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RESEARCH ARTICLE

Understanding how teachers guide evidence construction conversations

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Abstract

Many classroom units and lessons are now organized around engaging students in developing claims and evidence. An aspect of teachers' work that is understudied is how teachers manage the complexity inherent in navigating between claims and empirical data. In other words, what do teachers do when students do not see what they are "supposed to" see or when they make sense of observations in unexpected ways? We contend that such complexity is inherent to the scientific endeavor, and that engaging with it is central to doing science. Therefore, the moves that science teachers make in this context have important consequences for students' conceptual and epistemic understandings. We apply an *epistemic levels* coding scheme to three classroom episodes in order to better understand the complexity of classroom evidence construction and to develop a description of strategies that teachers might enact to manage this complexity. We then discuss the implications of these strategies for how students are positioned to engage in scientific knowledge construction.

KEYWORDS

scientific evidence, scientific argumentation, teacher talk moves

1 | UNDERSTANDING HOW TEACHERS GUIDE STUDENTS IN EVIDENCE CONSTRUCTION

Managing the gulf between observation and theory is a central aspect of scientists' work. As Pickering (1995) points out, the world does not offer up facts to scientists. Instead, it acts in ways that are difficult to interpret, and scientists have to figure out how to "capture, seduce, download, recruit, enroll, or materialize" its agency by developing protocols and instruments that allow them to test hypothesized relationships (p. 7). When these captures of material agency produce data, scientists wrestle with how best to see those results and to help others see them in the same way. Complicating matters is the fact that "seeing" is theory-laden and depends on categories, definitions, and measures (Hanson, 1958), the development of which is usually pursued as scientists attempt to understand a phenomenon (Gooding, 1990). From this perspective, scientists do not simply *use* evidence; they *construct* it.

Consistent with an emphasis on supporting students to participate in scientific practices (National Research Council, 2012), many classroom units and lessons are now organized around engaging students in developing claims and evidence. For example, students might develop their understandings of food web relationships by engaging in argumentation about what an invasive species eats based on population fluctuations in the ecosystem (Berland & Reiser, 2011); they might explore the relationship between force, load, and velocity by varying the number of blocks on a car and making claims about how to design the fastest car (McNeill, 2011); or they might develop a model of the atom based on empirical observations collected in guided activities (Sampson, Grooms, & Walker, 2011). In each of these tasks, students are meant to reach desired content understandings through a process of making and supporting claims. The evidence for these claims is inferred from the empirical data collected in investigations. The hope is that organizing instruction in this way will help students make progress toward disciplinary understandings as they work with evidence and develop an understanding of, and skill with, scientific practices.

An aspect of teachers' work that is understudied is how teachers manage the complexity inherent in navigating between claims and empirical data. In other words, what do teachers do when students do not see what they are "supposed to" see or when they make sense of observations in unexpected ways? Returning to the examples above, how do teachers respond when students fail to interpret the graph of population fluctuation in a way that supports an explanation, attend to the size of the car rather than its mass, or construct an incorrect atomic model from the empirical data? A core challenge teachers face is determining how best to guide students to tie the physical world to abstract, high inference ideas generated by disciplinary practitioners who are engaged in far more sophisticated activities than are made accessible to students. As a result, mishaps like those described above emerge regularly in classroom science investigations (Atkinson & Delamont, 1977; Chinn & Brewer, 1998).

In this paper, we explore how teachers manage talk during empirical investigations. In particular, we seek to understand how they wrestle with the complexity involved in helping students to see, represent, and interpret data in the ways that support progress toward conceptual understanding. We contend that such complexity is inherent in all scientific endeavors, and that engaging with it is central to doing science. Therefore, the moves that science teachers make in this context have important consequences for students' conceptual and epistemic understandings. Previous research has examined the difficulties students face in using evidence (Berland & Reiser, 2011; McNeill, Lizotte, Krajcik, & Marx, 2006) and has offered more general moves that teachers can use to position students as knowledge generators and to support them in evidence construction (Michaels & O'Connor, 2012; Stroupe, 2014). However, to our knowledge no studies have examined the moves that science teachers might employ as they support students in dealing with the complex and contradictory evidence that naturally emerges from engagement with empirical data. In this paper, we begin this work by using three episodes of discussion to pose and explore the following questions:

- **(i)** What are the complexities involved in using empirical evidence to support claims in science classrooms?
- **(ii)** What instructional strategies might teachers employ to manage these complexities?
- **(iii)** What implications do these strategies have for students' access to knowledge construction?

1.1 | Evidence construction as transformation

Latour (1987) argues that the heart of scientists' work is transforming complex, material particulars (what the world does at a specific place or time, under specific conditions) into abstract statements that transcend context: what we call "facts." He organizes scientific activity into a series of transformations from observable features to abstract generalizations. Each transformation is an act of *reduction* in the sense that some aspects are selected while others fall away. In turn, reduction promotes *amplification*, in that the phenomena of interest are made more visible, manipulable, transportable, and subject to calculation and standardization. For example, understanding the activity of an endorphin might entail choosing the guinea pig as a model, isolating tissue, injecting hormones to study interactions, making contractions visible by hooking the tissue to a stylus, then using the inscription made by the stylus to support statements about endorphin behavior (Latour, 1987). The statement of endorphin function is supported by evidence when audience members accept the representational chain that stretches from the statement about endorphins back through the inscription to the animal tissue in a laboratory, considering each object legitimately to stand in for the previous one in the chain. To critique a claim about the endorphin, a reader can call any of the transformations into question; for example, arguing that the guinea pig is not a useful model organism or that other factors might account for jumps in the stylus. Convincing scientific arguments carefully stack epistemic transformations so that each seems inevitable. Understanding and managing these transformations is central to skilled scientific action, both for producers and consumers of scientific knowledge.

1.2 | Challenges and teaching strategies in classroom evidence construction

Organizing instruction around engaging students in collecting, interpreting, and arguing about evidence is challenging. Students can find it difficult to construct arguments that tie theory and evidence together (McNeill et al., 2006). They might not revise their understandings as they examine new evidence (Berland & Reiser, 2011; Chinn & Malhotra, 2002). They might not perceive the purpose of using evidence as involving convincing an audience and might perceive their only audience to be their teacher, who already knows the "right answer" (Berland & Reiser, 2009; Sandoval & Millwood, 2005). Researchers have described ways that teachers can address these challenges. For example, teachers can make explicit the reasons to engage in argumentation (McNeill & Krajcik, 2008), model components of arguments (McNeill, 2011), and provide structured opportunities for students to engage in supporting claims with evidence (Sampson & Blanchard, 2012).

Another robust literature has focused on the microlevel of teachers' interactions with students, showing how teachers' ways of asking questions and responding to students' ideas frame students' understanding of the purpose of their activity and their relationships to the teacher, each other, and the content (Berland & Hammer, 2012; Kelly, 2008; Michaels, O'Connor, & Resnick, 2008). Here, the focus is on how teachers position students as knowledge constructors and frame scientific knowledge development as dialogic, that is, the result of participants comparing and reasoning among alternative ideas (as opposed to the transmission of a "correct" explanation). To this end, researchers have identified teacher moves that support students to participate to reason collaboratively, including asking open-ended questions that call for justification and probing for students' thinking rather than evaluating the correctness of an answer (Martin & Hand, 2009; McNeill & Pimentel, 2010). In addition, teachers can shape discussion of content while still positioning students as the authors of ideas by revoicing student thinking to highlight important ideas (O'Connor & Michaels, 1996), selecting and juxtaposing ideas (Stein, Engle, Smith, & Hughes, 2008), and asking other students to respond to ideas rather than themselves directly evaluating or correcting student contributions (van Zee & Minstrell, 1997). These moves can support the development of classroom communities where reasoning strategies, accountability to the community, and content understandings develop together (Michaels et al., 2008).

The fact that scientific experiments rarely demonstrate concepts unproblematically produces tension when teachers employ empirical investigations for the purpose of demonstrating natural phenomena. Researchers have documented several problems that can emerge. Students might fail to observe what they are expected to observe (Chinn & Malhotra, 2002; Eberbach & Crowley, 2009), especially when the result is an ambiguous event that conflicts with students' current understanding, as when a heavier and lighter object are dropped side by side. Students may not have developed the content knowledge that would allow them to make the judgments that disciplinary experts would use to make comparisons (Eberbach & Crowley, 2009; Trumbull, Bonney, & Grudens-Schuck, 2005). In addition, students might observe the desired data, but interpret the data differently than expected or privilege other observations that lead to a different conclusion (Chinn & Malhotra, 2002; Ford, 2005). They might struggle to understand the role of measurement error or variation and interpret small differences as supporting a conclusion (Masnick & Klahr, 2003). Finally, the experiments employed by teachers often misbehave, leaving students and teachers perplexed as to whether the experiment or the hypothesis is faulty.

Several ethnographic studies have detailed the ways that teachers, when faced with these challenges, might discipline students' perception of the experiment to produce shared "knowledge" (Atkinson & Delamont, 1977;

Edwards & Mercer, 1989; Lynch & Macbeth, 1998; Watson, Swain, & McRobbie, 2004). Teachers often employ simple setups that focus students on one clear result and control the pace of the lesson so that students are told exactly when to observe the desired result. They shape student talk so that the important observation is named and linked to an explanation. When necessary, teachers might even tell students what they "should have seen." Once the desired package of observations, evidence, and explanation is established in the classroom learning space, teachers can then recast it in scientific terms and link it to scientific knowledge so that students know what they have "discovered."

It is understandable that teachers feel compelled to shape students' perception of an empirical inquiry and shepherd them toward the desired explanation that the inquiry is meant to support. They are charged with developing particular content understandings, and are constrained by many variables, including time, materials, and the complexity of evidence construction. But disciplining students' perceptions of an investigation without involving them in the work of transformation is likely to cut off important opportunities for students to explore how scientific knowledge is constructed. The very aspects of empirical evidence that students struggle with (seeing attributes, making relevant comparisons, and interpreting evidence in light of scientific principles) are the exact transformations that Latour demonstrates to be central to scientific activity. What, then, might be involved in teaching to help students both manage these transformations and develop an understanding of their centrality in the scientific endeavor?

As we noted above, to our knowledge no studies have directly addressed this question. However, research suggests that teachers are likely to find it challenging to skillfully knit content understandings and deep engagement with evidence together in conversations. When lessons emphasize inquiry and empirical activity, teachers often sideline content goals and focus instead on students' experiences and feelings of doing science, believing that they should avoid "telling" students information (Furtak & Alonzo, 2010). Teachers often struggle to enact strategies that replace telling students answers (Furtak, 2006) and find it easier to elicit students' questions than to help students develop their ideas in discussion (Harris, Phillips, & Penuel, 2012). As they help students construct explanations, teachers can find it difficult to help students analyze data, consider what should count as evidence, and develop explanations that move beyond statement of comparison or major trends (Zangori, Forbes, & Biggers, 2013). To better support teachers in doing this work, we find it helpful to look closely at the challenges teachers and students face as they engage in evidence construction, which enables us to describe strategies teachers might employ to manage this complexity.

