show students how to correctly think in physics. The goal was usually to get students to use the right line of reasoning so they could answer questions and explain situations properly.

The goals, roles, expectations, and ways of interpreting associated with this familiar framing became active. Dave's interview statements about this episode referenced his goals associated with this framing of the interaction (he needed to get Aisha to develop the right explanation), not his original intentions (to get his students to be honest about their thinking). It is possible that these justifications (needing to get Aisha to develop the right explanation) were developed in retrospect, once he had already started telling Aisha a lot of information. Once this way of framing was triggered, it was reinforced (both by the frame itself and by other participants in the interaction) and became the way to think about and see the interaction.[9]

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[9] Part of this may be because Aisha's actions may have reinforced this way of framing the conversation. At the beginning, Aisha behaved as if her ideas were an important part of the conversation. She initiated the interaction with an explanation of her answer. When Dave asked her in line 102 "So you don't think there's gravity on the moon?" she responded (lines 103 & 105) with her rationale. In fact, when Dave interrupted Aisha in line 104, Aisha kept talking in line 105 about her thinking as if Dave had not interrupted her. But when Dave told her how to think about the moon

From the view of the TMG model (and other unitary accounts), one might say that Dave enacted a different routine with he worked with Aisha on question 2b. The frame analysis account does not disagree with this. What frame analysis can add is an explanation for why this routine was adopted. Dave started performing behaviors that seemed a lot like ones associated with this routine. This routine is frequently associated with a particular way of framing (getting to the right understanding). As this framing became more stably activated in this interaction, he developed a different way to consider the work on this question and this routine became the driving decision-making mechanism. The cognitive resources that are activated helped to constitute a person's framing of the interaction. Once Dave started to act as if he framed the interaction as getting to the right understanding, what and how he thought about the situation (and the events) changed.

In a separate paper on these two episodes from Dave's class, Elby, Lau, Hammer, and Hovan (in preparation) provided detailed analysis showing evidence that, in his two episodes, Dave exhibited two different (and somewhat conflicting) epistemological views, or beliefs about how knowledge develops. Each of those views was associated with the way Dave framed his interactions with his students. Rather than repeating their work, I will summarize their analysis and discuss its connection to this dissertation.

(lines 106-112 & 120-124), Aisha did not interrupt with her ideas. Instead, she gave responses that did not draw attention away from what Dave said (e.g., she lowered her volume in line 109 and responded with gestures that indicated she did not have anything to contribute to the discussion in line 122). These moves reinforced how Dave framed the interaction and allowed Dave to speak more than Aisha in this conversation. In this study, I mostly studied the teacher's interpretation of events. Students' participation in the co-construction of a way of framing was not the focus of my work. Looking at what Aisha did suggests that understanding how a teacher's framing of a situation evolves may require looking at how students contribute to that evolution.

In the first episode, where Dave, George, and Naveed discussed the first worksheet question, Dave exhibited a consistent epistemological view that Elby, et al, labeled the misconception-constructivist epistemological view. The evidence from this episode suggests that Dave believed students needed to figure out their own ideas first before they confronted their misconceptions and worked toward the correct understanding. The teacher is to help students with that process of figuring out their ideas, and confrontation of those misconceptions occurs after the students have figured out their thinking. Explaining concepts to students can be productive only if explanations take into consideration students' ideas or misconceptions.

In the second episode, Dave exhibited a different epistemology, which the authors labeled the transmissionist epistemological view. In this view, there were three distinct assumptions made about students, their learning, and teaching. Students were assumed to not have prior knowledge relevant to learning targets unless they had direct experience with the phenomenon or were previously exposed to the ideas by an authority (e.g., the teacher). If they did have the relevant prior knowledge, then students would produce the right answers. Students were expected to be able to learn well from a clear explanation or an extremely direct Socratic chain of questions, even if the explanations treated students as blank slates. Lastly, elicitation of student ideas was either for purely motivational and affective reasons or to draw out the correct information and concepts that they had been exposed to in previous classes.

I am arguing that as Dave's framing in the second episode became more stable, this second epistemological view took on a stronger role and helped Dave (re)organize his thinking about their work on question 2b. In this way of thinking, if

Aisha, or any student for that matter, had been exposed to the right ideas at some point in time, Dave should be able to draw out the correct answer. But if she did not have ideas that were relevant to the problem, he needed to provide them (and possibly help replace the irrelevant ones). Here, relevance was defined in terms of whether or not those ideas helped students produce the correct answer to the worksheet problem.[10]

This may also help explain why: 1) Aisha's point that the heavier object fell faster than the lighter one triggered Dave's decision to lead Aisha to the correct answer, but in the first episode, this same point did not lead Dave to do that with George and, 2) he treated question 2b during the whole class discussion in a different way from how he dealt with the other questions on the worksheet. It may be that this way of framing conversations with students became linked with the worksheet problem for Dave. Since it was unlikely that students had direct experience with lunar gravity, he did not expect them to have ideas that were relevant to the question — with relevance defined in terms of whether or not the ideas helped students produce the correct answer to the worksheet question. Dave's role in this framing was to help provide students with those ideas and to check to see if they could articulate the correct answer.

