Exploring Resources for Responsiveness to Student Thinking in Practice

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Abstract

Supporting teachers' attention and responsiveness to the substance of student thinking is increasingly emphasized across disciplines. Yet studies demonstrate how such responsiveness, in practice, is highly contextualized and often fleeting. This study conceptualizes and examines what functioned as "resources for responsiveness" within and across nine sustained cases of responsiveness in three science teachers' inquiry-oriented classrooms. Analyses demonstrated how a diverse range of personal, social, and material/structural resources facilitated teachers' responsiveness, with some commonalities but also much variation across teachers. These findings contribute to the field's understanding of what may support teachers' attention and responsiveness to student thinking and suggest the importance of a) responsiveness in the design and facilitation of professional learning and b) increased attention to teachers' affect.

Keywords: Instructional Practices, Professional Development, Resources, Responsiveness to Student Thinking, Science Education

Exploring Resources for Responsiveness to Student Thinking in Practice

Across disciplines, supporting teachers' attention and responsiveness to student thinking is an increasingly central focus (e.g., Kavanagh et al., 2020; Lampert et al., 2013; Richards & Robertson, 2016; Watkins et al., 2018). Attending and being responsive to the substance of student thinking involves focusing on the meaning students make in disciplinary contexts, including varied intellectual and experiential resources they bring to bear (Ball, 1993; Rosebery et al., 2016), and pursuing students' contributions in classroom talk and action (Empson & Jacobs, 2008; Hammer et al., 2012). Centering students' contributions has numerous documented benefits for student learning, including but not limited to supporting deeper conceptual understanding (e.g., Radoff et al., 2018), engagement in productive disciplinary activity (e.g., Engle & Conant, 2002; Haverly et al., 2020), and at times broadened forms of disciplinary activity (e.g., Rosebery et al., 2010). In science education, the context for the present study, foregrounding students' contributions is part of the fabric of current K-12 reform efforts (NRC, 2012).

However, centering and responsively building from students' contributions is challenging work, and K-12 classrooms in the United States rarely foreground student thinking in this way (e.g., Thompson et al., 2016; Weiss et al., 2003). While professional learning (PL) efforts have shown some successes with novice and experienced teachers (discussed further in the next section), they have also documented the deeply contextualized and often fleeting nature of responsiveness within teachers' situated classroom practices (Levin et al., 2009; Richards et al., 2020; Sherin & van Es, 2009; Stroupe, 2016). Such findings raise open questions about why responsiveness occurs

when it does in classroom settings—what sparks and supports teachers' focus on student thinking?

The present study speaks to these questions by exploring resources (Cohen et al., 2003) that facilitated teachers' attention and responsiveness to student thinking—what I frame as *resources for responsiveness*—within and across nine sustained cases of responsiveness from three teachers' science classrooms. Cohen et al. (2003) highlighted how classroom instruction can be understood through exploring the impacts and interplays of multiple types of resources, including "personal" resources like a teacher's knowledge or goals, "social" resources from others, and more "conventional" resources like books or time. I draw on this perspective to illuminate varied resources in play within sustained responsive classroom interactions and consider implications for supporting teacher learning.

To illustrate with a partial example, consider the following from Ms. L's[1] fifth-grade science class. The class was considering a student's question of whether magnets can work underwater in service of elevating key ideas about forces for a statewide standardized test the following week. Ms. L initially attempted to bound the lesson to testing the scenario and drawing connections to forces. Yet as discussion unfolded among students, including deeper considerations of why magnetism would or would not work underwater, Ms. L took up and pursued these ideas with students over the course of a twelve-minute discussion. In moments, she started to shift back toward her original plan, but ultimately, she prioritized students' contributions ("So here's the procedure- did you have a comment?") and acknowledged in the moment how students were "excited about

[1] All study participants' names are pseudonyms.

this." Upon reflection, *student investment* was particularly salient to Ms. L—when she watched video of the lesson during an interview, she exclaimed, "They were so into this!" four separate times. Further, student investment seemed to drive her responsiveness; when reminded of the original bounded plan, Ms. L replied, "Just, it just ballooned. ((laughs)) Yeah, it did. Yeah, because they were obviously so into it that it was like unavoidable, you know?" In other words, student investment seemed to function as a *social resource for responsiveness* in practice in this case, among other resources.

In what follows, I argue that analyses of sustained cases of responsiveness in practice can yield novel insights into resources for responsiveness. Further, cross-case analysis demonstrates both commonalities and, importantly, variations within and across teachers in terms of resources for responsiveness. This study expands understandings of the types of resources and interplays among them that may support teachers' attention and responsiveness to the substance of student thinking and points to the importance of teacher educators' responsiveness in the design and facilitation of PL, given the rich variability evident across teachers in this study.

Cultivating Attention and Responsiveness to Student Thinking

Facilitating teachers' attention and responsiveness to student thinking is a growing emphasis of PL efforts (e.g., Kavanagh et al., 2020; Robertson et al., 2016). Multiple approaches have demonstrated successes in focusing teachers on student thinking in PL settings and, to an extent, in their classrooms. For instance, collaborative analysis of student work and/or classroom video has been shown to deepen teachers' attention to and interpretation of students' ideas, as well as connections between student contributions and teachers' instructional moves (e.g., Barnhart & van Es, 2018; Franke et

al., 1998; Sun & van Es, 2015). Other generative approaches to supporting attention and responsiveness to student thinking include inviting teachers to experience responsive environments themselves from the perspective of a learner (e.g., Hammer et al., 2012); exploring diverse sense-making repertoires within historically non-dominant communities (e.g., Rosebery et al., 2016); and/or engaging teachers in lesson study (e.g., Guner & Akyuz, 2020) or practice-based approaches like approximations (e.g., Kavanagh et al., 2020).

Variable Impacts on Classroom Practice

Yet studies of participating teachers' classroom practice often show variable impacts, with some teachers coming to foreground student thinking in their classrooms and others not (Barnhart & van Es, 2018; Franke et al., 1998; Haverly et al., 2020; Levin et al., 2009; Stroupe, 2016; Thompson et al., 2013). Contrasting teacher cases have provided important insights into what may shape responsiveness to student thinking in practice. For example, Thompson et al. analyzed novice science teachers' practices and reasoning as they participated in a university teacher preparation program that promoted ambitious teaching, including an emphasis on being responsive to student thinking. Eleven novices worked with student thinking in their classrooms, whereas eight novices appropriated language from the program but focused on correcting wrong answers in practice. The researchers conceptualized and accounted for differences in novice teachers' practices as being shaped by both a) teachers' personal ways of thinking about teaching and learning and b) varied social and institutional influences, with school settings in the study elevating priorities like regimented pacing that drew attention away from students' ideas. Other studies show similar interplays between teachers' personal

theories or goals and priorities within the settings and systems in which they work (e.g., Barnhart & van Es, 2018; Stroupe, 2016).

