Research Article

Understanding the Co-Construction of Inquiry Practices: A Case Study of a Responsive Teaching Environment

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Abstract: We set out to understand how different instantiations of inquiry emerged in two different years of one elementary teacher's classroom. Longitudinal observations from Mrs. Charles' 5th grade science classroom forced us to carefully and deliberately consider who exactly was responsible for the change in the class activities and norms. We provide empirical evidence to show how a focus on the teacher can easily overlook the complex dynamics of the classroom. The data reveal that students had a substantive and generative role in the class's arrival at the different instantiations of scientific inquiry—the nature and form of inquiry—that were constructed each year. We argue that, in an environment where a teacher carefully attends and responds to student thinking, the nascent resources students have for reasoning about phenomena can affect not only the conceptual ideas that emerge, but also influence what inquiry activities or practices become established as normative and productive over time. Our work with Mrs. Charles illuminates an important methodological concern with research on teacher development as well as the construct of teacher learning progressions; research accounts that focus primarily on the teacher may overlook the classroom norms that are negotiated between teacher and student, and thereby provide an incomplete portrayal of the teacher's activity within one classroom *and* the teacher's progress across multiple years. © 2012 Wiley Periodicals, Inc. J Res Sci Teach 49: 429–464, 2012
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Within science education, there is an ongoing focus on scientific inquiry as a student-centered endeavor, where students themselves do the intellectual work and teachers play a more responsive, adaptive, supporting role in the classroom (NRC, 2000, 2011). Although it is widely acknowledged that complex teacher–student and student–student interactions take place in the classroom, much of the research on promoting scientific inquiry places teachers at the center of reform. As the representative of science, the teacher is often charged with introducing and enforcing the productive scientific, social, and intellectual practices of the classroom (Anderson, 2002; Blanchard, Southerland, & Granger, 2009; Woodbury &

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Gess-Newsome, 2002). The implicit assumption therein is that students' habits and nascent knowledge are unproductive and impede inquiry practices, and therefore the enactment of inquiry ultimately realized in a classroom should be attributed almost exclusively to the teacher. Thus, the extant literature has given more attention to *how to produce* certain scientific norms in the classroom than to documenting and describing their evolution (Berland & McNeill, 2010).

Within the context of a 2-year case study of an experienced science teacher and her 5th grade classes, we provide empirical evidence that highlights the extent to which a focus on the teacher overly simplifies the complex dynamics of the classroom. Our data show that the students in Mrs. Charles' (pseudonym) classes had a substantive and generative role in the class's arrival at different instantiations of scientific inquiry—the nature and form of inquiry—that were constructed each year. The differences observed between the 2 years cannot be accounted for when focusing primarily on Mrs. Charles'. Instead, the differences seem to emerge from a negotiation between Mrs. Charles and her students, afforded by the high degree of responsiveness and flexibility in her goals and practices. Our analysis explores the role of the inquiry resources that the students brought to the classroom; we investigated how students' ideas and ways of thinking influenced the reasoning and discourse practices that became established and formed the normative activities of the class. Our findings therefore contribute to the literature on the co-construction of scientific inquiry in a classroom where the teacher is sensitive to children's productive resources for doing science.

Context for This Study

The impetus for studying the evolution of inquiry norms arose from our participation in an NSF funded project to develop student and teacher learning progressions (TLP) in scientific inquiry. Often, inquiry is not an objective in itself, but is a means of achieving students' acquisition of correct canonical facts and concepts (Anderson, 2002). In our work, we do not treat inquiry as merely a vehicle for conveying or assessing scientifically accepted understandings; rather, we argue that inquiry should have equal footing as an educational goal in and of itself (Hammer, Russ, Scherr, & Mikesa, 2008). Drawing upon the work by Hammer et al., we define inquiry as "the pursuit of coherent, mechanistic accounts of phenomena," and we believe that students bring productive resources with them into the science classroom: abilities to reason about causes and effects, draw connections to aspects of their experiences, and attend to consistency among ideas and observations (NRC, 2011). Furthermore, we are committed to the idea that elementary science curricula should engage students in talking together, establishing classroom norms for sharing and challenging each other's ideas as the classroom community explores explanations for phenomena.

With respect to teacher professional development (PD), one aim of our larger research project was to understand in-service teachers' development in their ability to facilitate inquiry by being responsive to the productive resources that students bring to the science classroom. In focusing on one experienced teacher, Mrs. Charles, we were forced to carefully and deliberately consider who exactly was responsible for the change in the nature and form of inquiry in her science classroom from one year to the next. An initial analysis of the normative inquiry practices in her classroom led us to prematurely assume that the differences we saw were the result of shifts in Mrs. Charles' instructional goals and epistemological framing of science (Maskiewicz & Winters, 2010). The literature on in-service teacher change largely attributes changes in teachers' practices to changes in their beliefs and goals (Richardson & Placier, 2001). Follow-up interviews with Mrs. Charles, however, led us to reconsider our interpretation of the events within her two classrooms.

Upon closer analysis of the classroom data, we found that Mrs. Charles displayed a striking consistency in her goals for her students and her initial strategies and behaviors in the classroom. Despite this continuity from one year to the next, two very different instantiations of inquiry developed each year. As such, we set out to understand the complex dynamics through which different scientific inquiry norms emerged and became stable in these two classrooms. As our analyses will show, investigating the origins of the inquiry norms revealed that differences in the *students'* approaches to scientific reasoning led to much of the differences in the inquiry practices of the two classrooms.

Background Literature

The Enactment of Scientific Inquiry

The idea that students can and should contribute to the enactment of classroom science is by no means new. Dewey (1933) argued that schooling should preserve and perfect children's ‘‘ardent curiosity, fertile imagination, and love of experimental inquiry’’ (p. 292), and that students should be provided opportunities to link their ideas to their experiences. More recently, the NRC (1996, 2000, 2007, 2011) has proposed that in science class, students should engage in the evaluation of scientific knowledge, where they propose ideas, make claims, and justify their decisions. With this renewed focus on *students* as active pursuers of science knowledge, there remains great diversity and variation in how—and to what extent—students contribute to the scientific understandings and practices realized in the classroom. On one side of this spectrum, the conventional approach emphasizes the role of the scientific expert (e.g., a knowledgeable teacher or a carefully designed curriculum) as the authority for establishing appropriate scientific inquiry practices and content knowledge in the classroom. This is not to say that teachers or curriculum promote memorization of facts or arguments; students are still expected to perform the bulk of the intellectual work, synthesizing information, formulating conclusions, and communicating their ideas to others. However, in examples of this approach, it is the *teacher* who directs the students' investigation (Fradd, Lee, Sutman, & Saxton, 2001; Full Option Science System, 1993; Reiser, Tabak, Sandoval, Smith, Steinmuller, & Leone, 2001) or imparts the rationale for and components of an argument to the students (McNeill & Krajcik, 2008; Osborne, Erduran, & Simon, 2004). Many of these studies also stress the importance of a well-structured or scaffolded curriculum that leads students to adopt appropriate inquiry practices (Cuevas, Lee, Hart, & Deaktor, 2005; McNeill, Lizotte, Krajcik, & Marx, 2006).