1.3 | Application of an epistemic levels coding scheme to understand how teachers guide evidence construction

For our inquiry, we use an *epistemic levels* coding scheme developed by the first author to examine the complexity of classroom evidence construction (Manz, 2016). The coding scheme is based on Latour's (1987) idea of transformation and is adapted from the work of Gregory Kelly and colleagues, who developed a scheme to identify where statements lie on a continuum from specific, personal, observations to more general, widely shared understandings (Kelly & Chen, 1999; Kelly & Takao, 2002). Kelly and Takao (2002) argued that proficiency with evidence construction consists not of making more "high-level" statements, but of spreading statements across the epistemic levels and forging tight connections among them. As an example, they scored college student's term paper argument as less skillful because it involved many high-inference statements (e.g., "[The Mid-Atlantic ridge] is an underwater mountain range.") but did not adequately link these statements to specific features evident in the data and to interpretations of what those features represented. In contrast, they scored another student better because she focused on linking features and interpretations to one central, high-inference claim. In her paper, this student referenced specific data representations (Epistemic Level 1 [EL1], in Kelly and Takao's scheme), identified the features they represented (EL2), demonstrated how the features were oriented (EL3), and linked these statements to theoretical assertions (EL 4 and 5). That is, the more skilled student made visible the multiple kinds of work required to use the geological survey data to support an argument, whereas the less skilled student took the data as unproblematic in relation to claims. The scheme makes evidence

TABLE 1 Epistemic levels adapted from latour's framework

Epistemic Level (EL)	Description
Level 6: Facts	Statements treated as generalizable beyond the scope of the investigation and as not needing empirical support from it.
Level 5: Experimental claims	Inferential claims based on the results of an investigation.
Level 4: Experimental variables/Evidence	Talk that frames an attribute of a system as a variable (independent or dependent) and/or as evidence to support a claim.
Level 3: Data collections	Talk where attributes are used as data to compare and relate across cases, conditions, and time periods. Can include generalizations across cases, attribute relations, or exp. conditions.
Level 2: Public attributes	Talk that transforms observations into objects so others can "see" the same thing and fix it as an attribute. Can include the development of inscriptions, defined attributes, and measures.
Level 1: Noticings	Talk that introduces or challenges an observable attribute of the system.

transformation visible both in terms of which epistemic levels are evident and how those levels are connected to support an argument.

Manz adapted this scheme to capture multiparty conversations and applied it to classroom conversations during a 6-week plant growth experiment in which she worked with a teacher and third-grade students to construct evidence of plant success in order to understand plants' needs. The analysis showed that the class discussed many aspects of evidence consistent with those described in Kelly and Takao's scheme. Ordered in levels from most to least concrete, the community engaged in seeing attributes, defining and measuring them, treating them as data that could be compared across cases, deciding what should count as evidence to support claims, making claims, and using facts or principles that were treated as generalizable beyond the scope of the investigation (Table 1). Manz examined which levels were evident in conversation and how students and teachers connected those levels to support arguments. In initial conversations, teachers were responsible for introducing and linking epistemic levels. In later conversations, students both introduced and connected epistemic levels to develop, contest, and refine communal arguments.

In this paper, we apply Manz's epistemic levels scheme to several episodes, both from the plant needs investigation described above and a second classroom context, to better understand the moves that teachers make to guide students' construction of evidence. In particular, we are interested in what aspects of evidence teachers introduce or make use of in discussions and how they position students in relation to these aspects of evidence (i.e., whether teachers tell information, evaluate ideas, or position students as authors of ideas). In this way, we hope to develop a detailed description of how teachers might navigate evidence construction. We apply the epistemic levels coding scheme to three episodes, each a conversation in which students have divergent ideas, in that they see and interpret potential evidence differently from each other and from the ways necessary to support desired content understandings. We argue that the field has much to gain by looking more specifically at the aspects of epistemic work in which students are asked to participate (noticing, defining, comparing data, deciding what counts as evidence, making connections to general ideas) and better understanding how teachers shape students' participation in epistemic work.

2 | CONTEXT FROM WHICH THE FOCAL EPISODES ARE DRAWN

We focus our analysis on three episodes in which teachers support evidence construction while faced with the challenge of guiding students to see and privilege evidence to draw a conclusion consistent with canonical understandings. We purposefully selected episodes that showed tensions around constructing evidence and different strategies for managing these tensions. In this way, we sought to catalog and examine a diverse set of strategies that teachers might put in place to support evidence construction. Two of our episodes are drawn from the 6-week plant growth experiment previously analyzed by the first author (Manz, 2016). The experiment consisted of 16 lessons undertaken in a third-grade classroom in an urban public elementary school; it was facilitated both by the classroom teacher (Mrs. W) and the first author. It was the third instantiation of the plant growth experiment that the first author conducted with the classroom teacher. Mrs. W was an experienced teacher in her 30th year of teaching; she expressed a strong interest in eliciting and building students' ideas but considered her content knowledge for teaching science to be less strong. In our analysis, we treat both the first author and Mrs. W as "teachers" because they planned the lessons together and Manz often interjected questions and comments during the lessons. Involving the researcher as a teacher or coteacher is consistent with methods of design-based research, in which both descriptions of student learning and means of instructional support are under development, making it difficult to anticipate learning opportunities and useful teaching moves (Cobb, 1999).

Eighteen students (five female and 13 male) were in the classroom; most were African American native English speakers. Students used the experiment to understand whether light mattered for plant growth—a question that emerged from their study of a wild backyard area behind their school. They grew Wisconsin Fast Plants^{TM}, bred to complete their life cycle in 40 days, in three controlled conditions similar to those observed outside: "sun" (continuous light from a lightbox with grow lights); "sun-and-shade" or "sun + shade" (light for 7 h/day); and "shade" (the lightbox was off, though some ambient light hit the plants). Over the course of the experiment, students were prompted to make and record their observations and claims about which plants were more successful —both writing and drawing— on "evidence sheets" kept in a plant journal. They shared claims and evidence throughout their work with the plants and also thought about the implications of their findings for the backyard area.

The experiment involved numerous sources of ambiguity; many of these were designed purposefully into the experiment to provide a context for students to participate in the construction of evidence (Manz, 2015). First, students could notice a variety of aspects of plant growth and could see plant attributes differently. For example, one student might suggest that a particular plant was "dying" while another countered that the plant was simply losing its seed leaves and continuing to mature. Second, students could privilege different plant attributes, leading them to draw different conclusions about which plants were more successful. For example, early in their work some students thought the shade plants were more successful because they were taller, while others focused on thickness or color and argued that these plants were less successful. This, in turn, generated disagreement among the students over how much light the Fast Plants^{TM} needed. From this data corpus, we selected two episodes to analyze: one near the beginning of the experiment, when disagreement was expected by the teachers; and one near the end of the experiment, when disagreement was seen as more problematic by the teachers, who hoped students would agree on a shared conclusion.

In addition to the Fast Plants^{TM} episodes, we wondered what an epistemic levels analysis would reveal about more typical science instruction of the kind that has previously been described in the literature (cf., Atkinson, 1977; Lynch, 1998). Therefore, we selected one episode where instruction was designed to minimize ambiguity in evidence construction but ambiguity and disagreement crept in all the same. This lesson was drawn from the publically available "US2 Polymers" video and transcript from the TIMMS Video Study (1999) conducted to investigate eighth-grade math and science instruction in seven countries.[1] The teacher's experience is not described on the site, but the setting is described as rural and there are 35 students in the class. The polymers lesson we observed was the second of six lessons on matter. The teacher's goal was to help students understand the difference between polymers that are arranged in chains with molecules bonded in long lines versus polymers that are "crisscrossed," with molecules bonded across several dimensions, thus forming networks and lattices. In particular, the teacher sought to use demonstrations involving the manipulation of plumber's tape and an inflated balloon to link properties of these objects to their polymer type. She and students manipulated these objects in order to make claims about the polymer arrangement. As the lesson unfolded, students did not always see what the teacher wanted them to see or make the kinds of conceptual connections she hoped they would make. Using the epistemic levels scheme described below, we were able to examine the strategies that the teacher employed when faced with these challenges.

TABLE 2 Epistemic levels coding scheme

Epistemic Level (EL)	Description	Examples of Teacher Talk	Examples of Student Talk
Level 6: Facts	Statements treated as generalizable beyond the scope of the investigation and as not needing empirical support from it.	What do you know about pollination?	Cactuses grow in hot places.
Level 5: Experimental claims	Inferential claims based on the results of an investigation.	Which of your conditions do you think was more successful?	Sunny was more successful.
		How do you think the chains in the polymer are arranged?	I think the chains are crisscrossed.
Level 4: Experimental variables	Talk that frames an attribute of a system as a variable (independent or dependent).	And what makes you think that they're growing well, or better?	I think they are both doing well because they are both growing.
		So it went back to normal. What does that tell us about how the chains are arranged?	
Level 3: Data collections	Talk where attributes are used as data to compare and relate across cases, conditions, and time periods. Can include generalizations across cases, attribute relations, or exp. conditions.	Have the sun and sun plus shade been growing for the same amount of time in days?	Is there a bump on your shade plant too?
		Anyone notice that if you have the same conditions?	It's stretched out inside there on top, but down on the bottom it's not blown up all the way, so it's thicker on the bottom.
Level 2: Public attributes	Talk that transforms observations into objects so others can "see" the same thing and fix it as an attribute. Can include the development of inscriptions, defined attributes, and measures.	Who can show us her main evidence in her drawing?	What do you mean by bigger?
		What do you mean by come out?	[When I said bigger I was thinking about] height.
Level 1: Noticings	Talk that introduces or challenges an observable attribute of the system.	So let's start out by just telling us what you notice…	I noticed the bump.
		See, it kinda makes a cute little ribbon. Okay?	I didn't make a cute little ribbon.

3 | ANALYTIC METHODS

To understand the complexity of using evidence to support shared conclusions and describe how teachers might guide this work, we used two coding schemes. The first was the epistemic levels scheme previously used in Manz (2016). The second scheme focused on the talk moves teachers might employ to guide students' participation in evidence construction and was drawn from the literature on teacher talk (Martin & Hand, 2009; McNeill & Pimentel, 2010; Michaels & O'Connor, 2012).

Table 2 shows the epistemic levels scheme used to describe how students and teachers negotiate the links between observation, claim, and theory. It was initially developed and refined through inductive coding and repeated viewing of episodes from each of the 16 lessons taught during the plant growth experiment (as described in Manz, 2016). It was further refined for the purposes of this paper. We applied the scheme to seven fully transcribed instructional conversations from the plant growth data set, selected because students were wrestling with important aspects of the experiment. We also applied it to conversations conducted outside of the plant growth experiment, specifically publicly available videos from the TIMSS study and the Tools for Ambitious Science Teaching[2] Website.