Further, studies of responsiveness in practice have highlighted how even for a given teacher, responsiveness to student thinking can be "episodic" (Levin et al., 2009, p. 147) and shift on quick timescales (Richards et al., 2020; Sherin & van Es, 2009). For instance, Sherin and van Es examined connections between what teachers did in video clubs focused on noticing students' mathematical thinking and how they interacted with students' contributions while teaching. While teachers increasingly took up students' mathematical ideas while teaching, there were times when they did not do so:

> Also of interest is the case of Linda. Late in the year, we observed several instances in which Linda investigated the meaning of her students' ideas and methods. Yet within the same lessons, there were also moments in which Linda did not attend to students' comments and made no attempt to reason about what her students were thinking (Sherin & van Es, 2009, p. 31).

Here, Linda could attend and respond to student thinking while teaching but demonstrated variability within a given lesson. Studies exploring these quicker shifts in responsiveness highlight similar constructs as in contrasting teacher cases in interplay with interactional dynamics within classrooms (e.g., Richards et al., 2020).

The present study builds on and adds to the above lines of work by conceptualizing and unpacking *resources for responsiveness* (described next) in sustained classroom cases of responsiveness to student thinking, across teachers in a professional development (PD) program that drew on multiple of the approaches described above. While contrasting cases have provided generative insights into what may support or

detract from responsiveness, deeper investigation across multiple examples of the phenomenon of interest can provide additional support for, further specify, or complicate existing understandings. For instance, examining sustained cases within and across teachers can illuminate both commonalities and variations in what may support responsiveness. Variation in what supports responsiveness across teachers has not yet been a concerted focus of study, though understanding varied ways into responsiveness could productively shape the design of PL opportunities.

Conceptualizing Responsiveness to Student Thinking in Practice

Building on insights from the studies above, I conceptualize responsiveness to student thinking in practice from a situative perspective (Greeno & Gresalfi, 2008), emergent from what a given teacher brings to bear and what a given environment affords. Some scholars have theorized teacher and environmental contributions as different types of *resources* that can impact classroom instruction (Cohen et al., 2003; Haverly et al., 2020; Lampert et al., 2011; Stroupe, 2016). For instance, Cohen et al. argued for a broader theorization of resources in and for instruction that expands beyond "conventional" resources to "personal" and "social" resources contributed by varied actors within the educational ecosystem. In turn, they called for expanding research on resource use in instructional contexts, including consideration of what resources facilitate or inhibit particular forms of teaching and learning.

In this study, I drew on this perspective to ask two questions: 1) What resources facilitated teachers' attention and responsiveness to student thinking while teaching? 2) What commonalities and variations were there among teachers? Building on

conceptualizations from Cohen et al. (2003) and others, I focused on the following types of resources in use:

- *Personal resources*: The teacher's aims, knowledge, experiences, etc.
- *Social resources*: Contributions from participants other than the teacher; may include students' ideas (Stroupe, 2016), collegial interactions, etc.
- *Material/structural resources*: Like "conventional" (Cohen et al., 2003); may include physical objects, classroom routines, etc.

Further, I attended to how varied resources worked together (Lampert et al., 2011) as they played out within and across sustained responsive interactions.

Research Design

To analyze *resources for responsiveness* in practice, I employed a collective case study design (Merriam, 2009; Yin, 2006). A case was a classroom episode in which a teacher's attention and responsiveness to the substance of student thinking was sustained (defined further in Case Selection). Identifying nine cases in total, three cases from each of three partner teachers, I triangulated across multiple data sources (see Data Collection) to analyze the resources that facilitated teachers' attention and responsiveness to students' ideas (see Analytical Approach).

Study Context

Data come from a multi-year PD partnership between a university and school district in the United States aimed at promoting student inquiry in fourth through eighth grade science classrooms (see Elby et al., 2013 and Appendix A for fuller descriptions). We positioned attending and being responsive to students' ideas and questions about scientific phenomena as central to enacting inquiry in classrooms, and we engaged

teachers in numerous PD activities in line with the approaches described above. Through summer workshops, teachers engaged in inquiry as learners, in which we as PD facilitators/researchers were responsive to their ideas and questions to provide concrete experiences of what this might look and feel like. We also analyzed videos of students' science inquiry with an emphasis on student thinking, and we co-planned inquiry-oriented instruction. In co-planning, we aimed to be responsive to the goals and needs of individual teachers, sometimes digging into specific science content, and other times planning classroom routines and questioning. During the school years, we held regular small group meetings of teachers and PD facilitators/researchers in which we reflected on work and classroom videos from teachers' classrooms, again focusing on student thinking and possible next steps. These meetings were also sites for collaboration around teachers' ideas and questions and further co-planning. Finally, PD facilitators/researchers provided direct support in teachers' classrooms as desired and negotiated with individual teachers, which ranged from being an extra set of ears to co-facilitating classroom inquiry.

For this study, I partnered with three teachers (Ms. L, Ms. R, and Mr. S) from different schools and grade levels (grades 5-7). These teachers were identified by the PD team as regularly facilitating rich science discussions in their classrooms that centered students' contributions during their first two years in the partnership. All three teachers had at least five years of teaching experience but did not report experience with science inquiry discussions prior to their participation in the project. Ms. R and Mr. S taught in Title I schools, and all taught in settings with emphases on curricular coverage and test preparation among administrators and colleagues, known to constrain responsiveness to student thinking (Levin et al., 2009).

Data Collection

Multiple sources of data were collected and drawn on in this study. As part of the broader PD and research effort, we videorecorded teachers' classroom inquiry lessons, planning and debrief sessions with PD facilitators/researchers, and small group meetings. Additionally, I conducted videotaped semi-structured stimulated recall/reflection interviews (Lyle, 2003) with partner teachers. In these interviews, we watched and discussed the selected classroom cases together, with either party pausing the video periodically to discuss what was going on, what stood out to the teacher, and/or claims and questions stemming from my preliminary case analyses. I also invited written feedback on case analyses, which I received from Ms. L. This design afforded triangulation on classroom cases across multiple data sources and perspectives, including member checks with partner teachers (Creswell, 2007).

Case Selection

From between 12-20 videorecorded inquiry lessons per partner teacher, I selected three cases to analyze based on several criteria. To count as "sustained" attention and responsiveness to student thinking, a case had to a) be extended in duration (ten minutes or longer), and b) demonstrate responsiveness to students' ideas in the majority (over 50%) of the teacher's speech turns. I assessed the latter by transcribing the classroom conversation and coding whether and how each speech turn from the teacher connected to ideas shared by students, such as pressing for elaboration, or identifying differences across ideas (e.g., Brodie, 2011; Lau, 2010; Pierson, 2008). The full set of discursive markers of responsiveness is included in Table B1 in Appendix B. Additionally, cases

were limited to larger group discussions, as these discussions were consistently accessible across the video corpus.

I also considered whether there was evidence of the teacher reflecting on the case proximal to when it occurred; while this was not a criterion for sustained responsiveness, it was a way to maximize insight. I then selected the earliest case that fit these parameters from each teacher's classroom and two other cases that included instructional routines or tools each teacher commonly used to explore their impact on responsiveness. Appendix C briefly describes the focus and context of each selected case, and Appendix B includes which discursive markers were present in each case (Table B2) and a summary of these markers across cases.