Although students have opportunities to participate in the construction of their own understanding of science in these classrooms, this research emphasizes the essential role of the teacher and/or the curriculum as the arbiter of normative science practices (Cuevas et al., 2005; Reveles, Cordova, & Kelly, 2004). For example, a curriculum may institute patterns of scientific practice by prompting students to share and discuss their initial ideas about a scientific phenomenon, perform a scripted experiment that highlights a causal relationship, and then connect their findings back to their initial predictions (Goldberg, Robinson, & Otero, 2006). While students following such a curriculum may bring in unique initial ideas, and are certainly performing intellectual work, the lesson format is scripted and inflexible. In such a curriculum, a student's role is to ‘‘take up’’ the scientific practices promoted either explicitly or indirectly by the classroom authority and representative of the scientific discipline (Driver, Newton, & Osborne, 2000; Fradd et al., 2001). In such classrooms, the negotiation of scientific norms is sometimes conceptualized as a game of tug-of-war, where teachers lobby for scientifically appropriate interactions and students cling to unproductive habits adapted from their everyday experiences (EE) or learned in previous years of schooling (Smith, Maclin, Houghton, & Hennessey, 2000). Not surprisingly, researchers have found that the scientific norms instituted by teachers or structured curricula do not necessarily promote engagement in the desired inquiry practices (Berland & Reiser, 2009; Driver et al., 2000). Rather, the students are oftentimes merely engaged in ‘‘doing the lesson’’ (Ford, 2006; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000).

Resource-Based Focus. In contrast to the above enactments of inquiry, a handful of science education researchers have begun to reconceptualize what classroom science can look like. Informed by research into the proto-scientific ways of thinking and reasoning that children possess innately, these researchers advocate an approach to scientific inquiry grounded in children's everyday ways of characterizing, organizing, theorizing, and arguing about scientific phenomena (Danish & Enyedy, 2006; Hammer et al., 2008; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). Because studies show that children have abundant nascent resources for reasoning about and making sense of the world around them (diSessa, 1993; Louca, Elby, Hammer, & Kagey, 2004; Metz, 1995, 2004; Tytler & Peterson, 2004), this alternate approach to science focuses on bringing forth and building upon students' productive resources (Danish & Enyedy, 2006; Hammer & Elby, 2002; Tang, Coffey, Elby, & Levin, 2010).

Our use of the term ‘‘resources’’ refers to the diverse set of productive assets students have for making sense of the world, which can be grouped loosely into two types of contributions from students. The first type involves concrete, phenomenon-specific intuitions, and experiences that can serve as evidence—whether informally or formally gathered—to inform class-constructed scientific theories (diSessa, 1993). A second category involves epistemological resources (e.g., that knowledge about the natural world can be constructed rather than received from authority figures) and corresponding approaches related to the generation of knowledge (e.g., analogy generation, argumentation, modeling) that can form the nature of the classroom's inquiry activity (Louca et al., 2004; May, Hammer, & Roy, 2006). For example, May et al. (2006) present a case study of a 3rd grade student who generates an analogy to describe how lava exerts pressure on solid rocks, likening the lava to water and the rocks to ice cubes. The student and his classmates continue to reason about this phenomenon, posing arguments, and modifying the lava/water analogy to reconcile inconsistencies. May et al. find within this episode ‘‘specific aspects of nascent expertise in analogy use’’ (p. 316). In this instance, we would identify multiple resources that the student brings to the discussion: experience with water and ice cubes, expertise generating and employing analogies, and resources for recognizing and responding to peers' arguments against his reasoning. We use the term ‘‘resources’’ rather than ‘‘expertise,’’ ‘‘knowledge,’’ ‘‘beliefs,’’ ‘‘skills,’’ or ‘‘conceptions,’’ to emphasize that students' contributions are often composed of small-grain-sized, disjoint, context-sensitive, and value-neutral pieces that serve as building blocks for spontaneously constructed conjectures or activities.

In an approach to inquiry that elicits and builds on students' nascent reasoning abilities, the scientific concepts at play in class are often determined by the insights, experiences, and questions that the students themselves pose (van Zee, 2000). As different groups of children come up with different ideas—or similar ideas but in different ways—teachers find themselves in situations that scripted curricula either cannot anticipate or simply do not address (Hammer, 1997; Levin, Hammer, & Coffey, 2009; NRC, 2007). Although existing classroom studies effectively account for the influence students' ideas can have on the science *content* of the classroom, we contribute to this line of research by illuminating the positive contributions students may bring to the negotiation of normative inquiry practices. We claim that the epistemological and intellectual resources students have for reasoning about phenomena, if recognized and attended to, not only can affect the conceptual ideas that emerge, but also can influence what inquiry activities or practices become established as normative and productive over time. In order for this to occur, however, the teacher must be *responsive* to students' thinking; she must be skilled at recognizing and valuing students' resources as building blocks for scientific inquiry. When teachers are responsive to students' ideas, this can transform how children talk and, ultimately, impact what they learn (Ball, 1993; Jacobs, Lamb, & Philipp, 2010; Pierson, 2008; Sherin & van Es, 2009).

Responsiveness in the Classroom

If students' experiences and resources are to influence both the topics for science discussions and the inquiry norms practiced in the classroom, then the teacher must work to surface students' ideas—eliciting, interpreting, and following up on students' reasoning in the moment, in a fashion that values students' ideas as objects of inquiry (Cohen, 2004; Hammer, 1997; Levin et al., 2009). We refer to this type of classroom environment as r*esponsive*. Responsiveness is defined by Pierson (2008) as ''an attempt to understand what another is thinking displayed in how a conversational partner builds, questions, probes, clarifies, or takes up that which another has said'' (p. 25). In contrast to the environment promoted by a packaged or scripted curriculum, what happens day-to-day in a responsive classroom depends on the ideas and issues that students bring up themselves. The teacher listens carefully to students' ideas and brainstorms—either in-the-moment or between class periods, either alone or with others—what possible next moves might be warranted by the ideas in play. In this way, the direction of the classroom discussion is flexible and difficult to predict.

The teacher does not assume the full responsibility of listening to, assessing, and responding to students' thinking; a truly responsive environment requires every participant—teachers and students—to be responsive to others' ideas and contributions. In a responsive community, the students do the majority of the intellectual work by considering, responding to, and challenging each other's ideas (Cohen, 2004; Lampert, 1990; van Zee, 2000). Students' ideas and wonderings become the terrain for discussions and investigations, and the teacher's and students' expectations for how to pursue a scientific understanding are negotiated over time and vary depending on communal resources. A responsive classroom, therefore, is one in which the students' intellectual and epistemological resources are cultivated (Ford, 2006; Hammer, 1997; Louca et al., 2004). As such, the practices of inquiry that become normative are co-constructed by teacher *and* students, not passed down from a classroom authority.