While applying the epistemic levels scheme, we identified different aspects of evidence that teachers and students could introduce or discuss. At EL1, teachers and students engaged in noticing attributes, for example green leaves or the thickness of the balloon. In EL2 talk, participants did work to make noticings public and shareable by using representations, definitions, or measures. Consistent with Latour's description, this level was treated as "higher" because the attribute had moved from private to explicitly public. In EL3 talk, participants treated attributes as data to compare and relate across cases, conditions, or periods of time. In EL4 talk, they used attributes as evidence to support experimental claims (e.g., which plants were most successful or how the polymers were arranged). At this level, participants made, or were asked to make, an inference about an attribute's importance in relation to the question at hand (in comparison to lower levels, where the focus was on reporting and organizing attributes without a commitment to whether and how they were important). EL5 concerned the main claim that was the focus of the lesson; it consisted of the teacher asking students to make the claim or the teacher and students making a claim (e.g., which plants were more successful, how the polymers were arranged). Finally, we coded at EL6 talk in which "factual" knowledge was taken as established, commonly accepted, or beyond the need for empirical support; for example, statements about the general growth pattern of plants or the fact that two different polymer arrangements are possible. As the examples show, both the questions participants asked and the statements that they made could be coded using the epistemic levels scheme.

Again, we highlight that, consistent with Latour's description of scientific activity and Kelly and Takao's work, the "higher" levels of the scheme refer to higher levels of abstraction rather than higher levels of skill or desired forms of talk. Scientific arguments are constructed from the links made between claims at different levels of abstraction. Scientific skill consists of moving between the levels and tying them together in ways that are convincing to others. Therefore, after we coded lines of discourse at particular epistemic levels, we looked across lines to understand how connections were made and across each episode to understand how arguments were built within the classroom community. These analyses serve as the basis of our findings.

We also drew from the literature to understand the talk moves that teachers used to guide evidence construction (Table 3). We identified instances where a teacher engaged in *telling* by stating an observation or information. We also considered teacher *questions*. We began with the distinction between "open questions" that invite many possible ways of thinking without signaling the presence of a correct answer, and "closed questions" that narrow possible ways of thinking and signal the presence of a correct answer (Martin & Hand, 2009; McNeill & Pimentel, 2010). This latter category of questions we referred to as *recall/known answer* to indicate a teacher's presumed intention of eliciting a specific piece of knowledge or information from students. However, we found that we needed to refine the notion of open questions to further characterize whether teachers directed students to consider particular aspects of evidence, or particular levels in our Epistemic Levels scheme. For example, teachers could ask *directed questions*, as when the TIMMS teacher asked students during the polymers inquiry "What do you notice about the tape now that we've stretched it?" or when a teacher in the Fast Plants™ inquiry asked "What are you thinking now about which plants are more successful?" Both questions could elicit many possible answers but were directive about the form of epistemic work students were being asked to engage in (EL1 in the case of the former question, EL5 in the latter). *Undirected questions*, in contrast, did not seem steer students to respond within the boundaries of a particular epistemic level. For example, teachers might ask "Who else has something to say about leaves?" or ask at the end of a presentation if there was anything else students wanted to share.

Finally, we attended to other ways described in the literature that teachers could respond to students' ideas. The teacher could respond by *evaluating* students' ideas, providing explicit information about whether they were correct or incorrect (Mehan, 1979). Alternatively, we looked at patterns of teacher responses in which the teacher used *meta-talk* to work with students' ideas, including restating ideas to make sure others heard them; revoicing statements to elevate ideas, introduce language, and/or check on what students meant to say; highlighting particular ideas; or juxtaposing different students' ideas to draw students' attention to particular ideas (Michaels & O'Connor, 2012; Stein et al., 2008). Finally, we were interested in the aspects of evidence construction around which teachers chose to have

TABLE 3 Talk moves coding scheme

Talk Move	Description	Example
Telling	Teacher states a fact, idea, or observation in a way that doesn't invite student comment	T: One of things you guys should know from a science point of view is the petals of the flower can fall off without seeds forming in the pistil
Teacher Questions (Prompt or Follow-Up Probe)		
Recall or known answer	Teacher prompts student response that is treated by the community as unproblematic, with no justification needed.	T: And how tall was your plant?
		S: Eighty millimeters.
Directed	Teacher appears to prompt a student to engage in thinking at a specific epistemic level, or to shift thinking in one direction on the continuum.	T: So the shade ones you see are tall but they're not growing as successfully. What did you see that made you think that?
		T: What do you mean when you say thicker? What looks thicker?
Undirected	Teacher prompts student to provide a response without indication that the response should be at a specific epistemic level.	T: What about the leaves?
		T. And why do you think they're parallel?
Evaluation	Teacher explicitly evaluates an answer as correct or incorrect, or as what they were looking for.	T: Good.
		T: I agree with that.
Meta-talk	Teacher comments on discussion, often by highlighting, restating, revoicing, or juxtaposing student ideas.	T: And what Jim said was, he felt that the polymer chains are crisscrossed.
		T: So you are saying there are bumps on the sun-and-shade plant.
Promote student interaction	Teacher invites students to respond to each other's ideas. Could be in the form of direct interaction or asking students to consider similarities and differences in their ideas. Can occur in conjunction with meta-talk, though not always.	T: Can you tell him why you're not sure you agree?
		T: I've heard other people using height as evidence. But Charles….

students interact with each other; therefore, we coded questions that *promoted student interaction* around a student idea by asking other students to agree, disagree, or question the student.

4 | FINDINGS

In this section, we apply the coding scheme to the TIMMS polymers video as well as to two episodes from the third-grade Fast Plants^{TM} investigation. We begin by sharing an episode from the Fast Plants^{TM} investigation in which teachers[3] appear to be primarily concerned with positioning students to understand and participate in the complexity of evidence construction and show how the epistemic levels scheme makes visible the strategies that they enact to engage students in this complexity. We then turn our attention to the TIMMS polymers video, which provides a stark contrast in that the teacher, while attempting to engage students in supporting claims with evidence, is primarily concerned with helping students develop canonical understandings of polymer chains. Applying the epistemic levels scheme in conjunction with the talk moves scheme reveals differences both in terms of which aspects of evidence construction teachers make available to student discussion and how they guide students' work with these aspects of evidence construction. In the third episode, again from the Fast Plants^{TM} investigation, both goals (engaging students in evidence construction and supporting desired claims and understandings) are at explicitly at play and in conflict. In this last episode, we note strategies that are hybrids of those evident in the first two episodes, as well as new strategies.

4.1 | Conversation 1: Understanding "bigness" in the fast plants^{TM}

This is a transcript that has been published elsewhere (Manz, 2016) and used as an example of how teachers and students can work together to construct important aspects of the evidence needed to support a shared claim. The conversation occurred near the beginning of the Fast Plants^{TM} investigation, when students were divided on which of the plants were more successful. Some thought those growing in the shade condition were more successful because they were the tallest (a result that occurs because these plants put all of their resources into trying to reach the sunlight). Others judged the plants in the sun and sun-and-shade conditions to be more successful because they appeared healthier—i.e., they had bigger leaves, thicker stems, and darker color. This was a disagreement that was anticipated and explicitly identified by the teachers as a learning opportunity given previous work with this experiment. We use the epistemic levels scheme to understand how teachers surfaced and worked with this disagreement.

Charles (all student names are pseudonyms) first presented his claim that the plants in the sun-and-shade condition were more successful than the plants in the shade condition. On his evidence sheet, which was projected onto the whiteboard, he indicated this choice, writing under it, "because [the sun-and-shade] is not brokin [*sic*]." He drew pictures showing a difference in height and leaf color across the two conditions, as well as the presence of what students called "bumps" (leaf buds, although the students were not sure what they were) on the sun-and-shade condition. Underneath the plants he listed several descriptions of each condition, including his observation that the "sun-and-shade is smaller [than] the shade" and the companion statement that the "the shade is bigger [than] the sun-and-shade." He did not elaborate on what he meant by "bigger" and "smaller," although it is likely that he meant height, as at the time that he observed the plants his shade plant was slightly taller (59 mm as compared to 57 mm).

Based on the attribute of height, it would appear that shade plant was more successful, although Charles privileged another attribute—the plants' relative "brokenness"—to make his claim. Charles did not make the contradiction between height and other plant attributes public, but the students seemed puzzled and sought clarification between his claim, justification, and documented evidence. When students were invited to ask questions, Brady pointed on the screen to Charles' evidence sheet and asked, "What do you mean by the shade is bigger?" We consider this to be a student move to define an attribute (EL2). Charles (a fairly fluent, but not entirely fluent, English speaker) responded by holding his hands several inches apart vertically, as if to indicate height, and said, "The plant." He did not verbally distinguish height from other possible attributes that might make up "bigness." Brady then asked, this time pointing at the drawings, whether there were "bumps" on the plants in each of the two conditions. Charles looked at his drawing and stated that there were no bumps in his drawing of the shade plants and, yes, there were bumps in his drawing of the sun-and-shade plant.

At this point, after 10 lines of student talk, the teachers entered the discussion. Table 4 shows transcript and our coding for the ensuing teacher moves. First, EM (the first author) supported Brady and Charles to interact around the notion of "bigness" by asking Brady whether he agreed or disagreed with Charles's description (Line 1) and directing him to tell Charles why he disagreed (Line 3). Both teachers then worked with Charles, directing him to engage in definition ("What were YOU thinking?"; "Was bigger how?") until he specified that he was thinking about height. At this point, Mrs. W marked height as important by restating it with emphasis (Line 9, "OH in the HEIGHT, okay.") and then used this newly refined description of what Charles was looking at to contrast his ideas to those of others, making in instructional

TABLE 4 Teachers direct students to define "Bigger"

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	EM: So you are saying there are bumps on the sun-and-shade plant. So do you agree with him or are you questioning him?							Meta-talk Promote student interaction
2	Brady: Questioning.							
3	EM: So you're not sure you agree with him? (Shakes head) Can you tell him why you're not sure you agree?							Meta-talk Promote student interaction
4	Brady: Cause I think the leaves are bigger 'cause it's getting more sun than shade.							
5	EM: And Charles, what were YOU thinking when YOU said the shade was bigger?							Directed prompt
6	Charles: Like the PLANT *(holds hands up as if holding plant)* in the shade.							
7	Mrs. W: Was bigger how? In [what way?]							Directed prompt
8	Charles: [Bigger in millimeters,] in the height.							
9	Mrs. W: Taller. OH in the HEIGHT, okay.							Meta-talk
10	Mrs. W: I've heard other people who used the height of their plants as evidence of them being more successful because their plants were growing taller. But Charles, he's saying to me that he thinks this one is more successful with sun-and-shade, but the heights—this one is shorter than sun-and-shade. Hmmm. So is that different than what some people think? … But Charles, you didn't use your height as evidence, did you?							Meta-talk Directed prompt
11	Charles: I thought about the bumps as like making it more successful.							