Analytical Approach

To address the first research question about resources that facilitated teachers' attention and responsiveness to student thinking while teaching, for each case I initially built claims about potential resources from the classroom video itself. To do so, I drew on notions of consequentiality and tools from discourse and interaction analysis (Jordan & Henderson, 1995; Stivers & Sidnell, 2005) to examine a) what co-occurred with and plausibly reinforced the teacher's focus on students' ideas and b) what seemed salient to the teacher. *Co-occurrence* means that a potential resource was co-present with or preceded a shift into responsiveness to student thinking, using temporal organization as a means for understanding what was consequential in the classroom interaction. *Salience* means that a potential resource seemed significant to the teacher, based on multimodal cues like repeated reference to a potential resource and/or heightened affect in relation to it in the classroom video (i.e., elevated pitch, raised eyebrows, etc.).

I then iterated with other triangulating data sources to further test and refine claims. In data from planning and debrief sessions, small group meetings, and interviews, I attended to what was salient from the teacher's perspective as described above and considered confirming and disconfirming evidence of potential resources identified in the classroom videos. Interviews and written feedback provided additional opportunities for member checks with teachers, and multiple data sources and claims about resources were discussed within the PD team (Creswell, 2007). This confluence of evidence resulted in the identification of a range of resources for responsiveness specific to each case, which I then characterized as personal, social, or material/structural in line with the conceptual framework described prior. I also attended to how identified resources clustered and seemed to function together to facilitate responsiveness within cases.

To address the second research question about commonalities and variations, I looked across cases—both within and across teachers—to explore patterns. At this stage, I distinguished resources that were recurrent across cases for a given teacher from resources that were present in only one case, to consider commonalities and variations across cases for a teacher. I then examined resource patterns across teachers to identify what was shared and what was distinct.

Findings

A variety of personal, social, and material/structural resources seemed to function as resources for responsiveness to the substance of student thinking in the analyzed cases (see Table 1 for a list of resources identified in the study, many of which are demonstrated in the cases that follow). Here, I begin by sharing high-level patterns of resources for responsiveness within and across teachers (Figure 1). I then take a deeper

dive into one illustrative case to bring examples of resources for responsiveness to life and demonstrate how they worked together. Finally, I unpack key commonalities and variations in resources for responsiveness.

Table 1

List of Identified Resources for Responsiveness to Student Thinking in the Study

Resource	Description
Personal Resources	
Comfort with material	Teacher's ease with content being discussed
Curiosity about student ideas	Teacher's desire for knowledge in response to perceived gaps (Grossnickle, 2016) in their understanding of student ideas
Curiosity about topic	Teacher's desire for knowledge in response to perceived gaps in their understanding of the science being discussed
Enjoyment of student participation	Teacher expresses enjoyment about how students participate
Frustration with student participation	Teacher expresses frustration about how students participate
Goal for students to construct or clarify causal explanations	Teacher aims for students to build cause-effect explanations for scientific phenomena (Elby et al., 2013)
Goal for students to work meaningfully with own ideas	Teacher aims for students to engage in and take their own thinking seriously

Recognition of link to desired understanding(s)	Teacher sees emergent connection to conceptual or epistemic aim(s) of lesson/unit
Social Resources	
Changes in student participation	Shifts in how specific students participate
Collegial support	Support from teachers and/or PD facilitators/researchers on planning/enactment
Student appeals to authority	Students provide textbook answers
Student disagreement	Students disagree with each other or share different ideas
Student investment	Students show overall interest in pursuing a line of inquiry (e.g., raised hands, excitement)
Student question	Question asked by a student
Material/Structural Resources	
Classroom routines/structures	Repeated epistemic/participation routines or structures in the classroom (e.g., a fishbowl discussion)
Notes on student ideas	Teacher's own written notes on students' contributions
Plan for lesson	Plan involves eliciting the student thinking observed
Shared referents	Jointly accessible objects (e.g., class records, physical set-ups)
Task from PD	Inquiry task from prior PD activities

Note. In all cases, numerous students contributing ideas functioned as a baseline social resource.

Figure 1

Resources for Responsiveness Across Cases and Teachers

Note. Green = *personal resources*; blue = *social resources*; purple = *material/structural resources*. Arrows connect resources that clustered and seemed to function together or mutually reinforce each other in more than one case; dotted arrows represent connections that plausibly recurred, but for which there is only direct evidence in one case. The figure does not represent the dynamics of all resource clusters that occurred in individual cases.

At a high level, Figure 1 demonstrates significant variation in what facilitated responsiveness across teachers. This variation is evident at multiple grain sizes—from what stood out to teachers about students' participation, for instance, to the types of resources that recurred for individual teachers. Considering types of resources, for example, *personal and social resources* were more evident and influential across cases for Ms. L, whereas responsiveness in Ms. R's and Mr. S' cases was more consistently mediated by *material/structural resources*. I will unpack some of these variations later in the findings and argue in the discussion that openness and attention to such variations is critical for supporting teacher learning.

However, Figure 1 also demonstrates important commonalities across teachers. For all teachers, shared referents recurrently functioned as *material/structural resources* for responsiveness, often mediating discussion and understanding of students' ideas. *Personal resources* of goals for students that connected to epistemic agency, with students actively contributing to the construction of meaningful knowledge (e.g., Ko & Krist, 2019)— through working meaningfully with their own ideas and/or constructing causal explanations—also recurred and were often connected with other resources in play. All teachers also showed a broader pattern of reinforcement between some aspect of student participation (*social resource*) and their own affect (*personal resource*), at times

linked with their goals for students. For Ms. L and Mr. S, this involved enjoyment of either student investment or changes in participation; for Ms. R, this took the form of frustration with respect to student appeals to authority. Finally, all teachers demonstrated curiosity about the ideas that students offered (*personal resource*). I return to these commonalities after unpacking an illustrative case from Ms. L's classroom to showcase how resources for responsiveness often functioned in tandem, reinforcing and augmenting each other and teachers' attention and responsiveness to student thinking.

An Illustrative Case: Multiple Resources for Responsiveness Working Together

In "Case 2" from Ms. L's fifth-grade classroom, the class was engaged in a review of levels of classification, using a diagram from the textbook depicting the classification of a wolf. The diagram generally explained why given organisms were still included at each level, but at one level, it simply listed the organisms included. A student, Albert, asked why one organism, the fox, was no longer included at this level:

Ms. L: Who'd we get rid of, um, Raymon?

Raymon: The fox.

Albert: Why?

Ms. L: The fox because (pause) I, and I'm not exactly sure why the foxes get dropped out at this point. That would be an interesting thing to think about, wouldn't it ((Shavonne raises hand)), because somehow the wolves and the coyotes are more closely related than the-

Shavonne: Fox.

Ms. L: Fox, yeah, so it would be interesting to see why we lose that one. You think you know, Shavonne?

Here, Albert's question (*student question, social resource*) about the diagram (*shared referent, material/structural resource*) sparked a pause and a shift from the class' prior activity. Ms. L noted that she was "not exactly sure why the foxes get dropped" and expressed twice (repetition suggestive of salience) that it would be "interesting" to figure out, suggesting a potential degree of curiosity about the topic (*personal resource*) from Ms. L that preceded opening the floor for discussion and student thinking. Further, in an interview, Ms. L explicitly recognized Albert's question as "so relevant to what we were doing… when the whole point is we were trying to figure out the reasons" (*recognition of link to desired understanding, personal resource*).