The unitary approach to teacher cognition cannot account for the observed inconsistencies in Dave's work with his students in the two episodes. In both episodes, he encountered two very similar ideas (heavier objects would fall faster

[10] In the episode with George and Naveed, all student ideas that could help students develop a logical explanation were relevant to the discussion. It did not matter if those ideas were right or wrong. Dave could only address the rightness or wrongness of an idea after students had fleshed them out.

than lighter ones) but dealt with them in dissimilar ways (in one episode he encouraged his student to explore his errant thinking and in the other he told her the right answer so she would stop using her incorrect ideas). Accounts that rely on the assumption that a teacher has a central set of beliefs and knowledge that are always active and rationally drive what a teacher does do not match Dave's data. We need a way to consider how a teacher's cognition is situated in the local interaction.

As I discussed in the earlier section regarding Joanna's second episode, a teacher may have different cognitive resources that come on (or turn off) depending on the situation in which he or she finds him or herself. Framing theory can provide the explanatory framework for understanding this. In a given situation, an individual's experience of a situation is organized such that some cognitive resources are activated (and others are not) and certain external pressures are relevant (while others are not). As the teacher's framing of events shifts, the constellation of factors that impacts what a teacher does, notices, or thinks may change as well.

There is a bidirectional relationship between attention & framing

In Chapter Five, I discussed in detail how a teacher's framing may constrain the direction of the teacher's attention. But, the dynamic between framing and attention is not unidirectional. A teacher's attention may lead to shifts in how the teacher frames the situation. This is evident in Dave's and Joanna's episodes.

In Joanna's episode from Chapter Three, her students debated about the role of water in slipping on ice. Joanna thought she already knew which side would lose. But, she could not fathom why her students thought that the melted water would slow down the curling stone. If she was to show her students the counterargument was incorrect, the class needed a clear sense of what that argument was. Even though Gabe had already articulated the correct explanation for why one slips on ice, Joanna still needed to explore the counterargument. In an interview, Joanna explained, “I want people to be, sort of be able to look at counterarguments. And then you can more definitively come up with an idea or wipe out, like knock out a counterargument” (Interview, June 28, 2007).

In paying attention to the counterargument, she heard something in what her students said that caused her to reframe the discussion. In a way, she had mentally put the debate on hold so she could understand what they were telling her. Instead of listening because she wanted to determine how they were wrong, she listened simply because she was interested in what her students had to say. As she explained in an interview,

> “(But) I had no idea what they were talking about…. because I would have thought [???] made it go slower.... I hadn't even thought about the counterargument (before). So they needed to sort of explain that to me. I hadn't anticipated what that would be” (Interview, 6-28-07).

Once she understood what her students meant, she had to change how she thought about the debate because she was wrong and not her students.

> Joanna: As a teacher I was going, “OK, so where do I go with that?” Because I've agreed with the counterargument… And they've convinced me, and I've kind of convinced myself through my pictures (on the board)… And so that's also what I would call like this moment, where like (I thought), “OK, do I try and bring this all together (laughing) or do I just abandon this notion of

> bringing it all together because now I agree with both sides?" (laughing) And so that's where I said, "Pretend you're driving." That's me coming up with another example, like, OK. So I agree with the counterargument; let's come up with another argument, another situation. (Interview, June 28, 2007)

In the end, she abandoned how she initially thought about the debate. She initially thought she would tie everything together by showing how one side was wrong. But since she agreed with both sides, she needed to reframe the discussion. In this new frame, her role was to help reconcile the two arguments, which she achieved by coming up with the hydroplaning situation. These changes in frame came about, in part, because Joanna paid close attention to her students' thinking.

This suggests an explanation for why it may be hard for teachers to attend to student ideas. Students may say or do unexpected things which may challenge how a teacher frames, or wants to frame, what is happening. Sometimes, there is a heavy cognitive load associated with negotiating or changing frames (see Tannen & Wallat's (1993) study of a doctor maneuvering between three different frames during a medical examination). As we can see here in Joanna's case, it was a bit of a challenge for her to reframe the debate in light of the fact that the counterargument was not incorrect. With her expectations challenged, she did not know how to proceed.

We can also see this phenomenon of changes in frames led by a teacher's attention in Dave's second episode. Dave's attention was caught by Aisha's ideas about the moon. She was not thinking about the question in the right way. This may have contributed to a shift in how Dave framed the interaction. What Dave saw was that Aisha's idea would keep her from answering the worksheet question.