Gray shade signifies teacher contribution; black shade signifies student contribution.

strategies, visible to the class that some students were focusing on height as evidence (and therefore, would think the shade plants were more successful) while others were not. This move connected the definition of "bigness" (EL2) to consequential decisions about which plants were more successful (EL4 and EL5).

Over the next several lines of talk, Mrs. W continued to use meta-talk to help students think about the kinds of evidence that Charles chose to focus on and the way he showed others what he was looking at. In particular, she focused on another meaning of "bigness" evident in Charles's drawing, leaf size:

> *So you see bigger leaves there, too. [To Charles] Did you mean for that to be, that these leaves look bigger than these? [Charles nods] So you think that could make a difference, too? [Charles nods] I mean, to me, that's what I can see. How many of you can see that Charles, he thinks that the sun-and-shade is more successful right now. And it looks like he used leaf size, too, to see that. Because he didn't really think about height that much, did he? [Student: No.] That was not your evidence there, was it? Because if we were just using height, this one was taller, right? [Charles nods] But this one was not as tall. So he used different evidence, didn't he?*

Here the teacher's meta-talk again made connections across the different epistemic aspects of students' work by defining attributes of leaf size as shown in Charles's drawing (EL2), comparing them across conditions (EL3), and contrasting the use of the different comparisons (leaf size and height) as evidence of plant success (EL4) that would lead to different conclusions about which plants were more successful (EL5).

TABLE 5 Teachers direct students to define a plant attribute and reconsider their evidence

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Malik: Everyone who has the sun, their plant is short. But it's really thicker than the ones who have shade. The shade is just tall but isn't growing well.							
2	Mrs. W: So the shade ones you see are tall but they're not growing as successfully because—what did you say about the ones that are sun or sun-and-shade? …. What did you say that made you think that?							Meta-talk Directed prompt
3	Malik: Every time I look at their plants, I always see the one on the sun and shade growing more well.							
4	Mrs. W: And what makes you think that they're growing well, or better? You said it earlier, that you think what-and sun or sun growing well.							Directed prompt
5	Malik: Thicker.							
6	Mrs. W: What do you mean when you say thicker? What looks thicker? There's another really good describing word.							Directed prompt
7	Malik: The leaves.							
8	Mrs. W: The leaves look thicker—[Student: Fatter.]—fatter… Wow, Miss Eve!							Meta-talk
9	EM: And you know Azhad just told me that he changed his mind earlier today. He thought one of his was more successful because it was…							Meta-talk
10	[Azhad speaks but cannot be heard in the video. He does say, "I changed my mind."]							
11	EM: So Azhad, as he's hearing Charles's evidence, he's even starting to change his mind about what it might mean for a plant to be successful. That's very interesting. Anyone else starting to change their mind based on what they thought earlier today, or not? I'm just curious, you don't have to change your mind, I just wondered if anyone had thought of anything new.							Meta-talk Promote student interaction

Gray shade signifies teacher contribution; black shade signifies student contribution.

A few turns of conversation later, Malik noted that the plants that were taller appeared to be less thick, and explicitly connected this contrast to a claim that the taller plants were not as successful. Mrs. W engaged with this comment over several lines of talk (Table 5). She first sought to explicitly draw out the connection to a claim about which condition was more successful; she revoiced Malik's use of "growing well" as "growing successfully" in the class's preferred claim-making language. But rather than assume which attributes Malik was privileging or what he meant by "thicker," she posed questions that seem intended to encourage him to elaborate upon and refine his thoughts by defining attributes. Malik eventually identified that he was focusing on the "thickness" of the leaves, which was then repeated by the teacher (Line 8).

At this point in the conversation, EM made a similar move to that made by Mrs. W in her interaction with Charles and Brady: she employed meta-talk to animate a side conversation that she had just been having with Azhad, noting that he had indicated that listening to the discussion has made him change his mind about which plants were more successful. In doing so, she underlined the importance of Malik's thinking for work at higher epistemic levels, that is, deciding what counted as evidence and making a claim about the results of the experiment.

4.1.1 | Talk strategies for managing the complexity of evidence construction

In this conversation, teachers used talk moves to capitalize on and make visible to the rest of the class important epistemic aspects of agreeing on a shared conclusion, that the Wisconsin Fast Plants^{TM} needed a lot of light. Namely, they capitalized on three opportunities presented by students: Brady's confusion about what Charles meant by "bigger"; Charles's use of meanings of "bigger" and plant features other than height to make a decision about which plants are more successful; and Malik's contrast of taller and thicker plants. Conversation focused students on defining attributes, deciding what constituted evidence, and exploring the consequences of these decisions for making a claim about which plants were more successful. Three talk strategies in particular stand out to us.

Using students' disagreements and misunderstandings to prompt epistemic work

Across the episode, teachers highlighted students' disagreements with each other and used these to motivate work, particularly to define variables and decide what to consider as evidence. When Brady asked Charles what he meant by describing the shade plants as bigger and began to point to other ways to think about which condition was bigger, the teachers turned their focus to uncovering differences in the ways that the students were thinking about bigness. These moves motivated a conversation to define Charles's use of "bigness" as focused on "height," a measurable, single dimension attribute. In addition, Mrs. W purposefully highlighted the idea that Charles was focusing on a different form of evidence than other students, and therefore had reached a different conclusion about which plants were more successful.

Using questions to direct students to particular kinds of epistemic work

We found that the teachers often used questions to direct students to particular kinds of epistemic work; for example, Mrs. W asked several questions of both Charles and Malik to support them to define the attributes that they were using (e.g., "What about the plant was bigger; What do you mean when you say thicker"). In one sense, these questions were directive, highlighting an exact aspect of epistemic work for students to engage in; on the other hand, they still positioned the students as the authors of knowledge; that is, they focused on the students' thinking rather than a correct answer. For example, only Malik could know what he was thinking about when he considered one plant to be thicker; only Charles could make clear the form of evidence that he was using.

Using meta-talk to make connections across different kinds of epistemic work

In this conversation, the teachers often made explicit connections between different levels of the coding scheme. For example, Mrs. W built on the conversation between Brady and Charles about what "bigger" meant to show that while Charles was thinking about height, he was not using it as evidence of plant success. She then supported students to look at Charles's journal, identify other attributes they could see that he was focusing on, and discuss how he was using these attributes (e.g., leaf size) as evidence of success. In these cases, the teacher continued to position Charles as the author of the ideas being worked with, but shaped these ideas to highlight particular reasoning processes (O'Connor & Michaels, 1996).

4.2 | Conversation 2: Helping students make desired claims

We now turn our attention to the episode from the TIMSS video collection. We use this episode as an example of classroom conversation when instruction has been designed to minimize the complexity of evidence construction, but this complexity emerges despite the teacher's best efforts. The teacher's goal was to help students understand the difference between polymers that are arranged in chains, that is, where molecules are bonded in long lines, and those that are "crisscrossed," that is, where the molecules are bonded across several dimensions, forming networks and lattices. In particular, she sought to link properties of objects to the kind of polymer the object is made from. For the first investigation, the teacher had the students stretch a piece of flexible tape at their desk and discuss

TABLE 6 Teacher directs students to leap from what they see to experimental claims

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Teacher: See, it kinda makes a cute little ribbon. Okay?							Telling
2	Student: I didn't make a cute little ribbon.							
3	Teacher: You didn't make a cute little ribbon?							Meta-Talk
4	Student: No, mine's (inaudible), and then we got a pink // (inaudible)-							
5	Teacher: Okay.							
6	Student: It looks like yellow bacon.							
7	Teacher: Looks like yellow bacon, okay. So, that's something that I could do with this. Okay, can you guys see that? All right. Now, I stretched it this way. Did that tell me anything about how the chains were? // In the- in the tape?							Meta-talk Directed prompt
8	Student: Yeah.							
9	Student: No.							
10	Teacher: Did you learn anything about how the chains were aligned in the tape? No you didn't. Okay.							Meta-talk

Gray shade signifies teacher contribution; black shade signifies student contribution.

what it told them about the arrangement of polymers in the tape. In the second investigation, the teacher attempted to use the activity of skewering a balloon in different locations to support the determination that the polymers in the balloon are crisscrossed. In this episode, we notice the teacher using several strategies that have been documented in the literature on how teachers discipline students' perception of experiments. We use the epistemic levels analysis to explicitly name these strategies and describe how they shape students' participation in the evidence construction.

We begin our analysis as the teacher set up the first demonstration involving plumber's tape, a tape made from Teflon, in which polymers are arranged in parallel chains and thus stretch best in one direction, rather than the other. As she introduced the material, the teacher reminded the students of the relevant canonical knowledge (EL6)—that polymer chains can be either parallel or crisscrossed. She began by noting that students did not have "super-duper eyeballs" that would allow them to see how the chains were configured; therefore, they would need to do work to figure out the arrangement of the chains. The teacher thus began the activity by noting the gulf between observation (EL1; impossible due to the limitations of students' eyes) and the claim for which they sought to collect evidence for (EL5, the arrangement of the polymers).

The teacher next asked the students to stretch their tape, then explored what they saw and what it revealed about the arrangement of the polymer chains (Table 6). While the teacher told students what they should see ("a cute little ribbon"), students appeared to see other things—for example, they disagreed and made other analogies ("yellow bacon"). It was unclear what attribute the teacher was highlighting in her analogy and no work was done to help all participants see the same attribute – that is, there was no work at EL2 to define attributes. The teacher then connected what students saw to the claim (EL5) that they were trying to make (how the chains were arranged). Again, students appeared to disagree, and she ratified one answer (they did not learn anything) without exploring the evidence for that statement. Note that Table 5 shows talk located entirely around what was seen (EL1) and a claim about chain arrangement (EL5) with no mid-level work to identify shared attributes and agree on what attributes indicated.