The Role of the Teacher

As described in the resources literature cited above, children come to the classroom with valuable ways of theorizing about scientific phenomena. The notion of responsive teaching, in conjunction with this literature on children's nascent resources, suggests a possible social dynamic through which children's ideas and reasoning can become the building blocks for both the *process* of scientific inquiry and the scientific understandings that constitute the *products* of inquiry. In this social dynamic, students and teacher share the responsibility of proffering, taking up, or vetoing classroom scientific practices, allowing the whole community to take part in negotiating productive norms while simultaneously engaging in the intellectual work of inquiry itself.

The teacher's role in facilitating scientific inquiry responsively is quite different from what her role would be in a traditional science classroom. For instance, listening and attending to the sense students are making, rather than focusing primarily on how their responses align with curriculum-prescribed scientific concepts or skills, can be challenging even for experienced teachers (Empson & Jacobs, 2008; Hammer, 1997). In addition to mastering the complexities of *really* hearing the substance in students' ideas, the teacher needs to be responsive in a way that engages the entire classroom community in considering the merits of those ideas. Responsive practices, however, can contrast with the social and institutional objectives to which teachers are often held accountable (Levin, 2008). Extensive, targeted PD, ideally conducted within a community of teachers, is needed to help teachers learn to facilitate inquiry in a way that is responsive to the ideas and resources of their students.

Several PD projects in mathematics have focused on helping teachers learn to invite, support, and respond to learners' ideas (Carpenter, Fenneman, Franke, Levi, & Empson, 1999; Cohen, 2004; Jacobs et al., 2010). Based on the premise that children bring an intuitive knowledge of mathematics to school with them, Carpenter et al. (1999) worked to help primary school teachers elicit children's mathematical thinking and problem solving strategies so that these resources could serve as the basis for mathematics instruction. With a similar focus on students' thinking, both Cohen (2004) and Hammer and van Zee (2006) offer case studies of teachers in the midst of changing their practice. This work looks at teachers discovering how to create classroom environments where the learners' mathematical or scientific ideas were invited, encouraged, and treated with careful consideration. While the existing literature looks at teachers' progress in becoming more responsive to students, it does not explicitly consider the implications for the co-construction of normative classroom practices. Our work aims to build on extant work on teacher responsiveness by documenting and analyzing the evolution of scientific inquiry practices and norms in a responsive teacher's classroom.

Background: The Professional Development Project

Thirteen practicing 3rd through 6th grade teachers from a large school district in southern California volunteered to participate in a PD project. A central goal of this 3-year PD and research project was to improve teachers' responsive facilitation of scientific inquiry while simultaneously documenting teachers' and students' learning progressions. These 3 years of PD (2008–2011) included 1- to 2-week summer workshops, 2-hour biweekly teacher meetings throughout the school year, and, for some teachers, one full-day workshop held just prior to classroom implementation of project curriculum. During workshops and biweekly meetings, teachers participated in two primary activities: (a) "science-talks" designed to engage the teachers in scientific inquiry (Gallas, 1995; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001); and (b) discussions of classroom video—often taken from their own classrooms—where children's scientific reasoning was on display (Hammer & van Zee, 2006; Sherin & van Es, 2009). The science talks provided an opportunity for the teachers to experience sustained inquiry, where their own ideas were elicited, validated, taken up, and extended by their peers. Throughout each summer workshop, for example, the group developed theories, posed questions, and investigated phenomena within a single scientific domain. These experiences were intended to help teachers view science as engaging in collaborative discourse to make connections, provide support, question, clarify, generalize, and refine explanations. For the video discussions, the range of activities included identifying and interpreting the students' ideas, reasoning about the scientific phenomena itself, and proposing possible ways a teacher might respond in order to build on the students' reasoning. These PD activities provided opportunities for participants to experience a responsive learning environment where *inquiry*—not acquisition of predetermined facts—was the goal, and to develop their ability to listen with deep understanding to the substance of children's ideas (Coffey, Hammer, & Levin, 2011).

One 15- to 20-hour modular unit per grade level (Grades 3–6) was developed by our research group to provide teachers a generative context that would facilitate teacher responsiveness to students' scientific thinking. As opposed to focusing on specific content objectives, the PD and curricular materials highlighted scientific inquiry as the primary objective (Chinn & Malhotra, 2002; Hammer et al., 2008). The modules consisted of an opening question and several possible follow-up questions that would allow space for students' ideas and reasoning to become explicit and be considered, investigated, and expanded upon by those in the classroom community. The water cycle served as the scientific context for the 5th grade module. Teachers posed the following question to their students during the first day of the module:

> Suppose that one night it rains. When you arrive at school you notice that there are puddles of rainwater in the parking lot. But when you go home you notice that the puddles are gone. What happened to the rainwater?

Rather than follow a scripted curriculum, teachers were encouraged to spend the next 15–20 classroom hours pursuing ideas and questions that students brought up during the discussion of this first question, with the goal of helping the class develop coherent, mechanistic accounts of phenomena related to water cycling.

Selection of Case Study Teacher and Classroom

Although all of the participating teachers had 5 or more years of teaching experience, the research shows that even experienced teachers have difficulty hearing the substance in student thinking (Coffey et al., 2011; Empson & Jacobs, 2008; Sandoval, Deneroff, & Franke, 2002; Sherin & Han, 2004). To trace the processes by which teachers develop in their ability to be responsive to students' thinking—a research goal that was central to this project—several research project members each followed a different teacher for an extended period of time (Lineback & Goldberg, 2010; Maskiewicz & Winters, 2010; Weller & Finkelstein, 2011). For this study, we chose to follow Mrs. Charles, a 5th grade teacher with 17 years of experience, because she was one of several teachers who took very quickly to the practice of giving students space to express their ideas. From the initial opening question about a puddle, Mrs. Charles facilitated discussions and encouraged everyday reasoning about various topics related to evaporation. Her classroom interactions and follow-ups demonstrated a variety of clearly responsive moves: she provided space for students to articulate their ideas; she took up student thinking by rephrasing, challenging and building on it; she probed for further clarification; and she shifted the direction of the discussion in ways that addressed student ideas.

A 2-year study of Mrs. Charles' science class revealed that in both years the students engaged in the pursuit of explanations for phenomena, but the nature and form of inquiry were different each year. In year 1, the students spent a majority of class time planning, implementing, and debriefing experiments in pursuit of using empirical evidence to support their ideas and distinguish between competing claims. In year 2, the class spent much more time reasoning about puddle phenomena in terms of their experiences from everyday life, and collectively worked to develop theoretical explanations of evaporative processes.