> Dave: So you know, she says it's not going to fall on the moon, she's thinking…if it's in space, there's no gravity therefore there's no gravity on the moon. So I'm just trying to get them to realize that you know, if something has mass then it, you know, exerts a gravitational force on other objects around it….The question is about an object on the moon and we haven't really talked about gravitational forces on things or exerted by things other than the earth…. I don't think that they've been exposed to the idea that as long as you have mass then you exert a gravitational force on other things that have mass... if they don't know it, then I just end up explaining it. (Interview, July 6, 2007)

Dave's attention to how inappropriate Aisha's idea was led to a shift in his framing. Aisha's thinking was problematic and Dave needed to help her. To do so, he told her about the moon. This turned into telling the right answer to the question and disregarding her ideas about gravity.

It seems that if a teacher's attention becomes focused on the wrongness of students' thinking, it may lead to frames that direct attention away from student ideas. Whereas, if a teacher's attention is primarily focused on the substance of students' thinking, irrespective of the correctness, this seems to encourage frames that in turn support teacher attention toward student ideas. These two points are worth further investigation in future studies as this may have implications for how we consider teacher training.

Implication for teaching: Create structures that support frames that include a focus on student thinking

More than knowledge, beliefs, and goals.

As I discussed in an earlier section in this chapter, whether or not Joanna, Dave, and John attended to their students' ideas depended on more than just what knowledge, beliefs, or goals they had. All three showed that they were capable of and valued attending to their students' thinking, though these abilities and values seemed to influence their teaching in intermittent ways. They just did not always use this knowledge or belief. Their attention (and the usage of those cognitive resources) depended on how they framed their interactions.

Additionally, the frames that supported attention to student ideas seemed fragile. Sometimes, subtle shifts in the conversation led to changes that directed a teacher's attention away from student thinking (e.g., see earlier discussion in this chapter about Dave's interaction with Aisha). Frames that focused attention on how correct student responses were and what terms, procedures, and algorithms students used were more common and stable. This reflects a larger pattern noted in the literature regarding teacher attention to student ideas.

There is research that suggests it is challenging and uncommon for teachers to attend to student ideas (Ball, 1993; Davis, 2001; Feldman, 2002; Gallas, 1995; Hammer, 1997; Levitt, 2001; Paley, 1986; Simmons, et al, 1999; Roth, et al, 2006). In Chapter Two, I mentioned that I had a difficult time finding many examples of teachers attending to student ideas. This was true of the data from all three cohorts in the Mod Squad Project. When I did find examples of teachers attending to student thinking, the attention seemed brief and fickle. Though I did not set out to document the limited occurrence of teachers attending to student ideas, the data from the Mod Squad Project supports the claim that attending to student ideas is uncommon. I would argue 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. A framing account may shed some light on why it is so challenging for many teachers to pay attention to student thinking.

Why would frames that support attention to student ideas be fragile? Building on the work of other researchers, I would argue that teachers are part of a system that encourages frames that direct attention away from student thinking. What can we do to help teachers regularly frame classroom conversations such that their attention is directed at their students' thinking? We need to help teachers develop structures that support other ways of framing classroom activities so teachers' attention to student reasoning is supported. In the upcoming sections, I will provide further discussion of these two questions.

Why would frames that direct attention to student ideas be difficult to maintain?

In the episodes in Chapter Four, Dave, Joanna, and John attended to the conceptual correctness in the words their students said rather than the reasoning in their statements. Attending to correctness does not automatically preclude attending to student thinking. If one uses the practice of science (e.g., evaluating claims about data against alternatives) in making decisions about correctness, examination of student ideas about physical phenomena is necessary. But, in these examples, evaluations of correctness were made along the lines of how well statements matched the points teachers had in mind instead of how well they met the criteria for establishing scientific arguments.[11]

Making the argument that teachers usually focus on correctness in this way is not new. Others have argued that teachers exist in a system that encourages this fairly limited view of correctness (see Levin, 2008; Roth, et al, 2006; Tang, Coffey, Elby, & Levin, 2010). This system includes, among many things, their districts' educational policies, the parents and students, the department and local teaching community.

For example, a biology teacher, Ms. Hawkins, in Levin's (2008) dissertation, showed she was able to attend to student reasoning. But during a debate about the evolution of long necks in the giraffe population she focused on the terms her students used instead of the meaning they may have intended. Ms. Hawkins intended to use the debate to contrast Lamarkian with Darwinian explanations of evolution and to show her students that the Darwinian view was, ultimately, the correct view.