Continuing with the plumber's tape demonstration, the teacher asked students to pull on the sides of the stretched-out tape (Table 7). A student described what she saw —that the tape went "back to normal" (EL1)—and thus made a comparison to how the tape looked before any manipulations (EL3). The teacher ratified this interpretation and

TABLE 7 Teacher positions an observation as unproblematic evidence of a preferred claim

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Teacher: Now what I want you to do, is take one end and take the other end and I want you ever so gently to stretch it that way. And tell me what happens.							Undirected prompt
2	Student: The chains… go back to normal.							
3	Teacher: Back to normal. It goes back to normal. Okay? And if you want to have your other partners or somebody who didn't have a chance to do this, do this again. It's stretching this way; and I'm kinda getting a little distorted- if I were to write my name on it and stretch it like this, my name would be real distorted. But if I were to pull like this I would have my name nice- nice and original again; normal again.							Meta-talk Telling
4	Teacher: What does this tell you? Someone in here raise your hand and tell me what you think this tells you about how the polymer chains are arranged. Do you think the chains are arranged parallel to one another or do you think they're crisscrossed? Based on what this can do. Do you think they're parallel to one another or do you think that they're crisscrossed? Depending on what I can do with this. I see some hands going up. Some hands going up. Jessica.							Directed prompt
5	Jessica: Parallel.							
6	Teacher: They're parallel. And why do you think they're parallel?							Meta-talk Undirected prompt
7	Jessica: Because you can stretch it from side to side and it's kind of easy to do, and if it was crisscrossed it would be harder.							
8	Teacher: Yeah. I agree with that. I don't know if you kinda heard what Jessica said, but she said because of the fact that you could pull them side to side and then you can get it to go back into its original shape again, just by pulling it this way, it's giving you an indication that the chains are parallel. If the chains were crisscrossed do you think we'd be able to get it back to its original way real quick? No, we don't. Okay.							Evaluate Meta-talk

Gray shade signifies teacher contribution; black shade signifies student contribution.

positioned the "back to normal" observation as evidence of how the polymer chains were arranged (EL4), then asked that students use this observation to make a claim (EL5). Jessica made a claim ("Parallel"), and when probed, supported it by noting the ease with which the tape could be stretched. The teacher quickly closed discussion and affirmed Jessica's response ("I agree with that"). She then reintroduced the form of evidence that she, rather than the student, had positioned as useful for making a claim by noting how the chains moved back to normal when tugged from the sides rather than top and bottom. In this excerpt, we see more talk at EL 3 and 4 of the coding scheme and more moves to invite and respond to student thinking; however, the teacher maintained control of what counted as evidence and how it counted.

TABLE 8 Teacher positions demonstration result as uninformative for claim generation

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Student: Now do it right in the bottom; right where all the thick stuff is.							
2	Teacher: Right where all the thick stuff is, huh?							Meta-talk
3	Student: Yeah, might not pop there.							
4	Teacher: Do you think the, the, the thick stuff is not on the side?							Directed prompt
5	Student: No.							
6	Teacher: No?							
7	Student: No, cause—cause it's stretched out inside there on the top, but down where the bottom is it's not blown up all the way, so it's thicker on the bottom.							
8	Teacher: Okay. Let's find out. Okay… (inaudible) popped. Just to be on the safe side. Oh, it still popped! That's because I haven't been successful with this all day long.							Telling

Gray shade signifies teacher contribution; black shade signifies student contribution.

The next part of the polymer investigation involved the skewering of an inflated balloon to demonstrate the arrangement of polymers in the balloon. As in the tape demonstration, the teacher introduced the balloon demonstration by specifying the kind of claim to be made: the arrangement of the polymer chains. This time, the students watched the teacher manipulate the material. After she put the skewer through the side and the balloon popped, a student suggested that she try the bottom (Table 8). The teacher then directed students to compare the material at the bottom and side of the balloon, noting where it was thick as opposed to stretched (EL3). She next skewered the balloon in the bottom and narrated the result (the balloon pops). Rather than asking students to use the result to generate a claim about polymer arrangement, the teacher immediately positioned the result as uninformative by attributing it to her lack of success with the demonstration. This move served to tell students not to consider the result as evidence to support a claim about polymer arrangement (EL4).

Over several turns of talk, the teacher engaged students in working with her to develop a successful test; that is, one in which the skewer would not pop the balloon when placed at the top or bottom of the balloon (as opposed to the side). After several tries, she was able to put the skewer in without popping the balloon. As shown in Table 9, she then turned her attention to guiding students to make a claim about the arrangement of the polymers (EL5) by reminding students of the salient comparison in results (the skewer popped the balloon from the side but not from the top) and asked them to compare the "chains" in the two places. It appeared that she wanted students to discuss how stretched out the chains were, rather than what kind of polymer they were. But her prompt was relatively undirected and the first student to answer, Crystal, misunderstood the form of epistemic work desired and made a claim that the chains were parallel (EL5). In turn, the teacher explicitly directed the students to move to more concrete levels of discussion; then only when the relevant comparison was introduced into conversation (Lines 4 and 6) did she direct students to make a claim.

In this excerpt, a student initially made a claim (Line 8) that differed from the one that the teacher was seeking. Rather than probing or asking for students to interact around this claim, she asked for a different idea. Another student provided a claim and rationale, which the teacher then evaluated ("I like that explanation") and restated. To bring the investigation to a close, the teacher asked the students to confirm the polymer chain arrangement of the balloon ("Crisscrossed"). She thus presented the outcome as a given—a known answer—and expected the class to ratify it, which they did without issue.

TABLE 9 Teacher focuses student attention on a particular comparison for claim generation

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Teacher: What you need to do now is that- I was- when I put the skewer going in this way, it popped; but when I put the skewer in this way, it didn't pop. What's the difference between the chains here and the chains here? What's the difference? What's the difference? Crystal?							Telling Undirected prompt
2	Crystal: It's parallel.							
3	Teacher: Well, don't know if it's parallel. What's the difference between the way the chains are arranged here? Not so much whether they're parallel or crisscross right now, but Jim had said this before. Jason?							Directed prompt
4	Jason: Uh, the ones on the side are like, I guess, like so stretched apart that it, when you hook something in it, it just, like, makes it pop cause it won't stretch into where you (inaudible) to go inside.							
5	Teacher: Okay, and then what about the top?							
6	Jason And then the ones on top aren't as, like, stretched apart or pulled so tightly; they're so loose so you can just stick something in it and (it will) pop right away.							
7	Teacher: Okay, excellent. So how do you think the polymer chains are arranged? Do you think they're parallel or you think they're crisscrossed?							Evaluate Directed prompt
8	Student: Ones on the top are parallel and the ones on the side are crisscrossed?							
9	Teacher: Okay. Anybody else (has anything) different, Jim?							Directed prompt
10	Jim: I believe the ones on the top may be crisscrossed because that means they're closer together and then so you could stick something through, and they, like, squeeze around it easier and do not have to (explode); and the ones on the bottom and the ones on the side are stretched out a little more so they're more like crisscrossed, so when you stick something in they just like… (inaudible).							
11	Teacher: Okay. I like that explanation. And what Jim said was, he felt that the polymer chains are crisscrossed. The ones at the top are crisscrossed, they're not stretched out, so when you poke something through it, the chains just kind of- what was the word that you used?							Evaluate Meta-talk Recall or known answer
12	Jim: Squeezed around it.							
13	Teacher: They kind of squeeze around it, whereas a polymer chain- the crisscross polymer chains on the side are a little bit more stretched out, and so when you try to put a skewer through it, are you really getting- you don't- they can't squeeze together. I think that's the word that he used. The polymer chains can't squeeze together. Okay?							Meta-talk
14	Teacher: So, we learned that the balloon is what type of polymer? Parallel or crisscrossed?							Recall or known answer
15	Student: Crisscrossed.							

Gray shade signifies teacher contribution; black shade signifies student contribution.

4.2.1 | Talk strategies for managing the complexity of evidence construction

In contrast to the first Fast Plants^{TM} episode, where talk was used to surface disagreements and motivate epistemic work around considering how to choose and define evidence, we see talk primarily used here to guide students toward using a particular form of evidence to support a desired conclusion. To do this work, the teacher enacted the following strategies.

Explicitly telling students what to see and what to use as evidence

In comparison to the first conversation, the teacher in this excerpt engaged in a greater number of telling moves. She explicitly told students what to see – for example, in the examination of plumber's tape, she told students that they should be seeing a ribbon stretching out and returning to normal. Potentially as a result, we see no work around helping students define or show data to others. She also told students what to consider, and not consider, as evidence. For example, when the balloon experiment did not go as planned, the teacher told students she was "not successful," therefore directing them *not to use* the result as evidence.

Directing activity to particular epistemic levels to control interpretations

As in our analysis of the "Bigness" episode, we found that the teacher here was generally very purposeful in directing students' activity to particular aspects of evidence construction. However, in the first episode, teachers appeared to direct students to particular epistemic levels to make the need for work visible (for example, by asking them to define what they meant by particular descriptive words). In contrast, here, the teacher appeared to direct students so that they would move together toward the desired conclusion. She first introduced the kind of claim students would be asked to make, did a demonstration and directed students to discuss what they saw, then after ratifying the desired observation, positioned it as evidence and asked students what it allowed them conclude. For example, she set up the investigation so that students would notice that the plumber's tape was stretched in one direction, then could be stretched in the other to go "back to normal," then asked students what this observation told them.

Choosing students and evaluating responses to ratify desired evidence–claim connections

Finally, we notice that the teacher shaped which claims and evidence were ratified, and which were dismissed, by selecting and evaluating students. She did not ask students to justify incorrect claims (only correct claims), moved past incorrect claims quickly and chose new students to share, and ratified the correct claim by evaluating it ("I agree with that, I like that explanation").

4.3 | Conversation 3: Struggling to see seedpods and agree on a shared conclusion

The final conversation we examine occurred on Day 52 of plant growth during the third-grade Fast Plants^{TM} experiment, in late April. Mrs. W had been planning for this conversation to be a wrap-up of the investigation; she expected that students would agree that the plants in the sun condition were more successful than those in the other conditions. The class had already decided to privilege the production of seedpods over other evidence, such as the fact that the plants that produced seedpods were beginning to die (which might lead them to conclude that those plants were less successful). However, students began to disagree with the desired conclusion, arguing that the plants in a second condition, the sun-and-shade condition, might still be growing seedpods, and therefore could be successful. In the ensuing conversation, the difficulty in defining what counted as a seedpod proved an impediment to the conclusion that teachers wanted the students to make. We find this to be a useful conversation to contrast with the first Fast Plants^{TM} conversation in that it was (a) unexpected by Mrs. W, (b) not a conversation she had led before (in contrast to the first, where the same issues had arisen in previous iterations of the experiment), and (c) came at a time when she was eager to wrap up the discussion and move on to her next content goals. In these ways, it was similar to the polymers conversation. We ask, then, how teachers reacted to the departure from their goals and managed the epistemic underpinnings

TABLE 10 Teacher reviews evidence that plants in the sunny condition are more successful

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Mrs. W: How many of you have thought or think that the sun plants have been more successful? Raise your hand. Raise your hand if you think the sun condition has been most successful. Even if it's not your plant, but just from what you have observed you think the sun condition is most successful. [a bunch of hands, lots of kids looking over at the boxes] Azhad, give us a reason you believe that.							Undirected prompt
2	Azhad: 'Cause all the flowers—the, uh, flowers have bloomed. And the seedpods grew, uh, grew and some of them opened up.							
3	Mrs. W: Some of the seedpods opened up? What happened then?							Directed prompt Recall or known answer
4	Azhad: Seeds fell out?							
5	Mrs. W: Seeds fell out. And, so what's going to happen?							Recall or known answer
6	Azhad: They're gonna, they're gonna like, uh, they're gonna grow again?							
7	Mrs. W: So you think they're going to grow new plants right from the parent plant. Right Azhad, is that what you're saying?							Meta-talk
8	Azhad: From the seedpods—from the seed…							
9	Mrs. W: From the seedpod of the parent plant. Or the seeds. Now, um, Jewel, one more, what do you think?							Meta-talk Undirected prompt
10	Jewel: About it being successful? Because, um, I think because of the leaves and the stem and it grew seedpods. [Mrs. W: 'Kay.]							
11	Brady: Ours grew seedpods.							
12	Mrs. W: 'Kay, hold on. We're just talking about sunny right now … Alright, as then we're thinking about this, some people are saying they felt like the sun plants were the ones that grew the seedpods, the seeds, the seedpods—the seedpods opened up and the seeds fell out to grow and they will grow plants that are like that plant right over there, the plant that they came from, the parent plant.							Meta-talk Telling

Gray shade signifies teacher contribution; black shade signifies student contribution.

of students' disagreement. The conversation shows the teachers using strategies that are interesting hybrids of the strategies demonstrated in the first two episodes, as well as new strategies.