Research Focus

This present study explores the question of how these two very different instantiations of inquiry emerged during the water module implementations in two successive years of Mrs. Charles' class. Longitudinal observations from Mrs. Charles' 5th grade science classroom forced us to carefully and deliberately consider who exactly was responsible for the change in the class activities and norms. We found that her facilitation of inquiry could not be meaningfully considered apart from the unique epistemological and intellectual resources of the students in the classroom. Thus, we set out to understand how the students' resources, the curriculum, and the teacher collectively created the complex ecology of the classroom. A 2-year case study of Mrs. Charles' classroom provides an in-depth investigation of the interplay between teacher and students, illuminating the process by which they co-construct classroom inquiry practices (Becker et al., 2005).

Methods

The Students in Mrs. Charles' Science Classes

Mrs. Charles is a 5th grade teacher at a public magnet elementary school in Southern California. One-fifth of the students at the school qualify for free or reduced lunch, and more than 20% are of Hispanic descent. In year 1, Mrs. Charles' science class consisted of 32 5th grade students, with three students designated as special education and three as second language learners. All students were in Mrs. Charles' classroom full-time for all academic subjects. Mrs. Charles began the module during the spring semester of year 1, spending just under 13 hours on the module over the course of 4 weeks. Several weeks prior to the module, Mrs. Charles' student teacher led the class in developing science fair projects where each student devised a research question, conducted an experiment to test the question, and presented the results on a poster. Although the student teacher planned and conducted some science lessons prior to the module implementation, Mrs. Charles facilitated the entirety of the water module.

During the second year of the study, Mrs. Charles' science class consisted of 38 5th grade students, with four students designated as special education and one as a second language learner. Mrs. Charles began the module in the second half of the fall semester, spending just over 13 hours on the module over the course of 5 weeks. Relevant to this study is the unique background of some of her 38 science students. Thirty-two were full-day students in her own classroom, and 6 came to her for science from the classroom of a different teacher whom we will call "Miss Kelly." Miss Kelly taught a mixed 4th/5th grade combination class, and was also a participant in our PD program. Although Mrs. Kelly's 5th graders went to Mrs. Charles for science, our data from Miss Kelly's classroom and her post-instruction debriefing sessions reveal that like Mrs. Charles, Miss Kelly was exceptional in her ability to elicit student thinking. Additionally, 11 of the 38 students in year 2 had completed 4th grade science with another teacher from our PD program who practiced responsive teaching.

In both years, Mrs. Charles began the water module with the same opening question about the disappearing puddle (see above). An in-depth description of the events that occurred in each class following the opening question is provided in the Findings Section.

Data Collection and Analysis

In our investigation into Mrs. Charles' classroom, we utilized ethnographic methods to understand how the teacher–student and student–student interactions that took place during science talks and investigations led to the co-construction of normative inquiry practices. The data sources for this study included video recordings of Mrs. Charles' implementation of the 15-hour module during two consecutive school years for a total of approximately 30 hours of classroom video. Two videographers were present in Mrs. Charles' classroom, with one camera following Mrs. Charles and the other camera following a focus group of four students. Cameras were stationed at the periphery of the classroom to remain as unobtrusive as possible. Mrs. Charles wore a transmitting microphone that captured all of her utterances and the utterances of students with whom she interacted. These means of data collection provided records of whole class discussions, all small group discussions within the focus group, and all teacher–student interactions. When the class went outdoors to experiment, the videographers followed the focus group and Mrs. Charles with hand-held camcorders. Additional data included classroom field notes taken by the second author, video and field notes from Mrs. Charles' debriefing sessions with the second author after each day's instruction, and three extended interviews with Mrs. Charles conducted by both authors; details of these interviews are included below. When resources permitted, student artifacts were also collected for this study.

Analysis of Mrs. Charles' classroom proceeded in phases, as unexpected findings led us to pursue new avenues of analysis. Observations from the classroom and PD meetings led the second author to initially question if changes in the classroom practices between years could be attributed to changes in Mrs. Charles' objectives for her students. Therefore, formal analysis began with both authors independently viewing all of the classroom video to determine the extent of the teacher's responsiveness. For the purposes of our analysis, we use the term *responsiveness* to mean noticing and responding to a student's idea either by rephrasing the idea, probing for further clarification, or shifting the direction of the discussion in a way that addresses the idea (Levin et al., 2009). To uncover any changes in the extent or character of Mrs. Charles' responsiveness, we compared analytic memos of classroom episodes selected from years 1 and 2, summarizing student ideas and interpreting Mrs. Charles' responses. We transcribed several segments of classroom discourse and uncovered differences in the students' inquiry practices between the two years. These differences were notable in that we could not easily attribute them to shifts in the teacher's practices (see Findings Section for details). This inspired us to conduct two semi-structured interviews (4 hours total) with Mrs. Charles in order to elicit her interpretations of specific classroom events and to understand particular choices she made. The interviews consisted of informal conversations, primarily about her students and her teaching, and stimulated recall (Clark & Peterson, 1986) using segments of classroom video. Stimulated recall episodes were chosen in which the authors had initially formed multiple possible explanations for Mrs. Charles' instructional moves, and corresponding prompts and interview questions probed her interpretation of events and the intent behind her actions (e.g., Tell us about what was happening during this exchange. How did you decide to follow up on Sam's idea but not Tony's?, What inspired you to start class with that particular question?, etc.). After transcribing and discussing the interview data, we were still unable to account for the differences in the classroom inquiry practices as changes in Mrs. Charles' goals and objectives for her students. We returned to the classroom video and viewed all the video again to identify how the students' inquiry resources influenced the norms and activities of the classroom. As part of our analysis, more than 75% of the 30 hours of classroom data was transcribed.

To understand the emergence and development of the types of inquiry practices that became established in each year, we coded all classroom time spent during years 1 and 2 on the water cycle curriculum module. We chose three coding categories to distinguish the inquiry activities of the classroom: *Structured Experimentation* (SE; including conducting experiments in the classroom and discussing those experiments both empirically and theoretically); discussion of everyday experiences (EE) (empirical and theoretical discussion based on experiences, but unrelated to classroom experiments); and discussion that was *Ambiguous* (A) in that it was unclear which category it fit best. Further details about this coding scheme are included in Table 1 and in the Results Section. Each author coded one day of science class from year 2, and after comparing our codes and revising the coding scheme, we each coded one day from year 1. We negotiated any remaining discrepancies in our coding, and then the first author coded all remaining classes for both years. Transitions from one code to another were made only if the activity changed for at least 1 minute. This decision was based on the assumption that if the students or the teacher were really taking up one another's prompting, then it would be sustained for at least 1 minute. This allowed brief or momentary diversions in activity to be rejected as emergent transitions.