One student, Hannah, wrote that the short-necked ancestors of giraffes evolved into long-necked giraffes because they needed long necks to survive in a changing environment (the long necks were needed to reach the food in the trees). During class, when she presented her answer, she added that the giraffes evolved by stretching their necks so they could reach the food. From these two responses, it was not wholly clear if this student was making a Lamarkian or a Darwinian argument (or possibly a mix of the two) about how the current giraffe population developed long

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[11] This was not restricted to just the data presented in this dissertation. Many of the other teachers in the Mod Squad Project (the larger project of which this dissertation is a part) were also typically focused on the correctness of student statements, rather than the ideas students articulated (see Levin, 2008 and Tang, Coffey, Elby, & Levin, 2010).

necks. Nonetheless, Ms. Hawkins attributed Darwinian ideas to Hannah even after watching the video of Hannah's muddled answer in an interview because Hannah used the right words in her answer. As Levin described in his dissertation,

> "Ms. Hawkins stated that Hannah 'had the terms' and she 'thought she was trying to say the right thing.' She admitted that she only did a cursory read of the responses before selecting them. She explained that she just 'rushed through, I flipped through them. I was like, okay, they have evolution, adapt, and I just asked them to read theirs.'" (Levin, 2008, p. 93)

Levin explained that this focus on scientific terminology was not unique to Ms. Hawkins. The biology teachers in Ms. Hawkins' school (the bio team) were expected to help students prepare well for their biology high school assessments (biology HSA). The bio team coordinated their efforts to help students through the production of a common curriculum and unit tests, discussion of anticipated misconceptions and problems, and sharing of pedagogical strategies. The predominant goal of the bio team's work was to improve the scores on the HSA's.[12] The teachers purposefully designed unit test items to match the format and focus of the biology HSA. "Although some of the items on the (HSA's) require more extensive reasoning, many of the items are fundamentally dependent on students remembering vocabulary terms and associating them with particular concepts (as well as) recognize(ing) examples of it" (Levin, 2008, p. 112). Both the HSA's and the practices of the bio team reinforced attention to vocabulary use.

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[12] At the time, students' scores on the HSA's were used to determine the school's annual yearly progress (AYP) rating, in accordance with the No Child Left Behind Act of 2001. A school's AYP rating helped determine the level of some of federal funds the school received.

Institutional priorities that privilege canonical answers over student ideas can draw teachers' attention away from student thinking. Though their influence may be strong, as the examples in this dissertation show, it may not always be constant. Instead, they seem to work in a locally situated, dynamic way to help teachers frame their interactions with their students. The rarity of frames that support teachers' attention to student ideas may be because the system overwhelmingly promotes frames that direct attention to things besides student ideas. Occasionally, supports for framing classroom interactions about student thinking move to the fore and play a more prominent role in a teacher's work.

Helping teachers regularly frame classroom conversations such that their attention is directed at their students' thinking.

If we are to take attending to student ideas seriously, there are implications for teacher education, teacher professional development, and schooling practice. In this next section, I will discuss some of these implications.

Schooling practice: Changing institutional priorities by changing what and how we assess science learning.

Currently, school science, at least in the U.S. school systems, is largely about the dissemination or reproduction of canonical science ideas and the enactment of technical procedures rather than theoretically grounded explorations about ideas and phenomena (Roth, et al, 2006; Windschitl, 2004). While many would agree making sense of ideas and engaging students in the disciplinary practices of scientific inquiry are important, these are fairly low on the priority list. This may be part of the reason why attention to student ideas is rare. A reordering of our institutional priorities such that the doing of science is the way in which the learning of science occurs may help promote frames that draw teachers' attention to student ideas.

Doing science is more than a recitation of correct terms or phrases, such as independent and dependent variables. As many teachers know, students can sometimes mask lack of understanding with scientific-sounding statements. It is also more than following a specific number and order of steps, such as the "scientific method" which is commonly taught in science classrooms across the United States (Rudolph, 2005). Doing science is developing mechanistic explanations for physical phenomena (Hutchison, 2008; Russ, Scherr, Hammer, & Mikeska, 2008). It is also engaging in the process of scientific argumentation, where methodological choices and analysis of data are rooted in the need to address the concerns of one's peers in science rather than because the teacher (or the textbook) said so (Ford, 2008; Tang, Coffey, Elby, Levin, 2010). Making this the focus of science education may help to promote student ideas in science classrooms more.

Common summative assessments of their science learning contribute to this sense of school science (see previous discussion of Ms. Hawkin's lesson from Levin, Hammer, & Coffey's (2009) article). Teachers feel beholden to those exams and teach to ensure students will succeed on those exams. An alternate approach to our current assessment practices can be one way to establish a new ordering of our priorities. Our summative assessments, such as district-mandated subject matter exams, often communicate what is important for students to learn. With our current assessment tools, it has become more important for students to articulate the right ideas with the correct terminology than to develop sound explanations for phenomena that can address competing claims. Sophisticated ideas that do not follow expected forms or do not use appropriate terms are often penalized. Correctness, as discussed earlier, is typically determined by external authorities and not by students engaging in disciplinary practices of science. Instead, assessments concerned with identifying student reasoning and student participation in scientific inquiry may emphasize a need for attending to the substance of student ideas.