The first part of the conversation (Table 10) suggests that Mrs. W believed that she was reviewing an agreed-on conclusion. She first asked students who thought the sun condition was most successful to raise their hands. She then chose a student who generally tracked classroom instruction well and was particularly articulate and led him through a series of known-answer questions that reviewed why students had privileged seed production and highlighted the implications of seedpods for the growth of new plants. She next engaged in meta-talk, summarizing these ideas and adding a new term, "parent plants," thereby bringing in canonical understandings of plant life cycles (EL6) that students had read

TABLE 11 Teacher prompts students to clarify what counts as a seedpod

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Mrs. W: Do we see—have we seen any seedpods on the sun plus shade plants?							Recall or known answer
2	[several students nod, say “Mmm, hmmm.”]							
3	Jewel: But they’re newborn.							
4	Mrs. W: Oh they’re newborns, okay. Have they grown any seeds inside?							Meta-talk Recall or known answer
5	[Some students say “No!” and others say “Yes!”]							
6	S: “How do you know? You haven’t cracked it open.”]							
7	Brady: It’s still growing. It’s still growing the seeds							
8	Mrs. W: ‘Kay. Listen. [Mrs. Wade asks EM for help thinking through whether we have seen seedpods in the sun and shade.]							

Gray shade signifies teacher contribution; black shade signifies student contribution.

about and reviewed on several occasions prior to the lesson. She injected this language three times into the students’ talk (Lines 7, 9, and 12), presumably as a way to provide conceptual tools that would allow students to privilege seedpods over other qualities (e.g., the presence of dead leaves on the sun plants). She wanted students to consider that the sun plants would, over multiple generations, likely reproduce and thus remain present in the “sunnier” location, while the plants in shadier conditions would not reproduce and would eventually die out.

However, not all students in the class agreed that the plants in the sun were more successful. In Line 11, Brady started to interject, making a comparison across the two conditions by noting that the sun-and-shade plants also had seedpods. He was attending to the pistil on these plants, which remained after the flower petals fell off. Therefore, these plants looked much as the sun plants had before the pistils had swollen and developed seeds, turning into seedpods. As the conversation continued, Mrs. W asked students who thought that the sun-and-shade plants were more successful to explain their thinking. Alex responded, “Because the sun-and-shade is still growing…its life cycle hasn’t ended yet.” This was an interesting response because it suggested that he (and classmates who echoed this idea) had begun to define plant attributes and plant success in relation to the life cycle of the plants rather than in relation to what they looked like in the moment. This was an important conceptual shift that the experiment was designed to support; however, it prevented students from agreeing with the conclusion that Mrs. W sought to draw.

In the next section of talk (Table 11), Mrs. W asked students to compare the sun and sun-and-shade plants on the basis of seedpods, essentially disciplining them to see the presence of seeds inside the seedpods as what makes something a seedpod (Lines 1 and 4). This move would then serve to help students see the sun-and-shade plants as not having seedpods, and therefore as less successful, since the sun-and-shade plants did not have seeds. However, here again students’ responses positioned the seedpods as part of the plants’ life cycle: they pointed out that the sun-and-shade plants could be still growing seedpods. Essentially, students were engaging in very sensible ways to bring the dimension of time into drawing a conclusion about whether the plants had seedpods, and therefore whether they could reach a conclusion about which plants were more successful. It was clear that Mrs. W felt conflicted about what she should do and, in Line 8, she turned to the first author for assistance.

As EM entered the conversation (Table 12), she asked students why their teacher was asking them about the seeds in the seedpods. This was a move away from the very concrete discussion about the presence of seeds to consider the meaningfulness of the discussion for agreeing on a shared conclusion about which plants were more successful. She picked up both on one student (Charles) linking the question of seeds to the plants being “perfect” (which we interpret as successful) and on Jasmine’s move to EL6 to discuss what students knew about seed formation and dispersal.

TABLE 12 Teacher pushes students to consider meaningfulness of question about observed attribute

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	EM: Why do you think Mrs. W just asked you whether the sun-and-shade seedpods had seeds growing in them? Why did she think that was important? Charles?							Directed prompt
2	Charles: Cause, cause if they have seedpods that means they might be perfect?							
3	EM: You think they might be perfect. What is Charles talking about when he says that if they have seeds or seedpods they'll be perfect? Brady?							Promote student interaction
4	Brady: It's because– (pause)							
5	EM: You want help? Do you have something else you were going to say or are you still thinking? … Jasmine what were you—							Promote student interaction
6	Jasmine: The plants have seedpods to form the seeds inside of the seedpods so when they're ready to open they'll be formed already.							
5	EM: So just like, just like kids were talking about… when they fall on the ground. One of the things that can be confusing is… we talked about, how does a seedpod get formed? Does anyone remember? How does a seedpod get formed? Does anyone remember that from books or from looking at your plants?							Meta-talk Recall or known answer

Gray shade signifies teacher contribution; black shade signifies student contribution.

EM next used a series of directed prompts to ask students to recall general information about pollination and seed formation (EL6) and relate that information to what they were seeing in their plants (EL1). After several turns of talk, she made a move to use this information to define seedpods (EL2) as having seeds in them.

> *Yeah, and one of the things that we're saying is really important is whether that plant was able to make seeds. So if we think seeds are important for success we'd wanna know there were seeds in the— [pauses and students complete the statement by saying, "Seedpod."] …One of the things you guys should know from a science point of view is the petals of the flower can fall off without seeds forming in the pistil, we called it, right? So it could be that you still see the pistil but no seeds formed in it…. And in fact from a science point of view, I think … you'd only call it the seedpod at the point when it had seeds in it, because it's like a pod for seeds.*

While EM was taking care to show students why they were defining a seedpod and to make the definition of a seedpod conceptually accessible, she was also effectively telling students how to see a seedpod to agree on a shared conclusion. In fact, she took this same approach slightly later in the conversation when another student, Steven, interjected by posing to the group, "I have a question for people! There's this question I want to ask people. What if their seedpods are dead, does that count as a seedpod? If all—if like Malik's is all brown in the sun?" Here again, a student directly challenged the idea of what counted as a seedpod by calling on life cycle concepts; Steven seemed to be wrestling with whether a seedpod could be "dead." EM first used meta-talk to amplify Steven's idea, then said,

> *I'm going to give you some scientific information that will help you make a decision. It's going to help Brady make a decision. It's going to help Alex know what he agrees with. So let's listen to what I say and think about what decision it helps you make. Okay? … Steven said once the seedpod looks brown, does it still count as a seedpod. And here's what I'm going to tell you: when the seed is made, you now have everything in it you need to make a—[pauses, student says, "Seed."]—new plant. It doesn't matter if the plant dies or the seedpod around it turns brown. Once the seed has been made, then when that seed falls on the ground what can it do?*

TABLE 13 Teacher directs students to make comparisons between conditions

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	Mrs. W: Some people are seeing some little bitty tiny ones[a], ok, alright. But some of them haven't even formed their flowers yet. And have they been growing the same number of days as the ones in the sun? Raise your hands if you say the sun plants and the sun plus shade plants have been growing the same amount of days? (Hands raised)							Recall or known answer
2	Steven: Well, not the same amount of seconds.							
3	Mrs. W: Raise your-well, how many of you think the same amount of time? How many of you think the sun and the sun plus shade plant-							Directed prompt
4	Steven: The exact same amount of time?							
5	Jasmine: Yes, they have the same amount of days.							
6	Mrs. W: Well, that they were planted on the same day. Raise your hand if you think they were- we're not going to worry about seconds and minutes, OK, we're not that worried about it, OK, but if you think-(*pause for behavior correction*). But if you think they were all planted on the same day, huh, so you mean the sun plus shade plants have had just as much time to grow seedpods as the sun plants. How many of you would agree with that? (Hands raised)							Telling Recall or known answer
7	Mrs. W: So that makes me question does the condition have anything to do with why they look different? That would be my question. Why do they look so different?							Directed prompt

Gray shade signifies teacher contribution; black shade signifies student contribution.
[a] Seedpods.

She went on to elaborate this point and Mrs. W joined in. Over several turns, they moved between reviewing information on plant life cycles and explicitly tying this information back to defining seedpods. Their conversation was driven by directed questions, recall of information, and meta-talk in which they revoiced student contributions and tied them back to a definition.

As the conversation unfolded, it became clear that many students still believed that the sun-and-shade plants would continue to develop and would grow seedpods. Mrs. W then tried to discipline students' perception of the differences in the two conditions, steering them to agree that because the sun plants had produced more seedpods in the same time period, they were more successful (Table 13). When students disagreed that the plants had grown the same exact amount of time, they moved discussion back to EL2, questioning what unit (seconds vs. days) the comparison was based on. Mrs. W did not pick up this discussion; she remained focused on helping students consider the comparison between the two conditions and treating time as a constant variable that could be removed from consideration. She told students what unit to focus on (days rather than seconds or minutes) and then reestablished the comparison she cared about and asked students to consider why the conditions looked different.

As students continued to interject ideas about why the plants might look different and argue that the sun-and-shade plants would eventually produce seedpods and reproduce, EM backed up the conversation again to what the class did agree on, that seedpods and seeds were important indicators of success, then positioned the comparison between the

TABLE 14 Teacher directs students to make comparisons between conditions

	Transcript	L1	L2	L3	L4	L5	L6	Talk Move
1	EM: It sounds to me that what you are saying is that a really important way to tell if a plant has been successful is to look at the number of seedpods because you can tell how many seeds it is making and how many new plants it's going to make. Thumbs up if you reached agreement about that.							Meta-talk Directed prompt
2	[Steven asks her to repeat the question. EM does.]							
3	Alex: I'm thinking "yes" because the sun and the sun-and-shade were most successful because those two they both grow into plants and they made seeds for their offspring so they can grow but the shade it didn't make any seedpods so it won't have any offspring.							
4	EM: Both sun and sun-and-shade make seedpods. We're about to check that. So we'd better do a pretty good comparison of how many seedpods they're making. We're going to look at the seedpods to see if we can compare the number. Who has a guess about sun and sun-and-shade, which will have made more seedpods?							Meta-talk Directed prompt

Gray shade signifies teacher contribution; black shade signifies student contribution.

number of seedpods the plants in each condition made as, at that point, not yet known (Table 14). That is, she accepted the students' continued unwillingness to agree on the desired conclusion. After taking several ideas and labeling them as predictions, she and Mrs. W directed students to begin counting seedpods, then developed a chart that labeled number of seedpods with space for recording future counts. Therefore, they essentially decided to continue the investigation longer than they had planned.