After discussing students' initial ideas for two minutes, there was a notable shift away from and then quickly back toward pursuing students' ideas:

> *Ms. L*: Um, so that might be something we want to pursue a little bit when we come-
>
> *Student*: Questions for later?
>
> *Ms. L*: Should we put it in our questions for later? ((gets the class' "questions for later" board)) Yeah, let- let's do that, and then we'll, um (pause) but I mean that, that sounds pretty interesting… so why fox is dropped (pause) from, in the genus level is what we're talking about, right? ((writes on questions for later board; students still have hands raised))
>
> *Randy*: Maybe that's just a certain type of wolf, like it is the grey wolf.
>
> *Ms. L*: ((returns questions for later board)) You know, turn to your partner and talk for a minute, if you think you see something. I mean, all we have to go on right now is their picture, so if your science book would be out, turn to your

> partner and talk to 'em a minute and see why do you think we, we lost the fox at this level?

In this exchange, Ms. L started to table further pursuit of students' ideas, adding the question to the class' "questions for later" board—a tool commonly used in Ms. L's classroom but not functioning as a resource *for* responsiveness in this case. Yet Ms. L also displayed some signs of self-negotiation (her pause followed by the "but," again noting how "interesting" the topic was, *curiosity about the topic* as a *personal resource*). Further, multiple students still had their hands up as Ms. L wrote the question on the board, and students continued discussing the question—including Randy (evident in the transcript) and Daria, who talked directly to Ms. L as she wrote on the board. The co-occurrence of these markers of *student investment* with Ms. L's continued pursuit of students' ideas suggest that student investment may have functioned as a *social resource* for responsiveness here, which Ms. L corroborated in an interview:

> *Richards*: It seemed, you know, for a minute that it was going up on the questions for later, maybe to be-
>
> *Ms. L*: Yeah, and then we, it was just too clear that everybody was really into it.

Given Ms. L's repeated indications that it would be interesting to figure out why the fox got dropped, it is likely that "everybody" included Ms. L herself (see also Richards, 2014). Further, in providing feedback on case analyses, Ms. L reiterated how much fun she has when students are invested (*enjoyment of student participation, personal resource)*: "The kids' excitement is definitely the strongest stabilizer for me… I have so much fun teaching like this when the kids are so excited."

While much more could be unpacked, this illustrative snippet provides a flavor of how varied resources for responsiveness appeared and worked together within classroom cases. Resources at times operated via mutual reinforcement and augmentation, as in the confluence here of a shared referent, a student question, Ms. L's recognition of a link to a desired understanding and curiosity about the topic, student investment, and her enjoyment of student participation. In what follows, I turn to broader cross-case patterns in more discrete types of resources, but in practice such resources were often in interplay.

Commonalities in Resources for Responsiveness Across Teachers

Several resources for responsiveness shared high-level commonalities across cases and teachers, though at times their specific manifestations differed. These included work with shared referents (*material/structural resources*) in the classroom, teachers' expansive goals for students (*personal resources*), teachers' own affect (*personal resource*) in relation to an emergent aspect of student participation (*social resource*), and teachers' curiosity (*personal resource*) with respect to the science discussions that occurred.

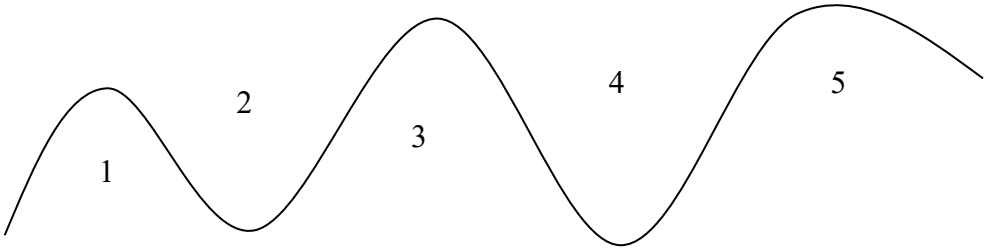
Commonality: Shared Referents

One common resource for responsiveness across cases and teachers was the use of shared referents in discussion, like the textbook diagram in the case above. Shared referents were jointly accessible to the teacher and students, such as class records, books, or physical set-ups; as such, these referents typically functioned as mediators in the pursuit of students' ideas. For instance, in the first case in Ms. R's sixth-grade class, an emergent discussion occurred when students counted different numbers of crests in the same "wave" (a jump rope on the floor, see schematic in Figure 2). Ms. R repeatedly

asked students to point out specific sections of the jump rope they referenced and used the jump rope as a tool for understanding their ideas.

Figure 2

Schematic of Jump Rope on Floor of Ms. R's Classroom



For example, one student, Gloria, stated that "the crests are at the bottom" of the rope. Ms. R pursued Gloria's line of reasoning by asking her to illustrate with the rope:

> Can you- can you clarify that for me? What do you mean? How about if you point at it so I'll know what you're talking about?... ((Gloria points at 3)) Uh-huh. ((Gloria points at 1 then 5)) So you're saying that if I'm counting these up here ((points to what Gloria just pointed to)), then I can't count these down here ((points at 2 and 4)) as crests?

In this exchange, interactions with the jump rope co-occurred with and were integral to pursuit of Gloria's definition of a crest. Shared referents such as other physical set-ups or class records served similar functions across responsive cases and across teachers.

Commonality: Goals for Students to Engage as Epistemic Agents

Another commonality was that teachers recurrently described and enacted goals that went beyond students developing specific content understandings. Such goals clustered around supporting students' epistemic agency as contributors in knowledge-building (Ko & Krist, 2019). In Figure 1, this commonality is reflected in goals of

students working meaningfully with their own ideas and engaging in knowledge-building processes like constructing and clarifying causal explanations. These goals were often salient parts of the design and motivation behind planned responsive interactions for teachers, as described in interviews. They were also implicated in emergent cases of responsiveness, like when students disagreed about what counted as a crest in Ms. R's class; Ms. R's responsiveness co-occurred with this *social resource* from students and a goal of having students "settle this" by working with their own and others' reasoning.

Commonality: Connections Between Aspects of Student Participation and Teachers' Affect

A high-level pattern that recurred across teachers, at times connected to the goals above, was that some aspect of student participation stood out to them and drew an affective response, as seen in the illustrative case from Ms. L in which her own enjoyment was entangled with student investment. I note this overall pattern here as an important commonality, but I describe the unique manifestations this pattern took by teacher when I unpack variations.

Commonality: Teachers' Curiosity

A final commonality across teachers was that they each displayed curiosity with respect to the discussions that occurred in their classrooms, arising from their attention to students' contributions and supporting continued attention and responsiveness to students' ideas. Drawing on prevalent themes in Grossnickle's (2016) literature review on curiosity within educational settings, I consider curiosity to be a desire for knowledge that motivates exploration in response to perceived gaps. For teachers in this study,

perceived gaps in their understandings of students' ideas and/or the science being discussed were co-occurrent with and motivated exploration of student thinking.