Teacher Education and Teacher Professional Development.

Attending to student thinking depends on more than just what beliefs or abilities a teacher has. It may be short-sighted to design teacher education or professional development programs as if changing teachers' beliefs and abilities were the only thing of consequence. Teachers need more than that to support attention to student ideas. We need to help teachers develop professional structures that encourage frames that entail the use of those resources.

There are examples of professional development activities that help teachers cultivate a professional focus on student reasoning in the subject matter, such as lesson studies and video clubs (see Lewis, 2002; Sherin, 2000). These programs provide teachers with the opportunity to engage in the practice of sharing videos or documents from class to examine their students' thinking. Others, like the Cognitively Guided Instruction model or the book, *Seeing the science in children's thinking: Case studies of student inquiry in physical science,* provide teachers with rich examples of student ideas (Fenema, Carpenter, & Franke, 1992; Hammer & van Zee, 2006). Here, teachers have a chance to practice diagnosing student ideas and to develop a pedagogy that is responsive to and informed by student thinking. These kinds of professional conversations can help create a purpose for and a way to maintain attention to student thinking.

In teacher education, there are fewer examples of how to help new teachers attend to student ideas. There is still debate about what novice teachers need to learn — whether or not novice teachers are developmentally ready for more theoretically challenging work, such as attending to student ideas. Stage-based developmental models that ignore the influence of context on development have been challenged both in the fields of cognitive science and education. Unfortunately, this kind of thinking still holds much sway in how we consider teacher education.

For example, Kagan (1992b) argued that novice teachers are at a developmental stage where they need to develop their self-conception as teachers and their routines for managing a smoothly run class first. At this stage, they are not able to do much else effectively. She calls on teacher educators to help novice teachers reflect on their experiences as students and to examine the incorrect beliefs they may have about students and learning. By exposing and creating cognitive dissonance, teacher educators can help novice teachers replace their incorrect ideas and (re)construct their images of themselves as teachers. Once novice teachers get past this stage, they can focus on deeper issues of teaching, such as attending to student thinking. If they are not past this stage, helping them explore the weightier aspects of teaching and learning is, at best, foolhardy and, at worst, detrimental to their development.

Accounts like Kagan's (1992b) are rooted in unitary assumptions about teacher cognition. In short, each teacher has a coherent system of knowledge and beliefs that dictates what they do and how they think (for a deeper discussion see Chapter One). Unless unproductive beliefs or self-conceptions are exposed and replaced, they will continue to impact a teacher's practice. Once they are effectively replaced, errant ideas associated with a teacher's work do not return.

This approach ignores the interplay between the teacher (and the teacher's cognition) and the situation. In this dissertation, even the new teachers Dave and Joanna had many resources for helping them think about teaching, learning, and science — some quite sophisticated and some not so much. Which cognitive resources they drew upon depended on the local dynamics of the situation in which they found themselves.

The local dynamics can be influenced by larger external structures. The Mod Squad Project, in which Dave, Joanna, and John participated, provided professional development to help teachers diagnose and be responsive to their students' thinking. The biweekly academic year cohort meetings functioned much like video clubs (see Sherin, 2000). The Mod Squad Project likely had an impact on these teachers' attention to student reasoning. For example, Dave mentioned to the cohort, when I tape his lessons, he tries to get his students to talk more about their ideas so it can be captured on video.

Other challengers to the stage-based models of teacher development present evidence that novice teachers are able to move past the surface concerns of teaching to the more challenging and critical issues of student learning if given the proper support. Teacher education or mentoring programs designed to help novices focus on their students' learning seemed productive toward this end (Athanases & Achinstein, 2003; Grossman, 1992). Though novice teachers still grapple with issues of classroom management, they were also able to wrestle with issues of teaching and learning with respect to their own students (Hughes, 2006; Levin, Hammer, & Coffey, 2009). Next, I will discuss two suggestions for how we can reorient our work in teacher education, one from Levin, Hammer, and Coffey (2009) and one that emerges as an implication of this dissertation's work.

Levin, Hammer, and Coffey's (2009) findings indicate science pedagogy courses with a strong emphasis on understanding the substance of student reasoning help preservice teachers regarding attention to student thinking as a critical element of science teaching practice. Levin taught the science pedagogy seminars to the graduate-level teaching candidates in this study. In the seminars, which ran prior and concurrent to the teaching candidates' teaching placements, the candidates analyzed records of practice for evidence of student thinking. They used both existing examples as well as examples the candidates collected themselves. The candidates also generated case studies from their classes. They were expected to use a video and associated transcript in at least one of their case studies. Eight out of nine teachers in the study showed varying degrees of attention to student ideas. Two of the teachers considered attention to student reasoning a core aspect of their teaching work and attributed this to their science pedagogy seminars. The need to gather evidence of student thinking for their seminar assignments, the authors argued, contributed to the candidates' framing of classroom activities such that attention to student ideas was important. Making attention to student ideas a core focus of the teacher training program seems to support novice teachers' attention to student reasoning.