4.3.1 | Talk strategies for managing the complexity of evidence construction

In this conversation, teachers negotiated an issue that they had not planned for. Their talk was more directed than in the first Fast Plants™ conversation, in that they prompted students to respond at particular epistemic levels, told students more information, and encouraged less student interaction around the ideas. Rather than highlighting uncertainty, they sought to discipline students' perception for the sake of achieving consensus and making progress. Like the polymers conversation, and in contrast to the first Fast Plants™ conversation, teachers' talk focused on shared ways of seeing and privileging attributes. The strategies evident in the episode include hybrid strategies from the first two episodes and new strategies.

Directed questions to review and instill particular chains of reasoning

Mrs. W's opening to the episode focused on encouraging students to agree on a shared conclusion. In this sense, it was similar to the moves enacted by the teacher in the polymers discussion, in that Mrs. W began with the conclusion that she desired (that the plants in the sun condition were more successful), then asked for evidence to support that conclusion. She called on a student who was known to track instruction effectively, then asked questions that directed him to replay a chain of reasoning in which seedpods were related to the production of more plants, thus rehearsing the reason for privileging seedpods as evidence. When students did not agree that the sun-and-shade plants had no seedpods, Mrs. W asked a series of directed questions that invited a narrow set of responses ("Have we seen any seeds on the sun-and-shade plants?" "Have they grown any seeds inside?" "Have the sun and sun-and-shade been growing the same number of days?") to discipline students' perception of the pistils that they were considering when they argued against her. However, in contrast to the polymers episode, her directed questions ranged over several different aspects of the epistemic work involved in agreeing on a shared conclusion, including not only the comparisons she sought to have students make (as evident in the polymers discussion), but also defining attributes and justifying why an attribute should count as evidence.

Controlling the form of activity students engage in

In this excerpt, there is also more evidence of teachers controlling what information was provided and when, presumably to strengthen a desired chain of reasoning. Rather than beginning the episode by asking for different claims and evidence about which plants were more successful, Mrs. W used questions to ratify the comparison she wanted to have students make: that the sun plants had produced seedpods while the other plants had not, and would therefore reproduce and grow more of their kind. She attempted to maintain control of this line of logic. For example, when Brady intervened to point out that Azhad's evidence was not strong because the plants in the other condition were also growing seedpods, Mrs. W directed students to continue to consider only one condition (the sun), strengthening the description before turning back to the comparison (the sun-and-shade). When students continued to disagree about which plants had seedpods, the teachers made repeated attempts to redirect the conversation toward shared understandings or comparisons that they thought could support a shared conclusion.

Telling to support desired definitions

In this excerpt, we see teachers engaged in a significant amount of telling and providing terms and scientific definitions; this is more evident than in either of the previous two excerpts. In particular, EM defined a seedpod as having seeds in it and noted that even if a seedpod turns brown, the seeds in the seedpod will grow into new plants. Mrs. W and EM spent numerous turns of talk helping students apply these ideas to develop shared definitions.

Using directed questions and meta-talk to make connections among epistemic activities

In this excerpt, teachers again strove to make connections among the different forms of epistemic activity that students were involved in. Mrs. W worked to link the production of seedpods to the production of new plants, and therefore a definition of plant success. EM interjected several times to link discussions about the definition of a seedpod or the production of seedpods to the question of which plant is more successful. In this way, both teachers continued to focus on making the logic of students' activity visible to the class.

Putting off a decision until further activity

A final strategy enacted in this excerpt is the decision by a teacher to postpone drawing a conclusion. While both EM and Mrs. W entered the conversation with the goal of having students agree that the plants in the sun condition were most successful, EM intervened in the conversation to put off the decision while also ratifying a way to make a final determination (counting seedpods now and again at a later date).

5 | DISCUSSION

Within science education scholarship, there has been much attention to how teachers promote dialogic interaction and support students' access to knowledge construction (Ford & Wargo, 2012; Michaels et al., 2008; Stroupe, 2014), as well as to the importance of students constructing claims and supporting them with evidence as they develop content knowledge (Berland & Reiser, 2011; McNeill & Krajcik, 2008; Sampson et al., 2011). The framework used here has the potential to contribute to both of these fields of work and bring them together, thus allowing for the identification and analysis of strategies teachers might use as they facilitate work with evidence. Below, we revisit our research questions to consider how our analysis of the three episodes revealed the complexity of supporting students to construct evidence. We then describe the differences in teachers' approaches to this complexity and discuss the consequences that these differences might have for students' access to knowledge construction. We end the paper by considering potential implications of this analysis for working with teachers and developing instructional strategies for supporting students in constructing evidence.

5.1 | Understanding the complexity of evidence construction

Applying the epistemic levels scheme to these three episodes showed that each conversation involved multiple aspects of evidence construction consistent with Latour's notion of transformation. In all three episodes, students disagreed with each other and/or their teacher about what they were seeing (e.g., bigness, ribbons, seedpods) and sought language to share ideas with each other, for example by inventing and challenging terms like "big," "bumps," and "bacon." In addition, they struggled about when to consider empirical demonstrations sufficient for supporting claims, as in the case of drawing a conclusion from the balloon popping or the success of plants in the sun-and-shade condition. Their conclusions depended on what evidence they chose to privilege. In the early Fast Plants^{TM} work, focusing on height led students to consider the plants in the shade as more successful than those in the other conditions, while privileging thickness supported the opposite conclusion. In the TIMSS polymers episode, there was tension as the student used the comparative ease of stretching tape in one direction as opposed to the other to support a claim about the makeup of the polymer, while the teacher sought to have students use as evidence the fact that the tape could be stretched back to its original shape.

5.2 | How teachers managed the complexity of evidence construction

In all episodes, teachers were sensitive to the complexity of evidence construction and employed strategies to manage this complexity. They used talk to shift students' participation to different epistemic aspects of scientific work and connect those different aspects in order to draw a conclusion from the investigation. In each case, teachers signaled when to engage in noticing and when to make claims and pushed students to use what they saw as evidence.

We highlight the purposeful, directed nature of all teachers' talk as an interesting finding that might influence how we think about how teachers support evidence construction. Studies on how learning environments can support students to act as knowledge constructors have highlighted the importance of teachers asking "open-ended questions" that have multiple possible answers (Martin & Hand, 2009; McNeill & Pimentel, 2010). As we began applying our schemes to the episodes described here, we found that the notion of an open-ended versus closed question did not fully capture the differences in teachers' questions. Instead, we found a preponderance of what we called *directed questions* across all three episodes; that is, questions that signaled the kind of work students should engage in, while not necessarily suggesting that the question had a right answer. For example, questions such as, "Which plants do you think are more successful? " and "What do you notice?" direct students to engage in particular kind of work, though they do not specify a "correct" answer and can thus elicit students' differing ideas. In fact, we found that it was difficult to code "undirected questions" because few questions appeared to give no clues about what kind of epistemic work was called for. While many studies have focused either on how teachers promote student agency in knowledge construction with open-ended questions or model and make explicit aspects of argumentation, we suspect that questions that are directed in relation to epistemic work but open in relation to correct answers are a promising avenue to explore in terms of how they guide students' understanding of, and participation in, evidence construction.

Our analysis of the three episodes suggests clear differences in how teachers directed talk in each conversation, in particular in relation to which aspects of knowledge production students were allowed to participate in. We do not seek here to make judgments about which conversations were better, which teachers were more skilled, or what allowed teachers to engage their students differently; we are unable to draw such conclusions due to the different sources from which the episodes were drawn and the little we know about the teacher in the TIMSS video. Instead, we explore how examining teachers' guidance of epistemic work uncovers teachers' goals, student learning opportunities (or constraints), and the tensions teachers face in orchestrating conversations when they are invested in what students see and claim.

We characterize the teacher in the TIMSS polymers episode as using directed and recall questions to move students efficiently through evidence construction to agree on content understandings in the form of shared conclusions. The transcript suggests that she wanted to position students as “figuring out” these content understandings using the investigations. In each of the two investigations, she posed the purpose, conducted the investigation, and then pushed students to justify their claims using the investigation. But the shape of conversation explicitly funneled students toward particular conclusions without making apparent the work needed to support those conclusions. Specifically, we noticed a tendency to ask students to make a leap from what they noticed (EL1) to supporting claims (EL5) with perhaps a brief stop at comparison (EL3) followed by an unproblematic linking of the conclusion to facts (EL6). There were few moves to engage students in defining attributes (EL2) or determining what should count as evidence (EL4). The work involved in agreeing on attributes, comparisons, and evidence was almost invisible, glimpsed only in moments of tension when the experiment or students did not perform as expected. In these cases, the teacher enacted a “quick fix” so that a shared experience of a correct explanation was made public.

The first Fast Plants^{TM} episode on “bigness” stands in the starkest contrast to the polymers episode and is the one that we suspect most quickly resonates with readers as showing teachers positioning students as constructors and critics of evidence and claims. The teachers both encouraged student argumentation and highlighted the diversity of ideas about which plants were more successful, moves that have been described in the literature (Michaels & O’Connor, 2012; Stroupe, 2014; Varelas et al., 2007). What the epistemic levels scheme makes visible is that teachers positioned the empirical challenges involved in seeing the same thing (e.g. bigness, thickness) and privileging observations as evidence (e.g., height versus leaf size or thickness) as occasions for sense-making, rather than attempting to move students efficiently past these points of potential confusion.

The second Fast Plants^{TM} conversation, where the teacher sought to have students agree that the plants in the sun were more successful and to use seedpods as evidence, presents an interesting contrast to the two other episodes. Like the polymers conversation, and in contrast to the first Fast Plants^{TM} conversation, the teachers focused students on shared ways of seeing and privileging attributes. The teachers, particularly Mrs. W, sought to control what comparison was on the table and what attribute was used as evidence. What stands in contrast to the polymers conversation, though, is how definition and considering what should count as evidence were made visible as tools for ratifying the desired conclusion. While the teachers engaged in many talk turns of telling and known-answer questions (in fact, more than evident in the polymers episode), these turns of talk were used to rehearse and strengthen aspects of evidence that would allow students to agree on a conclusion; for example, when teachers led students through the ways that seedpods resulted in more plants and defined seedpods as containing seeds to grow new plants.

5.3 | What are the consequences for students’ participation in knowledge construction?