After coding all of the classroom activity as SE, EE, or A, we used an interpretive analysis cycle (Clement, 2000) to continue analyzing video episodes and transcripts. In this

Table 1
Coding scheme examples for structured experimentation and everyday experiences

Structured Experimentation	The planning, executing, discussing, and interpreting of experimental endeavors and their results
Year 1	[The students are explaining their experimental results to the whole class] **Teacher**: So what do you think Ally? . . .Did you think that would happen? **Audrey**: No. I thought the warmer would evaporate first because it's hotter **Jake**: That's what we thought also **Teacher**: Which is kind of weird. Serena? **Tiffany**: I don't know, because maybe [the cold water] evaporated faster because it was a hotter day. And maybe on a colder day the warmer [water] would [evaporate faster]? **Teacher**: So you think outside temperature might influence what they found out? **Tiffany**: It might, but I don't think it *should*. But that's something to test
Year 2	**Teacher**: Stop [this discussion] for a second. Bob is driving me absolutely nuts, and I'm kind of laughing at it now. Because Bob's actually playing with the ideas we're talking about. Bob's sitting here with this nice [test] tube, . . .but he's over here going like this. [blows into tube] And he's making it foggy. And all of you keep talking about, "this trapped air seems to be causing the moisture." Mandy brought it up. Somebody said, "maybe it has to do with the room size, the space." Is there a way that I could use this and something else to prove to myself: does room size matter? What could I do? What do you think? What could I do? What do you think, Rita? What could I do? [calls on students, asking "what could I do?", less than 2 minutes] **Teacher**: Weren't we talking about room size of trapped air causes more moisture? Is this room size in this [container] different than this container? **Class**: Yes **Teacher**: Is the room size in this [container] different than these two containers? **Class**: Yeah **Teacher**: So, technically, if I had three of you [pause] take a deep breath, blow in them all the same, cover them up [pause] we should see a difference of moisture in each one, if it truly is caused by room size or container size. Would you agree? [Students: Yes. Yeah]

(Continued)

Table 1
(Continued)

Everyday Experiences	Both empirical and theoretical discussion and debate about scientific phenomena that did not in some way involve experiments performed at school
Year 1	**Trentin**: Well, um, the heat comes down on the parking lot, and the parking lot is really big. Then the heat won't go to that one little water spot, it will go everywhere and it won't be as hot in that water spot. If its smaller, it will focus in on that, on a littler spot and it will be hotter **Teacher**: You can talk to him. You already brought it up, I'm just standing here **Tiffany**: Um, well I think that the size of the parking lot doesn't really matter because, . . .when, um, like, it depends how big or small the puddle is, because the puddle is like. . .it's pretty big, and it doesn't matter because the heat is going to come down anyways. But if the parking lot is really small, then it's going to go down another place **Trentin**: Well, well, any size puddle, it will be, if the parking lot is bigger, like I said, it will be, like not as hot because the heat will go everywhere. And it has to cover all that surface ''cause'' it's attracted to black **Tiffany**: I also think that because, if it's like, um the blacktop that we have, or b/c if it's, if the parking lot is black, then yes, that table is right, but if it's like dirt, then that doesn't really matter because it could be dirt. Like, they could be in the middle of constructing something, and- **Trentin**: -but we said it was asphalt **Tiffany**: Yeah, but my point is like, I don't think it does matter. But, it's like (unintelligible) **Teacher**: Arlene, do you want to add something to it? **Arlene**: It actually does matter, because if the parking lot is bigger, the sun would go *everywhere* in that parking lot and the sun wouldn't go in that one area where the puddle is. And if it's small, it would be hotter because its more area and more heat would be able to go in there, in that one area **Teacher**: Roy, you are shaking your head. What's going on? **Roy**: Wouldn't the sun go to every single place?
Year 2	**Teacher**: So that's what I'm trying to figure out, does it matter, if I take a cold shower or a hot shower, about this foggy mirrors and windows and the walls being damp, does it matter? **Class**: No. Yeah. If it's like freezing cold out, then. **Teacher**: Whoa, you're treading on each other. . .Megan, you were over there starting to argue, what's wrong? **Megan**: Well, what's wrong is. . .my mom and dad keep their [bedroom] door shut. They have a bathroom in there, so [my dad] keeps the bathroom open, and [the moisture] wears off. But, um, so when he takes a shower he comes out, there's no moisture, but when he closes the [bathroom] door, he comes out with fog. So, like you step outside, the air's trapped, which just makes it moist **Teacher**: So wait a minute, so you're talking trapped air **Wendy**: I leave my door open, and there's no fog. [Students: Yeah] But then my brother closes the door and there's a lot of fog **Teacher**: Why, what's going on? [Students: I think that. . .] Okay, Holly, go **Holly**: I think it matters, the structure of the room. Going back to the steam in the bathroom. Because. . .when Rita said, when she takes a cold shower, none of the mirrors fog up. But when Megan said, when [her dad] took a cold shower, the mirrors are fogged up. So I think it just matters what the structure of the room is

cyclical analysis, we proceeded to modify our interpretation of what occurred in each classroom until we found a pattern that fit the data and presented a reasonable, coherent account of how the differences in these two classrooms emerged. There were only a few segments of year 2 class time that presented challenges for us because Mrs. Charles uncharacteristically asserted her authority as the teacher by directing her students to perform a particular task. In the end, our broader focus on Mrs. Charles *together with the students* allowed us to account for Mrs. Charles' common classroom practices *and* the aforementioned instances of atypical behavior in a way that aligned with her stated goals, her interpretations of classroom events elicited during stimulated recall, and our own interpretations of classroom video.

Findings

From close analysis of the data, it was evident that the instantiations of scientific inquiry in Mrs. Charles' two consecutive classes differed. We set out to understand what contributed to the different inquiry activities that came to constitute the classroom inquiry norms in each year. In both years, students identified and considered factors and scenarios pertaining to evaporation, bringing in resources for understanding concrete phenomena, but in very different ways. In year 1, the students drew on epistemological resources for empirical investigation, approaching the task of understanding evaporation by considering and implementing testable scenarios. In year 2, everyday experiences and personal anecdotes served as the primary context for conjectures and reasoning about the water cycle. The epistemological resources students brought to bear involved every day experience as a starting place for sense making. We exemplify these findings and describe the evolution of the two class's inquiry practices below. First, we provide a quantification of the amount of time each class spent on particular types of activities and discussions, and elaborate on some distinctions between those types of activities. Second, we look at pivotal points in the module where the strengths and resources of the students, afforded by Mrs. Charles' responsiveness, shaped the image of scientific inquiry that became stable in the classroom. Third, we illustrate the similarities in Mrs. Charles' pedagogical objectives in both years to challenge the claim that the differences in classroom activities were primarily the result of intentional teacher change.