Levin, Hammer, and Coffey (2009) suggested the candidates' teaching placement supervision also contributed to how these candidates framed their work with their students. Levin, in addition to being the seminar instructor, shared supervisory duty of all the teaching candidates with another colleague. The follow-up conversations he conducted emphasized the student thinking that was evident in the observed lessons. However, there is not much detail presented here about the supervisory work.

This dissertation has implications for how teacher educators supervise or mentor novice teachers. All three teachers in this study showed evidence of attending to student ideas. But that attention was episodic. In other words, the attention the teacher paid to student thinking was not constant. Shifts in the teacher's attention were closely associated with shifts in framing of interactions. In Dave's and Joanna's lessons for this study, both were able to focus attention on their students' ideas for large portions of their respective classes. But there were moments where their framing of what was going on encouraged attention away from those ideas. As supervisors or mentors, we need to help novice teachers become aware of student ideas and help them frame interactions such that their attention is focused on student thinking in science. This may mean supervisors and mentors need to look closely at what happens in the classroom to identify how events conspire to draw attention to or away from student ideas. In particular, we may need to help novice teachers be concerned with not only how they are framing matters but how their students frame the work they do in their science class.

Currently, there are not many tools available for helping supervisors or mentors do this kind of fine-grained work with their supervisees (let alone the time to do it). More often than not, a novice teacher is assessed as a whole with instances from classroom practice that exemplify the most common or outstanding feature of that teacher's teaching.

One commonly used tool is the Reformed Teaching Observation Protocol, or RTOP (http://physicsed.buffalostate.edu/AZTEC/RTOP/RTOP_full/). The developers of this protocol explain, "The Reformed Teaching Observation Protocol (RTOP) was developed as an observation instrument to provide a standardized means for detecting the degree to which K-20 classroom instruction in mathematics or science is reformed" (para. 1). Observers typically use this protocol to evaluate a teacher's entire lesson along several dimensions (Lesson Design and Implementation; Propositional Pedagogic Knowledge; Procedural Pedagogic Knowledge; Communicative Interactions; Student/Teacher Relationships). The utility of such evaluation tools is that they are a somewhat more standardized and efficient way of capturing an overall impression of the teacher's work along these dimensions. Much of the focus is on the teacher's work and not on drawing attention to the student thinking.

The difficulty with looking at an "average" lesson, or even across an activity within the lesson, such as the warm-up, is that we would miss the opportunity to talk with Joanna and Dave about the moments in their lessons where their attentions were directed away from student ideas. In each of their lessons, for the most part, Dave and Joanna attended closely to their students' thinking. As teacher educators, we need a way that can help us work with novice teachers to see and analyze the moments when a teacher does or does not attend to student thinking. Helping teachers look at how their students frame interactions may provide a way to do that.

Looking at their own work in a detailed way may help new teachers develop a more reflective practice. By analyzing their framing of interactions and shifts in how they frame, teachers can reflect on how a conversation unfolds. They also can examine how their frames impact their thinking about teaching, learning, and what is going on, as well as what their students do in science class.

Concluding thoughts.

Framing theory can be useful for research on teaching practice and for the more practical work of helping teachers change their teaching practice. In terms of research, it seems able to account for the variability in a teacher's teaching that other models could not sufficiently explain. It provides a theoretical model that situates teacher cognition in the local dynamics of classroom interactions. In terms of professional development and teacher education, a focus on teacher framing may help draw teacher educators' attention to the kinds of supports and environmental features that may encourage the use or development of specific frames that focus attention on student thinking.

Appendices

Appendix A

Video-stimulated recall interview questions

1) What you notice in what your students said or did?
2) Why do you think your students said or did that?
3) Do you recall what you thought that day or in that moment we just watched?
4) What were you doing in the video?
5) Why did you do what you did in the video?

Appendix B

Galileo Questions Worksheet

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1. A bowling ball and a small rock are dropped at the same time from the same height. Which one lands first? Here is a student's answer:

STUDENT: "They land at the same time. If there were no air, the bowling ball would land first. But air resistance slows the bowling ball down, so they land together."

Do you agree with the student's reasoning? Disagree? Explain.

2. A bowling ball and a small rock are dropped from the same height at the same time. Which one lands first if this experiment is done

(a) on the Earth?

(b) on the Moon (which has no air)?

Be sure to explain your reasoning and to answer both (a) and (b).