Ms. R's and Mr. S' curiosity tended to center on students' ideas directly. For instance, during a discussion of why dinosaurs became extinct in the second case in Mr. S's seventh-grade class, Mr. S engaged in an extended line of questioning with a student, Evan. This exchange, partly illustrated below, focused on Evan's idea that a meteor shower killed all the female dinosaurs:

> *Mr. S*: How did the, how did the meteor know that it was the female and not the male? How did it, how'd it differentiate?
>
> *Student*: There were-
>
> *Mr*. S: Uh uh uh uh, [Evan]'s answering. What? (4-second pause) What do you think? How did the meteor ((smiles)) decide that just the females, how did- why did the females die and not the males?

Notable here is Mr. S' affect toward Evan's idea—smiling as he questioned Evan, being a bit playful with the wording of his question (how did the meteor "know," "differentiate," "decide"). Mr. S' repeated questioning of and affect toward Evan's idea suggest that this exchange was salient to Mr. S. In a teacher meeting two months later, Mr. S had a similar reaction. He smiled when watching video of Evan posing the idea and described his response before seeing it in the video: "I was trying to understand from him, how did all the females… what was it about the females that made them susceptible to this mass extinction?" While it is possible that Mr. S questioned this idea because it was inaccurate or implausible, he did not correct or dispute it in either setting. Rather, he seemed to be authentically seeking understanding; as Mr. S indicated in an interview, "the kids

themselves are gonna put you in a posture where you're gonna be wondering well, why, why do you say that?"

Ms. L's curiosity tended to be about students' ideas as well as the topic elevated by students, which positioned her more as a co-inquirer. For instance, as depicted in the illustrative case above, Ms. L repeatedly noted that the student's question of why the foxes got dropped would be interesting to think about, and these statements co-occurred with pursuit of students' ideas. During the discussion that ensued, she treated students' ideas as possibilities to consider and voiced her own ideas and questions (see Richards, 2014 for additional depiction of this case). She described this discussion at a teacher meeting shortly thereafter:

> … every time the kids, we could understand the characteristic that was being used… and then all of a sudden, here they just drop it… so the one kid said so, so why do they do it here? And then we were all I don't know why, I don't know why the fox goes one way and the others, so it was pretty cool.

It is notable how Ms. L included herself with the students in terms of not knowing and framed the situation as "pretty cool," suggesting this was not intimidating but rather motivating for her. Her interview and written feedback corroborated that she was enthused to explore the question *with* students, noting how she "had NO idea. It was so cool!" and later writing, "I LOVE authentically trying to figure stuff out with the kids." This example points to another way in which teachers' own curiosity—in this case, sparked by a student's question and co-inquiry with students—can function as a resource for attention and responsiveness to student thinking.

Variations in Resources for Responsiveness Across Teachers

While there were commonalities in resources for responsiveness across teachers, Figure 1 also demonstrates significant variations across cases and teachers. Notably, each teacher found a unique aspect of students' participation (*social resource*) salient in ways that seemed consequential for their responsiveness and tied to their own affect (*personal resource*), and teachers demonstrated distinct patterns in the types of resources that facilitated their responsiveness to student thinking.

Variation: Diverse Aspects of Student Participation Salient and Linked to Affect

Looking across teachers, different aspects of students' participation (*social resources*) that co-occurred with responsive interactions were salient to teachers and connected with their own affect (*personal resource*) about what was happening in the classroom. Again, this broader pattern recurred across teachers, but the specific manifestations were varied.

Ms. L: Student investment (*social resource*) + enjoyment (*personal resource*). Across all cases from Ms. L's classroom, she repeatedly highlighted students' evident investment in the discussion and how it influenced her decisions. For instance, when watching video of the first selected case of her fifth-grade students discussing whether magnets would work underwater, one of the first things Ms. L noted was, "They were so into this!" She repeated this sentiment three more times during the interview and noted students' investment during the classroom interaction itself, stating, "I'm glad you're excited about this." Later in the interview, Ms. L noted that students seemed especially invested in figuring out why a magnet would or would not work underwater. While her original intent was not to go in this direction, Ms. L noted:

> It just, it just ballooned. ((laughs)) Yeah, it did. Yeah, because they were obviously so into it that it was like unavoidable, you know? It was like, well, we, we have to do this because they were so into it… And it was definitely so rewarding. I, I've, I mean personally, to me, it was very rewarding, to hear all this going on.

Ms. L's rhetoric here is telling—she *could* have made the decision to temper the discussion, but students' level of investment made the discussion "unavoidable" for her. This dynamic played out several times in the case when Ms. L made bids to test the magnets; when students offered continued reasoning instead, Ms. L quickly shifted back to pursuing their reasoning. A similar series of events occurred during Ms. L's second case as seen in the illustrative case, where she also tied her ongoing attention and responsiveness to student thinking to it being "too clear that everybody was really into it." In written feedback on these analyses, Ms. L concurred that, "The kids' excitement is definitely the strongest stabilizer for me… I have so much fun teaching like this when the kids are so excited."

Ms. R: Student appeals to authority (*social resource*) + frustration (*personal resource*). In contrast, in all three cases from Ms. R's classroom, her focus on students' ideas was partly sparked by moments when students seemed to appeal to authority and right answers. In other words, when students did not voice their own ideas, Ms. R zeroed in on prompting them to do so and seeking to understand what made sense to them. For instance, in the second selected case, Ms. R had an exchange with a student, Arielle, who described density as "how much mass is contained in a volume." Ms. R probed for more information:

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

Arielle: Mass times volume.

Ms. R: Mass times volume is what density is, to you. And what does that look like?

Arielle: I do not know.

Ms. R: Okay, so I don't want to know a formula… Who cares what the book says? Because it didn't make sense to us.

Here, Ms. R reframed the question as being about Arielle's thinking, asking what density is *to her*. When Arielle continued discussing mass and volume, Ms. R repeated what Arielle said and took a different tack to invite Arielle to flesh the ideas out, then explicitly framed the discussion as being about what makes sense, not what "the book says." In reflecting on this exchange at a teacher meeting shortly after, Ms. R described it as "the switch" when she stops students from "playing school" and focusing on "what the book is saying" to instead focus on "what it means to me." She again elevated this point as salient in an interview after watching the exchange with Arielle, expressing frustration with what is typically rewarded in school— "what sounds right, sounds good. Because you know, like, they've all played school before, they know, get the right answer, the teacher gets excited, we move on." This close attention to book-like statements occurred numerous times throughout Ms. R's cases and regularly preceded lines of pressing into students' meanings (see Richards, 2014 for another example).

Mr. S: Specific changes in student participation (*social resource*) + enjoyment (*personal resource*). For Mr. S, his attention and responsiveness to student thinking was facilitated by his noticing of increased participation of specific students during responsive

discussions—students who he noted were often marginalized in more traditional activities and systems of schooling. For example, in a debrief just after the first case in Mr. S' classroom, he immediately highlighted how some of the students who contributed ideas did not normally speak:

> I thought there were some kids who normally don't speak who— started to talk, like Martin over here… I thought that— the format (pause) um—allows some kids to, to, um, demonstrate their strengths that normally wouldn't be able to.