In sharing our findings, we often provide transcript evidence to support our claims. The use of [brackets] indicates additions to the spoken word intended to clarify or contextualize the exchange. Portions of transcript are underlined to draw attention to particular statements. Three dots (. . .) indicate omitted utterances.

Quantification of Time on Classroom Activities

An analysis of the data revealed different inquiry characteristics between years 1 and 2, as evidenced by how each class of students spent their time posing questions and pursuing explanations. Using the "SE/EE/A" coding scheme described earlier, we found that in year 1, the class spent 85.5% of its time engaging in SE or discussion that might be related to experimentation ("A"). The year 1 class spent only 14.5% of its time in discussions and activity grounded in EEs that were distinctly unrelated to classroom experiments (EE). In year 2, the class spent 66% of its time in EE discussions, and only 34% of its time directly (SE) or possibly (A) related to experimentation (Figure 1).

Structured Experimentation. Structured Experimentation involved the planning, executing, discussing, and interpreting of experimental endeavors and their results. In year 1, students did much of the intellectual work of experimentation. The class was arranged in small groups of 3–6 students. Each group decided what it wanted to explore, planned,

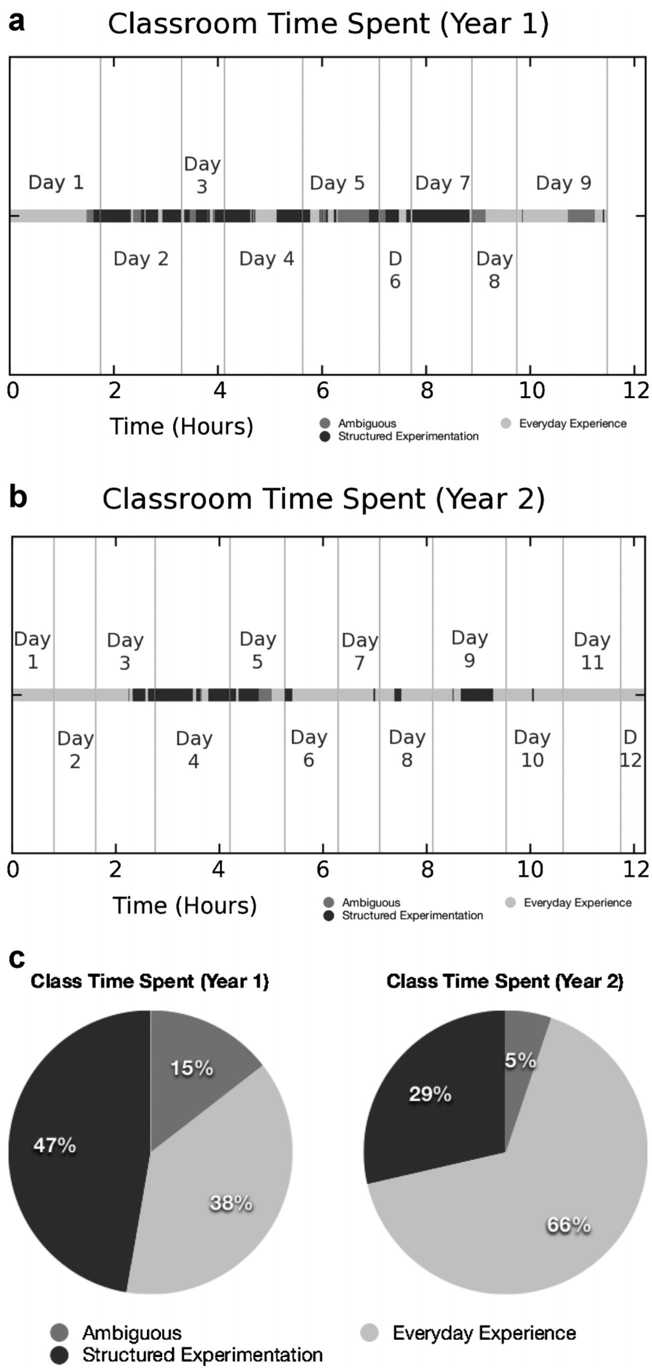

Figure 1. Representations of how each class of students spent their time during science. SE, structured experiment; EE, everyday experience; A, ambiguous. The figure at the top (**a**) and (**b**) represents timelines of years 1 and 2 revealing the repetitive nature of particular activities, while (**c**) summarizes the proportion of time in each type of activity for the entire module.

and carried out its test, and reported interesting revelations to the teacher and classmates. Groups worked independently except during whole-class discussions or when Mrs. Charles encouraged certain groups to compare their experiences. Mrs. Charles took on roles such as questioner, facilitator, devil's advocate, and sounding board; while her interactions with students influenced each group's work, she never used her status in the classroom to prescribe procedures or assign research questions. Students turned to Mrs. Charles for help finding equipment for their experimental designs, and sometimes to share unexpected results or the wonderings inspired by their experimental endeavors (see Table 1 for examples of SE classroom discussion). While coding year 1 data we found that four cycles of SE occurred during the module. Each of these experimentation cycles consisted of students (a) generating a variety of questions while discussing some aspect of the puddle, (b) selecting which questions to pursue, (c) designing and implementing experiments to test those ideas, (d) reporting outcomes, and (e) finding new questions and topics of investigation. Each cycle lasted approximately 2–4 hours spread over one to two class periods, and students spent a considerable portion of this time engaged in empirical investigation. This overall organization of the module emerged from Mrs. Charles and her students rather than from PD or project directives.

Although both years 1 and 2 had segments coded as SE, this activity was typically much more scaffolded in year 2 than in year 1. For example, year 2's class only carried out *one* cycle of independent group experimentation, and spent a larger proportion of this time in teacher-led discussions about what constitutes a testable idea. There were two notable subsequent instances coded as SE in year 2 (Figure 1b). Both were inspired by student comments, but the experiments were proposed and led by Mrs. Charles. The class discussion in Table 1—about showers fogging up bathroom mirrors, and the effect that room size and shape have on this phenomenon—inspired Mrs. Charles to lead the class through a demonstration to model that idea (see Table 1, Year 2, both transcripts). Mrs. Charles selected three students, gave each student a glass container of a different shape, instructed the students to blow into their container and trap their breath inside, and then led the class in a discussion of what they saw. The second instance of experimentation in year 2 had a similar amount of teacher scaffolding.

Everyday Experiences. In both years, the activity coded as EE consisted of discussion and debate about scientific phenomena, but did not in some way involve experiments performed at school. Most of this discussion involved concrete examples and reasoning about the water cycle, with occasional brief meta-discussions (lasting less than 1 minute) related to how and why the class—and the greater scientific community—does science. Notice in Figure 1 the long stretches of EE discussions that took place in the middle of the module in year 2. In many of these instances, the students drew on resources for seeking coherence, reasoning mechanistically, constructing and using models, drawing connections and generalizing from examples, and identifying and reconciling inconsistencies between conflicting evidence. These resources are quite often visible during SE as well; however, the resources related to the nature of knowledge and its construction differed greatly between SE and EE. While SE activity was dominated by epistemological resources associated with knowledge as empirically driven (''seeing is believing''; ''the data speaks for itself''), EE activity involved resources associated with knowledge as constructed through logic and debate, with prior everyday experiences serving as the basis for knowledge construction. As such, persuasive explanations did not require evidence gathered through formal experimental methods.