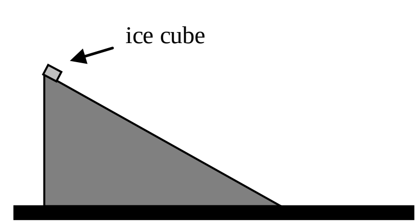
3. To escape a burning building, a father drops his baby out the second-floor window, and at the same moment, the father lets himself fall out the window. They both land in a padded "person catcher" set up underneath the window by firefighters. Who, if either, lands first: the baby or the father? Explain your reasoning.

4. Two identical plastic soda bottles, one of them full of soda and the other completely empty, are dropped from the roof of this school at the same time. A student, when asked which object lands first, answers as follows:

STUDENT: "We learned from those Galileo experiments that objects of different mass all fall at the same rate. So the full and empty bottle land at the same time."

Do you agree? Disagree? Explain your reasoning.

5. A slippery ice cube is released from rest from the top of the ramp shown here. It slides without friction and reaches the bottom in one second.



Then, a bigger, heavier ice cube is released from rest from the top, and slides without friction. Does it reach the bottom in less than a second? Exactly one second? More than one second? Explain your reasoning.

Appendix C

Heidi Rudyard
Science – Lesson 1 – Thinking about Sound
Third-grade

Time:
35 - 40 minutes

Objectives:
The students will:

- Share their ideas and questions about sound
- Investigate and describe sounds produced by tuning forks

Rationale:
This lesson is an introduction to sound. It provides a way for students to discuss what they know about sound and to ask questions about sound that they would like to explore throughout the unit. In this lesson, the students will work with two different-sized tuning forks, which produce noticeably different pitches.

Materials Needed:
For every student:
1 handout of "Tips on Using a Tuning Fork," pg. 16 in teacher's guide

For every three – four students:
1 large tuning fork
1 small tuning fork

For the class:
2 sheets of chart paper
1 marker
1 transparency of "Tips on Using a Tuning Fork," pg. 16 in teacher's guide

Teacher Preparation:

- Divide class into groups of three to four
- Handouts and transparency of "Tips on Using a Tuning Fork,"
- KWL chart
- Chart with questions to discuss with group (How were the sounds of the tuning forks alike? How were they different? How would you describe the sound of the small tuning fork? The large one? What did the tuning forks feel like when they were making a sound?)
- Read the "Tips on Using a Tuning Fork," pg. 16, and experiment with tuning fork

Lesson Procedure:

1. Have students come to the carpet and tell them the next science unit is about sound. **1 min.**
   <u>Tell:</u> *I would like everyone to quietly come to the carpet. Our next science unit that we will be learning is about sound. Before we begin, I want to know what you all know about sound, and what you would like to learn about sound over the next few weeks.*

2. Show them the KWL chart and have them brainstorm what they <u>k</u>now about sound. These can be words, phrases, or terms.
   3 min.
   <u>Tell:</u> *First, I want you to tell me everything that you know about sound.*
   <u>Ask:</u> *What are some different sounds that you've heard? How do you think those sounds were made? What are some words that you connect with the word "sound"?*

3. Have students brainstorm what they want to learn about sound.
   3 min.
   <u>Tell:</u> *Now, I want you to tell me what you want to learn about sound.*
   <u>Ask:</u> *What questions do you have about sound? What ideas would you like to explore about sound? What would you like to learn about sound?*
   <u>Tell</u>: *I would like to learn how the same instrument makes different sounds. We may be able to explore some of these questions over the next few weeks.*

4. Show the students the two different-sized tuning forks.
   3 min.
   <u>Tell:</u> *These are two different-sized tuning forks. You will be working with a partner in a small group to investigate the characteristics of tuning forks, but first we need to review the tips on using a tuning fork.* (Pass out handout)

5. Read and show students "Tips on Using a Tuning Fork"
   3 min.
   <u>Stress importance of:</u> *1) absolute quiet (seat work, if not quiet), 2) holding tuning fork by stem, and 3) not hitting anyone or anything hard with tuning fork (will be sent to seat)*

6. Tell students their group and where to go in the room, once dismissed from carpet. **1 min.**
   (Student names have been deleted)

Cubbie 1	Cubbie 2	Back Wall	Rdng Crnr	Frnt Rm (lft)	Frnt Rm (rt)
XXX	XXX	XXX	XXX	XXX	XXX
XXX	XXX	XXX	XXX	XXX	XXX
XXX	XXX	XXX	XXX	XXX	XXX
XXX	XXX	XXX	XXX	XXX	

7. Give two students from each group a different-sized tuning fork. Explain that they need to get into pairs in their group, because they will need to share the two sizes. Each pair will have a chance to work with both sizes. Have students go to their areas. **1 min.**

   Tell: *I am going to give a large tuning fork to one person in your group, and a small tuning fork to another person in your group. You will need to get into pairs in your groups, because you will need to share the two sizes. Each pair will have about 5 minutes to work with each size.* Reminder: *Must be quiet, and no hitting tuning fork on anyone else or anything hard!! Now you can go to your group's area.*

8. Have each pair experiment with their tuning fork. Switch tuning forks within the group after 5 min.

   10 min.