Martin and another student Mr. S specifically identified were the first two students to raise their hands and speak in the discussion. This co-occurrence, and in turn seeing idea-centered discussions as opportunities for students to showcase strengths that they "normally wouldn't be able to," likely supported Mr. S in continuing to invite and interact with students' ideas.

He was also "impressed" by the participation of another student, Nat, who contributed ideas toward the end of the discussion. Mr. S excitedly highlighted Nat's participation multiple times—in the debrief after the lesson, at a teacher meeting later that night, at a teacher meeting more than a month later, and during an interview two and a half years later when watching video of the case but prior to seeing Nat's contributions—showcasing its salience for Mr. S:

> *Mr. S*: I do remember that kid over there, Nat?... He didn't really say much in other activities, but I noticed at a certain point, he became very animated during discussion on the key drop.
>
> *Richards*: Yeah… I think we're gonna get to that point actually.

> *Mr. S*: That was uncharacteristic of him… You know, and I would see that every year that I was using inquiry in the classroom.

Thus, the differential participation of students in responsive discussions was striking to Mr. S, who described himself as "completely bowled over" when he saw these shifts. It was also connected to one of his broader purposes of impacting the lives of traditionally marginalized youth. In a teacher meeting, he noted that discussion centered on students' ideas "affirms them in a way that is not necessarily quote-unquote related to a grade… [providing] an equal chance to… engage in a way that's not related to… what happens in school." Noticing and enjoying changes in specific students' participation thus seemed to support Mr. S' continuation of these discussions and his focus on student thinking within them.

Variation: Types of Resources that Facilitated Responsiveness

Cross-case analysis of responsive cases also highlighted how different types and interactions of resources seemed more and less influential for different teachers. For instance, examine resource patterns for Ms. L and Mr. S in Figure 1. Across Ms. L's cases, *personal* and *social* resources were most common. In contrast, *material/structural resources* were more central to Mr. S' cases. For example, Mr. S intentionally planned and used classroom routines/structures to protect space for students' ideas in the face of competing pressures—setting aside entire class periods for discussion (what he called "inquiry Monday") and implementing a fishbowl discussion structure that allowed him to focus on the thinking of fewer students at a time. He also showed a unique reliance on collegial support in planning (*social resource*), often planning series of discussion questions and classroom routines/structures with other teachers in the partnership and PD

facilitators/researchers. Such differences even at the level of which types of resources functioned as resources for responsiveness across teachers have important implications.

Discussion and Implications

Across research and professional learning (PL) efforts, supporting teachers' attention and responsiveness to the substance of student thinking is commonly emphasized, yet studies also demonstrate how such responsiveness in practice is highly contextualized and often fleeting in nature (e.g., Levin et al., 2009). This study examined what functioned as *resources for responsiveness* in nine sustained classroom cases across three teachers and identified a diverse range of personal, social, and material/structural resources in play and in interplay with each other, contributing to our understanding of what may facilitate responsiveness in practice. Here, I discuss and draw implications from several key findings.

Common Resources Useful for Cultivating Responsiveness to Student Thinking

Cross-case analysis highlighted several resources that commonly facilitated responsiveness. These included use of shared referents (*material/structural resources*) to mediate discussion of student ideas, expansive goals for students (*personal resources*) that require attention and responsiveness to student thinking in order to be met, and teachers' own curiosity (*personal resource*)—commonly observed resources for responsiveness that could be particularly fruitful to tap into in PL settings. Additionally, all teachers found some aspect of student participation (*social resource*) during responsive discussions consequential. These are of course not intended to be exhaustive, but they represent useful common resources for responsiveness for teacher educators to consider in the design and study of teacher PL.

For instance, the centrality of shared referents as *material/structural resources for responsiveness* is consistent with situated, systems-oriented perspectives on human action and cognition (e.g., Greeno & Gresalfi, 2008; Hutchins, 1995) that demonstrate how tools shape and can help coordinate activity and meaning. The shared referents in this study, like class records or physical set-ups, seemed to function primarily as tools that focused collective attention among teachers and students and afforded concrete construction and negotiation of meaning, supporting teachers' responsiveness in practice. This suggests that inviting teachers to generate and draw on shared tools *with* students as part of teacher education efforts may be a productive avenue toward responsiveness. Future studies could explore what kinds of shared referents function as resources for responsiveness, how, and under what conditions.

Attending to Affective Aspects of Teachers' Experiences

Another observation from this study is that the personal resources for responsiveness were not always purely cognitive in nature. Take teachers' curiosity, for example. It was partly cognitive, as it was knowledge-oriented and involved perceptions of gaps in understanding. Yet curiosity is also generally framed as a desire and motivator (Grossnickle, 2016), and it was entangled with expressions of affect on the part of teachers, such as enjoyment or amusement from Mr. S as he tried to understand Evan's idea, or Ms. L's enthusiasm about the fox question. With respect to responsiveness, curiosity can spark authentic attempts to figure out students' meanings or figure out something together *with* students, affording ongoing attention to and work with their ideas. A consequential role for teachers' curiosity is similarly hinted at in other studies on attending and responding to student thinking (e.g., Empson & Jacobs, 2008; Franke et al.,

1998; Thompson et al., 2013), and "adopting a stance of inquiry" has recently been framed explicitly as a part of learning to notice (van Es & Sherin, 2021, p. 22). To cultivate curiosity in PL, teacher educators may seek to responsively appreciate and take up moments of curiosity that arise, as well as design for such opportunities. Organizing teachers' work around student artifacts that seem puzzling or intriguing, for which there are multiple possible interpretations and follow-ups, and explicitly asking teachers to share what they wonder may invite and validate curiosity in the context of teaching. Further research in this area could study how curiosity can be cultivated in PL and its impacts on classroom practice, and how responsiveness that operates primarily from a stance of curiosity may impact the nature of classroom discourse and dynamics.

Affective aspects in the study also went beyond curiosity—they were evident in Ms. L's and Mr. S' enjoyment of seeing students invest and Ms. R's frustration with what she perceived as students' appeals to authority (see also Richards, 2014), and they shaped teachers' practice and responsiveness. However, commensurate with broader trends to foreground cognitive aspects of teaching (see discussions by Fried et al., 2015; Hargreaves, 1998; Zembylas, 2005), research on teachers' attention and responsiveness to student thinking has tended to foreground personal resources like teachers' knowledge, abilities, and framings (e.g., Levin et al., 2009; Richards et al., 2020; Shaughnessy & Boerst, 2018). Findings from this study invite us to consider what it would look like to account for and support the fullness of teachers' experiential resources in research and PL on responsiveness, as some work is beginning to explore (Jaber et al., 2018).

An Argument for Responsive Professional Learning

The variation evident in what facilitated responsiveness across teachers is also an important takeaway from this study. Unique resonances for individual teachers were evident at multiple grain sizes as described in the findings. Such observed teacher-level variation in resources for responsiveness has important implications for research and PL.