Throughout EE discussions, students posed questions about everyday observations related to water phenomena, and in both small groups and whole class discussions, the students developed possible explanations and new wonderings to share with the class. Questions, conjectures, and debates were couched in stories from the students' experiences (examples provided below). This is not to say that students did not discuss personal experiences during SE, but rather, that SE discussions and activities were directly related to formal experimentation, while EE conversations were rooted in personal experiences without reference to any specific controlled experiments. In year 1, the EE conversations during the middle of the module were brief and often involved conjecturing about causes and associations in hypothetical situations (Table 1). The EE discussions that took place at the beginning of the module were similar for both years as the students posed explanations and questions related to the opening puddle question.

Instances where it was unclear whether or not a discussion was related to a past or future experiment were coded as A. Occasionally, in both years 1 and 2, Mrs. Charles led the class in reflections on the nature of the class's inquiry in relation to scientists' work, technological innovation, and learning in general. Any of these reflections or meta-discussions lasting longer than 1 minute were coded as A. Time spent on classroom management was also coded as A.

The Interplay Between Teacher and Students

In this section, we demonstrate how the science that the students engaged in during the module was the result of a negotiation or mutual signaling between the students and teacher. As previously mentioned, Mrs. Charles began years 1 and 2 of the module with the same question about a disappearing puddle. In both years, the first few hours of the module progressed similarly; after a couple of hours of discussion, Mrs. Charles prompted the students to design experiments to test their conjectures. Each small group of students designed and conducted its own experiment without any rigid structure imposed by Mrs. Charles. In year 1 the discussion following the experiments led to another round of experiments, while in year 2 a discussion of experimental findings quickly shifted to explanations and conjectures about everyday phenomena related to evaporation and condensation. Because both classes were quite similar for the first 3 hours, we describe in more detail how these classes transitioned to divergent paths *after* the first round of experimentation. Our data provide further insight into the complex dynamics of the classrooms and offers an explanation for the development of different normative inquiry practices each year.

Year 1. Opening day (hours 1 and 2). Upon posing the opening question about the disappearing puddle, Mrs. Charles gave the students a few minutes of "personal think time," and then elicited students' ideas about what happened to the puddle creating a long list of ideas on the board. For the next 30 minutes, whole-class and small-group conversations focused on evaluating and clarifying (e.g., defining the difference between "evaporate" and "absorb") the proposed ideas. Mrs. Charles encouraged students to consider and discuss which ideas could be eliminated from the list. One student suggested that the original puddle question needed to be more specific, and this shifted the whole class into discussing various factors that would affect the puddle (e.g., size of the parking lot, amount of sunlight, if cars drive over it, etc.). After sustained discussion and sharing, Mrs. Charles asked the students: "What do you think we should explore up there [on the white board], and how do you think we should explore it?" The students responded by proposing that they try out their ideas for what happened to the puddle, and the following day students began working in small groups to design their own experiments to test a specific variable that might affect the puddle. The experiments included testing rates of evaporation under varying conditions (warm vs. cold water, 1 cup vs. 2 cups of water, sun vs. shade, dirt vs. asphalt). Although these students had been working on their science fair projects prior to the module—and several groups' use of measurement and control of variables reflected this—Mrs. Charles did not establish any structure or guidelines for the puddle experiments, and the experimental questions the students chose to pursue were their own, not Mrs. Charles'.

Hour 3—Students draw conclusions and generalize from experimental findings. On the second day, in the last 10 minutes of class after completing their first experiments, several small groups reported their experimental findings. Mrs. Charles followed up by asking students: ''So what do you guys think you learned from what you did?'' Students spontaneously made connections between their experiment and their results, drawing conclusions from their findings. For example, Jason's exchange with Mrs. Charles includes a description of his findings and a generalization about what that means for evaporating puddles:

1	Mrs. C:	Did anyone else do something with shade? Took longer in shade then sun?
2	Jason:	We also measured temp in shade and sun. We don't have an exact temperature in shade, 31°C, direct, 40°C
3	Mrs. C:	What did you find out?
4	Jason:	In the shade, after 5 minutes, we thought about one-fourth evaporated, and. . .in sun, we thought about one-third evaporated. And then, a total of 10 minutes after we started, in the shade, about one-third evaporated, and then in the sun, like pretty much all of it
5	Mrs. C:	So in the shade there was still water on the ground, and in the sun there wasn't really?
6	Jason:	There was just a little puddle.
7	Mrs. C:	So what would you say, a statement might be [about] what you think you now know?
8	Jason:	That in the shade, it doesn't evaporate as much
9	Mrs. C:	So evaporation is slowed in the shade (writes on board). Anyone else agree?
10		[lots of hands raised]

Here Jason described his experimental results and concluded that water in the shade does not evaporate as quickly as water in the sun. The simplicity with which Jason made a conclusion based on his group's findings is representative of all five groups that shared out. Different groups' experimental investigations led them to make various conclusions about puddle evaporation, such as: water that was deep didn't evaporate as quickly as water that was ''spread out''; water in the shade evaporated slower than water in the sun; fog unexpectedly formed inside a moist tube in the sun; and ''stuff'' can be seen rising off evaporating puddles. In the example above, as was the case throughout the module, Jason's response is not constrained and guided by traditional, highly scaffolded and structured curriculum. His generalization comes in response to two prompts from Mrs. Charles (''What did you find out?'' and, paraphrased, ''What [do] you think you now know?''), both of which could have been interpreted differently. Evidence from year 2 shows that many students did not immediately abstract what they ''now know'' from their experimental results, but instead responded to Mrs. Charles' questioning by making connections to their everyday experiences.

Hours 3 and 4—Students propose and critique ways to design tests. Mrs. Charles began the class period that followed the first round of experiments (day 3) by reviewing the conclusions shared aloud the previous day. As she was summarizing, she stated: ''We found out that if [the water] spreads out really fast, it evaporates quicker.'' A student raised his hand and offered an unsolicited explanation for these findings:

> Parker: Because, the reason [why the water evaporated faster] is because when there's more surface area of the water, the faster it evaporates. Because the surface area of the water, the surface of the water, is where the evaporation happens. And then when there's

> less, when there's a big area, when you put [water in] this thing [cylinder] it would evaporate slower because there's more, the water's right up to there [on the cylinder].