   Tell: *The first pair has 5 minutes to experiment with their tuning fork.* (set timer, and repeat for second tuning fork)

9. Have students discuss with their group the sound they made with the tuning forks. (Post chart with questions.)

   5 min.

   Tell: *Now, I want you to talk with your groups about the following questions* (read chart).

10. Have handy helpers collect tuning forks. Have each group come to the carpet once tuning forks are collected. Discuss their answers to the questions.

    7 min.

    Tell: *I would like the handy helpers to collect the tuning forks from each group. Once your group has given a handy helper your tuning forks, then you can come to the carpet.*

    Ask: *What answers did you and your group discuss for the questions?* (refer to chart)

    Can we add anything to our KWL chart? What did we learn today?

Assessment:

My assessment will be a formative assessment based on informal observations. Since this is their first lesson on sound, I want to know how much the class already knows about sound, so I will use the KWL chart to see where I need to focus the unit. Also, I will use their answers to the tuning fork questions and their additions to the KWL chart to see how much they learned about sound in this lesson.

Appendix D

Dave and his class

At the time of the episodes presented in this study, Dave was in his second year of teaching and the first year of his participation in this study. As an undergraduate, Dave majored in physics and philosophy. He chose the physics education track of the major, which included requirements that helped prepare him for teaching. As a philosophy major, he took a variety of courses related to epistemology, metaphysics, ethical theory, and the history of philosophy. After he graduated from his undergraduate program, he entered into a Certification/Master's program, sponsored by a partnership between his university and the public school system of a local county. Through this program, Dave was able to teach full time while working towards certification (in physics) and a M.Ed. in science curriculum and instruction. While in this program, he and Joanna (discussed below) both took the same science pedagogy courses, which took attention to student thinking as its central mission in preparing science teachers.

Dave's class, which had a majority of African-American students and several students that did not speak English as a first language, was in a school system that served a predominantly middle-class African American school district. This school district was located in an urban fringe of a major Mid-Atlantic metropolitan area. I observed Dave teaching the general conceptual physics course for ninth graders. Dave regularly commented at cohort meetings that he was interested in trying new things in his class. His district did not have a mandated curriculum for the ninth grade physics course. As a result, he felt freedom to make his own curricular choices.

Joanna and her class

At the time of the episodes presented in this study, Joanna was in her second year of teaching and in the first year of her participation in this study. In the previous year, she had just obtained her Masters of Education in Chemistry and Physics at the same institution as Dave but in a different program. As mentioned above, though they were in different programs, they were in the same sequence of science pedagogy courses and knew each other prior to the project. Prior to her entry into the teaching field, she worked as an environmental engineer in the army for four years on Active Duty where she attained the rank of Captain. In addition to her masters, she also had a BSE in Chemical Engineering with a minor in Engineering Biology.

Joanna's class was a socially and economically mixed class located in a school that served a predominantly affluent suburban neighborhood located outside of a major Mid-Atlantic metropolitan area. I observed Joanna's teaching in the 9th grade general physical science course called "Matter and Energy". In the first half of the year, students studied topics in physics. In the second half of the year, students studied topics in chemistry.

John and his class

At the time of the episodes presented in this study, John was in his eighth year of teaching and his second year of participation in the project. Also at the time, he was in the process of applying for his National Board certification and taped himself several times. In the following year, he received his certification.

As an undergraduate, John majored in biology. Then he went on to obtain his masters in science education, with an emphasis on biology education. John taught at his current school for his entire career. During this time, he taught Matter and Energy (the course that the data for this study is from), Honors Biology, and Anatomy and Physiology. In addition to teaching at the high school level, he also taught college level Environmental Biology and Microbiology at local institutions of higher education. Though his specialty was Biology, John taught the Matter and Energy course for all of the eight years he was at this school and gained a much experience and subject-matter knowledge with regards to teaching the topics in Matter and Energy.

John's school was an ethnically and socially diverse school located on the urban fringe of a major Mid-Atlantic metropolitan area (in the same county as Joanna's school). In addition to running a program that served the local student population, the school also had a magnet program that drew from all over the county.

John's students were in the program for local students and not the magnet program. These students were mostly 10^{th} graders who were labeled by the school (and the district) as reading far below grade level and in need of remediation. Students classified as such were grouped together into a program aimed at helping them develop their reading skills. Though this was nominally the same course as the one Joanna taught (Matter & Energy), there were different expectations for these students and the course. These students were rarely expected to perform at the same academic level as other students of the same grade level in this school. This was partly because of their histories of low academic achievement and partly because of the prevalent problem of absenteeism among these students. In his interviews, John had commented that, as their teacher, he was more focused on helping them develop their critical thinking skills in the context of science rather than on making sure the entire M&E curriculum was covered.

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