First, it provides additional support for arguments in the research literature that examining resources and resource use (Cohen et al., 2003; Haverly et al., 2020; Stroupe, 2016) can be a generative lens for unpacking teacher practice and learning. As Stroupe (2016) noted, this lens goes beyond an emphasis on gaining more resources, and instead focuses on what resources are present and used, in what ways, and under what conditions. The diversity seen in this study and others (e.g., evident in models in Haverly et al.'s (2020) study, though not the analytic focus) highlights the promise of deeply situated analyses of resource use and openness to multiple types of resources, as what was salient in one case or for one teacher was not necessarily for another.

In terms of implications for PL, the unique resonances for individual teachers highlight the importance of *responsiveness in professional learning*. Just as teachers are asked to attend and be responsive to the substance of their students' thinking, PL design and facilitation can attune to and responsively pursue multiple ways into intended forms of instruction. Several recent articles (e.g., Shaughnessy & Boerst, 2018; Watkins et al., 2018) have made similar arguments and started to unpack the knowledge and skills teachers bring to specific PL settings. For instance, Shaughnessy and Boerst described a range of skills that novice teachers brought to bear in the context of eliciting student thinking in mathematics, including several that could be productively built on in teacher education.

The present study contributes to arguments for responsive PL and expands discussion of the types of resources teacher educators may attend to as they emerge and unfold over time for teachers. Importantly, a presumption of resource diversity across teachers and timescales invites designs for PL that offer a range of potential entry points into responsiveness and ongoing opportunities to elicit and explore what is at play for different teachers.

Limitations and Additional Future Directions

Finally, the findings and limitations of this study raise numerous open questions. With respect to limitations, this study was limited to classroom episodes across three teachers in a specific context and project focused on science. As such, the resources identified likely reflect a particular subset of potential resources for responsiveness, and future work could examine what functions as a resource for responsiveness for other teachers, in other contexts and disciplines. Data analysis was also limited to larger group discussions, leaving open questions about whether and how resources for responsiveness would differ in interactions with individual students or small groups. Additionally, the nature of the study design meant that there was no point of comparison with respect to whether and how the observed resources were used outside of responsive episodes, though teachers' statements supported their relevance for responsiveness to the substance of student thinking.

Future research could also examine the impacts and potential affordances and constraints of varied entry points into responsiveness. For instance, regularly attuning to the positionality of who is participating, like Mr. S, may afford evolving forms of responsive practice and specific efforts to elevate perspectives from students who are

often marginalized in school and science. Such entry points may enhance the potential within practices of attending and responding to student thinking to contribute to broadened forms of disciplinary activity, disrupting the centering of dominant perspectives. Additionally, future research could delve further into why particular resources are salient for specific individuals, connecting to work that demonstrates links between teachers' noticing and their personal histories and identities (e.g., Kalinec-Craig, 2017).

In conclusion, this study has conceptualized and identified diverse resources for teachers' responsiveness to the substance of student thinking in practice, contributing to ongoing efforts to understand and promote such responsiveness. Commonalities in identified resources and interplays among them can help shape designs for PL, including deeper attention to more affective aspects of teachers' experiences. Just as importantly, variations in identified resources point to the need for responsiveness in PL as we seek to support all teachers' learning and practice.

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Appendix A

Appendix A provides further description of PD partnership activities summarized in the "Study Context." Broadly speaking, the partnership aimed to promote students' science inquiry in elementary and middle school classrooms. We drew on a definition of scientific inquiry as "the pursuit… of coherent, mechanistic understandings" (Hammer et al., 2012, p. 53) of the natural world, seeking to develop causal explanations that cohere with evidence. Importantly, this pursuit can take many forms in practice; when supporting inquiry in classrooms or PD settings, we sought to follow pathways that emerged from participants' ideas and developing explanations. In what follows, I provide more detail about two central kinds of PD activities that recurred and grounded our work in the partnership.

Engaging in Inquiry as Learners

A recurring PD activity was engaging teachers in scientific inquiry as learners, from their own adult perspectives. Note that this differs from some PD models in which teachers are asked to assume the positionality of students and think as their students might. Rather, we wanted teachers to bring their full range of knowledge and experiences to bear in making sense of phenomena to gain experience with scientific inquiry that was authentic to them and to see the power of their own thinking.

Inquiries typically started with a launching question or scenario (e.g., the scenario depicted in the extended example in Elby et al., 2013), proposed either by the PD facilitators/researchers or by teachers. PD facilitators/researchers would then invite teachers' initial ideas and questions, and the group would explore them in service of developing causal, evidence-based explanations through responsive discussion and/or

experimentation. For example, a PD facilitator/researcher may invite teachers to discuss a launching question in small groups and listen to the varied ideas teachers raise. The facilitator may then pull groups together to have a whole-group discussion, pressing into the specifics of teachers' ideas and asking teachers to identify areas of agreement and disagreement and how the group might make progress on the ideas that came up. A teacher may propose a small experiment that would resolve a disagreement, which the group may workshop to ensure it will provide meaningful evidence. Teachers may then do the experiment in small groups, gathering evidence and clarity on the issue at hand but also raising new, related questions to be explored.

In short, inquiries tended to be cyclical and responsive to teachers' ideas and directions to build evidence-based explanations over time. The primary roles of PD facilitators/researchers were helping to mediate the group's understanding of varied participants' contributions, pressing for consideration of causality and evidence as needed, and transitioning between small- and whole-group work. Inquiries could range from several days during summer workshops, as in the extended example in Elby et al. (2013), to less than an hour if teachers raised topics for inquiry in small group meetings during the school years.

We anticipated teachers' own inquiry experiences would help them gain a deeper sense of scientific inquiry as the pursuit of coherent, causal explanations of the natural world and the kinds of support they may offer students in such pursuits in their classrooms. While the specific inquiries were not necessarily intended to be used in classrooms, teachers at times took up launching questions and scenarios that fit their instructional contexts. More importantly, as seen in this study, teachers at times engaged

in more open-ended, responsive explorations of students' ideas and questions and sought to facilitate students in articulating and developing causal, evidence-based explanations—the heart of what we hoped to support in classrooms.

Analyzing Videos of Students' Science Inquiry

Another recurring PD activity was collaboratively analyzing videos of students' science inquiry, similar to video-based approaches described in prior literature that emphasize leading with student thinking (e.g., Barnhart & van Es, 2018; Sherin & van Es, 2009; Watkins et al., 2018). During summer workshops and small group meetings, we regularly shared and discussed short clips of elementary or middle school students discussing scientific phenomena in classrooms, either from pre-existing video records or videos from participating teachers' classrooms. Regardless of the video source, the group's main task was to make sense of the students' thinking based on the evidence in the clip and often an accompanying transcript. PD facilitators/researchers asked questions like: What do you notice in the students' ideas and reasoning? What do you think [Student] meant by [something the student said]? How are students engaging with causality or evidence here? After spending time analyzing the substance of students' thinking, the group would then consider possible instructional responses that would value and build on what students were already doing and help the class make progress toward coherent, mechanistic understandings.