Within the lessons, three kinds of goals for students’ participation in knowledge construction were apparent: (1) helping students develop a shared understanding (e.g., the polymers are crisscrossed; Fast Plants^{TM} do best in a lot of light); (2) helping students engage in the process of supporting a claim with evidence; and (3) helping students understand how evidence is constructed. We suspect that each of the teachers held at least two of these three goals, and that their struggles illuminate the tension between the goals. In the TIMSS polymers episode, the teacher’s main focus was on developing a shared claim about polymers, and she funneled talk toward this goal. But the transcript suggests that she also wanted to position students as “figuring out” these content understandings using the investigations. In the discussion of plant “bigness,” the first goal did not appear to be as important—teachers encouraged divergence in claims about Fast Plants^{TM} and appeared to focus on exploring differences in student thinking. They contrasted what students saw and what evidence they privileged, then made the ramifications of these decisions visible to the class. By comparison, we might see the second Fast Plants^{TM} episode as best exemplifying the messiness of classroom scientific work when all three goals are at play. In this case, teachers seemed most focused on Goals 1 and 2 and struggled with representing the third goal without sacrificing the shared explanation they desired.

These goals and the choices teachers make to reach them have consequences for students’ access to knowledge construction. Both how teachers use talk to position students and the forms of epistemic work that teachers make visible are important for how students will come to understand scientific activity. In particular, we note the pattern in the TIMMS polymers episode—using a predetermined comparison presented by the teacher to mark noticings as evidence in support of a desired claim—as a pattern that is common but also worth continuing to interrogate. The idea that it is easier for students to make and support claims in settings with clear evidence, minimal material challenges, and no extraneous data is one that is fairly widespread in the literature and in curriculum design (Berland & McNeill, 2010; Klahr, 2002). However, this approach risks removing students' access to important knowledge construction practices concerned with the complexity of evidence, therefore providing an impoverished view of science (Latour, 1987; Pickering, 1995). In addition, as in the episodes we examined, ambiguity and uncertainty are likely to creep into activity despite efforts to contain them. When they do, a teacher unprepared for such dilemmas may undermine opportunities for knowledge construction or for positioning students as legitimate constructors of knowledge. In fact, there may be no alternative course of action in such moments, because there may not be a legitimate way for students to struggle and make progress on aspects of evidence needed to support shared ways of seeing, comparing, and privileging particular attributes. Faced with curricular materials that constrain opportunities to engage in meaningful evidence construction, a teacher must actively resist those materials and make significant changes to open up lessons in ways that allow students to both engage in critiquing evidence and make progress on disciplinary understandings by doing so.[4]

Consider a lesson in a widely used commercial science kit for the upper elementary grades, which directs students to time the movement of a car across a table with more and less force pulling on the car from washers attached to a paperclip hanging off the table. Here, time is relatively easy to measure and compare, in that more washers will pull the car across the table in less time. The teacher's manual directs teachers to engage their students in making claims about the effect of the greater force and gives the following direction to the teachers:

> *Your students may say "More weight on the string (or a greater force) made the vehicle move faster." This is acceptable, but help them understand that the greater the force, the greater the change in speed over the same distance. One way to describe this change in speed is "The vehicle got going more quickly with more weight" or "A bigger pull made the vehicle take off faster." (National Science Resources Center, 2002, p. 45)*

Here, while the easiest variable for students to measure and use to support a claim is speed (as measured by the time it takes to move a fixed distance), acceleration is actually more pertinent to a canonically correct explanation of the relationship between force, mass, and motion. However, there is little direction for teachers about how to handle the introduction or definition of this new variable and how to connect it to variables that students are likely to see. As a result, teachers have few options other than the strategies visible in the TIMMS polymers episode, such as replacing students' statements of evidence with desired forms of evidence.

What, then, do we make of the second Fast Plants™ episode, where multiple conflicting goals were at play and the messiness of evidence construction was readily visible, but teachers engaged more explicitly in telling and guiding student thinking toward specific conclusions? We believe that this kind of conversation is one that science educators must address. We find the ongoing discussion on what it means for teaching and learning to be dialogic to provide a helpful lens for understanding how this conversation might have positioned students in relation to knowledge construction. Several authors have pointed out that teachers can position *content* as dialogic, even as they move between authoritative and dialogic utterances (Ford & Wargo, 2012; O'Connor & Michaels, 2007; Scott, Mortimer, & Aguiar, 2006). In the seedpods conversation, the teachers, even as they clearly want to move toward a shared understanding, saw the work of definition of attributes and justification of evidence as central to the development of the shared understanding. We suspect that this emphasis might "frame" the work of the investigation and the desired conclusion as dialogic, similarly to how Ford and Wargo (2012) have described the way that a teacher framed theories of natural selection as dialogic by making evident the need to juxtapose and evaluate them. One form of evidence to support this claim is the fact that students continued to interject with the need for new definitions (e.g., "What if a seedpod is dead, does that count as a seedpod?") and to disagree with the teachers about whether it was fair to reach a conclusion, even as teachers continued to shape conversation with authoritative moves. These kinds of strategies—focused on making visible the complexity of evidence construction, while at the same time guiding students toward desired ways of seeing and privileging attributes—will be important foci for further work.

6 | IMPLICATIONS

As we increasingly ask teachers to engage students in supporting claims with evidence to develop content understandings, we will have to be aware of the tensions inherent in this activity and develop ways to help teachers make sense of and manage these tensions. Teachers would likely benefit from explicit discussion of what it means to develop evidence and from support in planning how to engage students in evidence construction. This implication is consistent with research that suggests that skilled teachers help students think about what should count as evidence, rather than simply directing students to use evidence (Simon, Richardson, & Amos, 2012) and that teachers sometimes struggle to support rich conversations in which students interpret data and use them as evidence (McNeill & Knight, 2013; Zangori et al., 2013). Even so, we must address the very sensible concern that a focus on evidence construction, among other science practices, necessitates both sacrificing content goals and committing more time to each investigation. We can continue to validate these concerns and help teachers address them both by explicitly discussing the value of opening up investigations to evidence construction and helping teachers develop specific strategies that allow them to balance multiple competing goals. For such efforts to flourish, however, we will need to continue to make efforts to shift districts from favoring narrow, scripted curriculum and reducing time for subjects like science (Jerald, 2006; Milner, 2013).

The epistemic levels scheme provides ways to think about how to talk with teachers about guiding conversations that invite students into important aspects of the construction of evidence. We notice in the TIMSS polymers video a tendency to ask students to make a leap from what they noticed (EL1) to supporting claims (EL5) with perhaps a brief stop at comparison (EL3) and then an unproblematic linking to facts (EL6). We suspect that this form of conversation is relatively common. To disrupt this tendency and allow teachers to more fully support students in constructing knowledge, it is likely important to name the activities involved in constructing evidence; in particular, defining variables and measures, considering how best to make comparisons, and determining what forms of evidence to privilege. We can begin to look at investigations with a lens toward understanding what might be difficult for students to see, relate, or privilege. We can then anticipate when these difficulties will emerge and plan so that these difficulties constitute opportunities for discussion and scientific work, rather moments where the teacher feels compelled to step in to "correct" student perceptions.

In addition, we can consider strategies that guide students in constructing evidence to support explanations and develop principled ways to consider the tradeoffs involved in invoking particular strategies. In particular, our analysis made visible the following strategies.

6.1 | Controlling students' activity

Teachers can use talk to control what information is provided and when, so that they can position students to focus on a desired observation and use it as evidence to support the target claim. This strategy was evident in the TIMSS polymers and second Fast Plants™ conversation involving seedpods, as well as previous research (e.g., Lynch and Macbeth, 1998). While this strategy can provide an efficient means toward supporting a particular explanation, teachers might benefit from discussion of when it cuts off opportunities to work on important aspects of evidence.

6.2 | Directed questions

Teachers' questions can direct students to engage in, and deepen reasoning about, particular aspects of evidence. Teachers might benefit from explicit discussion of kinds of questions that can encourage reasoning about particular aspects of evidence; for example "What do you mean by X" (definition, EL2) or "When you decided X, were you paying attention to Y or Z? Why was that important to you?" (privileging evidence, EL4).

6.3 | Promoting disagreement

Teachers can choose to select and juxtapose student ideas to make visible the need for work at a particular level, as when Mrs. W compared Charles's choosing not to think about height to other students' use of height as evidence. We might support teachers to think about what kinds of disagreements they want to make room for and what aspects of evidence these discussions will help students engage in.

6.4 | Providing content knowledge to guide students toward shared definitions or ideas of what counts as evidence

When teachers are oriented toward what students could see, define, or privilege differently from experts, they can begin to think about what content understandings might support students to construct these aspects of evidence along disciplinary lines. They might then consider how to introduce these content understandings and position them as tools that will help students make important decisions, as in the second Fast Plants^{TM} episode.

6.5 | Using meta-talk to make connections among different aspects of evidence

It is possible that students will engage in important aspects of evidence construction without understanding the import of these discussions for the question at hand (Manz, 2016). Teachers might use revoicing and highlighting to make these connections visible to students.

6.6 | Using next experiences

A final strategy is choosing to back off from asking students to agree on a conclusion, and instead planning further experiences that will provide a press toward the desired conclusion. In the first Fast Plants^{TM} episode on “bigness,” the teachers knew that it would be more obvious in a week that the shade plants were not as successful. In the second Fast Plants^{TM} episode, EM counted on the fact that over time, the sun-and-shade plants would not grow more seedpods. In this way, teachers can use feedback from the world, rather than their own overt pressure, to press on students’ claims.

7 | CONCLUSION

In this paper, we used a comparative analysis of three conversations to understand the strategies that teachers might employ to guide the construction of claims and evidence from empirical investigations. We acknowledge that these three conversations are not able to fully capture the multitude of issues that might arise and strategies for addressing these issues. As such, our list of challenges and strategies is not intended to be comprehensive. Instead, we hope that our detailed analysis of these episodes brings the problem of evidence construction to light as a focus for the field and invites others to share the complexities and strategies they are finding as they engage in this work. Given that there is agreement that both the development of canonical understandings and engagement in evidence construction are important in science education, we suspect that there will be many conversations in classrooms where these two goals are in tension with each other. It will be important to address these tensions: to collect more conversations where both goals are evident, to examine the strategies that teachers implement to navigate tensions, and to discuss the ways that these strategies support content understandings, position students, and offer them authentic ways to participate in knowledge construction.

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ENDNOTES

[1] The study was a joint effort between the International Association of the Evaluation of Education Achievement (IEA) and the National Center for Education Statistics (NCES).

[2] Accessed at www.ambitiousscienceteaching.org. We appreciate Dr. Mark Windschitl's permission to use the video on this site for testing the epistemic levels scheme.

[3] As described earlier, both the first author and the classroom teacher were coded and treated in data analysis as "teachers."

[4] We are grateful to one of our reviewers for pointing out the active work that teachers must do to resist constraining curriculum materials.

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