Appendix B

Appendix B lays out the discursive markers used to identify responsiveness in teachers' speech turns (Table B1) and the discursive markers present in the specific classroom cases analyzed in the study (Table B2).

Table B1

Discursive Markers of Responsiveness to Student Thinking

Marker	Example from Dataset
Acknowledging Attempts: Acknowledging a student's attempts to answer, especially with continued questioning (original category)	S1: Why did the meteor shower only hit the females and not the males? S2: It only hit, it hit both of them, but, um, some of them stayed, some of them were still there. S3: How come they only killed all the females, not the males? T: Okay, he just tried to answer that question.
Altering Activity: Altering activity in response to a student's idea (original category)	S: I say maybe we put one part of the magnet in the water, and the other maybe a little bit higher, so there's still a lot amount of space? T: If you want to try it- and then try it the way S's suggestion, with one underwater and one not.
Attempting to Elicit: Attempting to elicit student thinking when little is in evidence (Levin, 2008)	T: You have a different opinion? S: No. T: Yeah you did, you said "no!". So tell me what you see.
Attempting to Hear: Attempting to	S: Because they look the same. ()

hear the entirety of a student's idea when it is difficult to do so (original category)	T: What'd you say?... you're saying it's because they look the same what?
Clarifying Scenario: Clarifying the scenario in response to a student's question or comment (original category)	S: So like, are you walking right by the trash can, or are you walking, stopping, and then- T: I'm walking right by the trash can.
Confirming: Confirming that a student's idea was heard correctly (Brodie, 2011)	S: This is the highest point ((points to a spot on the jump rope)), and that's the highest point ((points to another spot)). T: Okay, so you're saying since those two are higher ((points to the same two spots)), that's why you didn't count that one ((points to another spot))? S: Uh-huh.
Countering: Countering or asking for a counterclaim to a student's idea (Pierson, 2008)	S: I think it, it has dog-like features, but I- it probably is related to a cat more than a dog. T: Well, we ditched the cats up here, didn't- or somewhere we ditched the cat, here, didn't we?
Eliciting: Eliciting something specific from a student related to their idea (Brodie, 2011)	S: Wouldn't it make it go down because it's heavier? T: What force will cause it to go straight down?
Identifying Differences: Identifying differences between	S1: Density, volume, and mass. T: Density, volume, and mass. So somewhere in there,

students' ideas (Lau, 2010)	that has to matter. And then S2 said density is how thick or thin something is, and that has nothing to do really- that won't affect if it sinks or floats.
Identifying Similarities: Identifying similarities between students' ideas (original category)	S1: Have you noticed that when you try to do it at that time when it's there, it doesn't work out if you do it after? But then when you do it before, it gets to the little thingie. T: So yours is similar to what S2 said a little while ago about timing.
Inserting: Inserting something in response to a student's idea, building with examples or illustrations (Brodie, 2011; Lau, 2010; Pierson, 2008)	S1: You know, the thing that reflects the light? S2: You know that- T: A mirror?
Maintaining: Maintaining a student's idea in the public realm by repeating, revoicing, or asking others to do so (Brodie, 2011; O'Connor & Michaels, 1993; Pierson, 2008)	S: Doesn't it start as liquid because when the snow falls down, it's liquid- I mean, liquid, but then it starts to form into a solid. T: So now, S's brought in the idea that, you know, maybe there's just- did that snow that they're, didn't it start off as water up there?
Pressing: Pressing a student for more clarification or elaboration on their idea (Brodie, 2011; Lau, 2010; Levin, 2008; Pierson, 2008)	S: The weight of the keys. T: The weight. What's, say a little bit more about the weight. What is it about the weight?

Reflecting: Reflecting a student's idea for the class to consider (van Zee & Minstrell, 1997)	S: Gender… if there's more girl foxes than boy foxes- T: Than boys? But—um, anybody have a response to that? About it maybe being gender that the foxes were dropped?
Returning Later: Returning to a student's idea later (Lau, 2010)	T: Now somebody said yesterday, after would be better. Why after? There are a couple- I remember S said after.

Note. In the examples above, "S" = student, and "T" = teacher.

Table B2

Discursive Markers Present in Specific Classroom Cases

Case	Discursive Markers Present
Ms. L Case 1	Altering Activity, Clarifying Scenario, Confirming, Countering, Eliciting, Inserting, Maintaining, Pressing, Returning Later
Ms. L Case 2	Altering Activity, Attempting to Hear, Clarifying Scenario, Confirming, Countering, Eliciting, Identifying Differences, Identifying Similarities, Inserting, Maintaining, Pressing, Reflecting, Returning Later
Ms. L Case 3	Attempting to Hear, Confirming, Countering, Eliciting, Inserting, Maintaining, Pressing, Reflecting, Returning Later
Ms. R Case 1	Attempting to Elicit, Attempting to Hear, Confirming, Eliciting, Identifying Differences, Identifying Similarities, Maintaining, Pressing, Reflecting, Returning Later
Ms. R Case 2	Attempting to Hear, Confirming, Countering, Identifying Differences, Identifying Similarities, Inserting, Maintaining, Pressing, Reflecting

Ms. R Case 3	Attempting to Hear, Clarifying Scenario, Confirming, Inserting, Maintaining, Pressing
Mr. S Case 1	Attempting to Elicit, Confirming, Countering, Eliciting, Identifying Similarities, Inserting, Maintaining, Pressing, Returning Later
Mr. S Case 2	Acknowledging Attempts, Attempting to Elicit, Confirming, Identifying Similarities, Maintaining, Pressing, Returning Later
Mr. S Case 3	Attempting to Hear, Clarifying Scenario, Confirming, Countering, Identifying Similarities, Inserting, Maintaining, Pressing, Returning Later

Numerous and varied discursive markers were present in each case, with several discursive markers evident across cases and teachers, including Confirming, Inserting, Maintaining, and Pressing. There were also some distinctions by teacher in their elicitation and follow-up of student thinking. For instance, Ms. L's cases more uniquely included Altering Activity, Countering, and Eliciting, consistent with the overall more emergent nature of discussions in her class.

Appendix C

Summary of Selected Classroom Cases

Case	Focus	Context
Ms. L Case 1	Do magnets work underwater?	Brief discussion initially intended as part of review for upcoming test; became focus of extended discussion and experimentation
Ms. L Case 2	Why is the fox classified differently?	Emergent discussion that occurred during review, followed by return to review
Ms. L Case 3	Is snow a solid or a liquid?	Emergent disagreement that occurred during debrief of snow observations
Ms. R Case 1	What counts as a crest in a wave?	Emergent disagreement that occurred while counting wavelengths in a shaken jump rope
Ms. R Case 2	What makes something sink or float?	Planned discussion, followed by inviting students to record their own "rules" for sinking/floating
Ms. R Case 3	What is energy?	Planned discussion of student groups sharing their definitions for energy
Mr. S Case 1	Where would you drop the keys?	Planned scenario-based discussion, followed by experimentation to test predictions
Mr. S Case 2	How did dinosaurs become extinct?	Planned discussion, followed by continued discussion of related questions
Mr. S Case 3	Where would you drop the keys?	Planned scenario-based discussion, followed by continued discussion of related questions