Here Parker offers a causal explanation for why water evaporates faster when it is spread out on the ground as opposed to contained in a cylinder: evaporation happens on the surface of the water, so there is more area for evaporation to occur when the water is spread out. After a brief class discussion about the meaning of surface area, Mrs. Charles proposed that the class ''explore'' Parker's conjecture about surface area. In the excerpt below, notice that although the students did not independently decide to test this idea, when prompted by Mrs. Charles to ''do that'' and ''explore that idea,'' the students immediately began making suggestions for how they could design such an experiment:

1	Mrs. C:	So surface area. How would you go about doing that? How might you want to explore that idea, to make sure that your thinking is accurate? Colin?
2	Colin:	Take the same amount of water, it might be a cup, then maybe another one [with] the same amount of water in a pie pan
3	Mrs. C:	Okay, so pie pan and anything else?
4	Colin:	Then you could say a cup made out of the same material with the same properties as the pie pan
5	Mrs. C:	Cup of same material. So you kind of want one that, let's see if I can draw this, looks something like that (draws on board). And one kind of like that?
6	Colin:	Yeah
7	Mrs. C:	Would that be okay (to the class)? Would that work, do you think?
8	Students:	[nod yes]
9	Mrs. C:	Okay, so that's something we can try. What else, Skylar?
10	Skylar:	I guess you can basically do the same thing but with a Petri dish and one of those
11	Mrs. C:	So a Petri dish and a graduated cylinder? That would work. So I'm guessing this is the Petri dish, and this is the graduated cylinder? . . .Okay. Yes, Jason?
12	Jason:	And what the surface area experiment, we can also find out with is, the Petri dish, it also has less depth. You can also learn about the depth, how it
13	Mrs. C:	Ooh, so not only surface area, but we can deal with depth of water as well? So kind of two birds with one stone maybe? Okay

Note how the students responded to Mrs. Charles' prompt by offering ways to design an experiment, controlling for variables by using a ''cup made out of the same material with the same properties as the pie pan.'' Skylar refined Colin's idea by proposing known containers of different dimensions that are made out of the same material (graduated cylinder and Petri dish), and Jason identified an additional variable that Colin's procedure could test (''You can also learn about depth''). These comments illustrate how year 1 students drew on existing resources—most likely developed and reinforced during prior classroom science—to generate testable questions and appropriate experimental designs. Following this discussion, a student asked Mrs. Charles *when* they would be able to ''try this out,'' indicating that the groups were eager to implement their experimental designs. Indeed, during debriefing sessions, PD meetings, and interviews (described later in more detail), Mrs. Charles described her year 1 students as inventive and eager ''doers'' of science.

Hour 4 and beyond—Experimentation emerges as a normative inquiry practice. As the lesson continued, the class began debating whether the ''stuff'' most groups saw rising from their puddles during the first round of experimentation was water vapor or heat. The majority of students seemed to be referring to what they saw as ''water vapor.'' Mrs. Charles asked the students: ''Okay, so we have a puddle, and we have water vapor. So now I'm going to throw out a tough question: How do you know it's water vapor? How do you know?'' By the end of the 4th hour of the module the students were proposing new experiments to show how one might collect evidence to prove whether water vapor rises from a puddle.

Upon completion of the module, the students had conducted four rounds of self-directed experimentation. Collecting empirical evidence to prove one's claim became the normative practice in response to several types of questions frequently posed by Mrs. Charles (e.g., ''How do you know?'' ''What would you do to find out?'' ''How would you prove that?''). Even in situations where one's prediction contradicted the empirical findings, the students drew on other past experiments and personal experiences to make conjectures about factors that might affect evaporation, and proposed future experiments to verify their new conjectures. For example, after the third round of experiments, one group shared their unexpected findings with the class that cold water evaporated faster than warm water, despite ''spreading out the same on the ground''. (See Table 1, SE, Year 1 for a transcript excerpt.) This dialog shows students considering factors that affected the evaporation of a puddle. They referred to quantified experimental results, generalized from their data, and tried to reconcile this with their common sense expectations. For instance, Tiffany's suggestion that cold water ''evaporated faster because it was a hotter day. And maybe on a colder day the warmer [water] would [evaporate faster]'' expresses a clear, inverse relationship between air and water temperature. Further, Tiffany's proposal that ''that's something to test'' suggests that a norm had been established in the classroom in which conjectures can gain or lose credence through empirical validation.

The students in this class, over the course of several weeks, spent a substantial amount of time reasoning about the effects of different variables on water and evaporation, foregrounding the role of experiments as a way to test their ideas. Mrs. Charles prompted students to ''prove'' and ''test'' their ideas, and students readily took to designing and implementing experiments to test the impact of a variable on puddle evaporation. By being responsive to the class's interest in conducting controlled experiments, Mrs. Charles allowed and facilitated four rounds of experimentation during year 1's module implementation. This enactment of science is quite different from the type of inquiry displayed in the year 2 classroom, where personal experiences played a more important role than formally gathered experimental results.

Year 2. Opening days—(2 hours Over 2 days). Mrs. Charles began year 2 with the same question about the disappearing puddle, and again, a long list of ideas was generated on the board about where the puddle may have gone. Similar to year 1, evaporate versus absorb emerged as a distinction that was contentious within the classroom, but Mrs. Charles did not use her authority as teacher to resolve the issue. Instead, she allowed the students to discuss the difference, and although many students suggested that the puddle evaporated as in year 1, there was a lack of consensus among year 2 students about whether a puddle could ''evaporate'' down into the ground. For much of the first 2 hours, the students engaged in small-group and whole-class discussions about the merits of the ideas on the board. As in year 1, Mrs. Charles encouraged students to consider which ideas could be eliminated from the list. At the end of the second hour, she asked the students what they currently thought happened to the puddle, adding: ''If you could have any of those questions [listed on the board] explored, what would you want explored?'' Many of the students did not write a question to explore, but rather restated a claim about the puddle. Mrs. Charles spent some time at the beginning of the 3rd hour helping students develop ''testable'' questions for their self-directed experiments. Halfway through this 3rd hour, small groups were designing independent, unique experiments to test their own ideas about what happened to the puddle.

Hours 3 and 4—Mrs. Charles scaffolds interpretation of experimental findings. Because many of the ideas on the board involved evaporation, and there was a sustained discussion about whether evaporation goes up or down, most of the groups designed experiments to explore *where* the water goes (i.e., up into the air or down into the ground). As in year 1, Mrs. Charles encouraged each group to share the findings of their experiments. While year 1 students summarized findings, cited numerical data whenever possible, and readily drew conclusions from their experiments (see Jason's exchange with Mrs. Charles above), year 2 students recounted their experiments in a more narrative format. One group, for instance, examined what occurred over 48 hours in two test cases—water trapped within a closed bottle and water contained within an open bottle—to collect evidence of water evaporating "up." Mrs. Charles asked the group to share their findings with the class: "So go ahead and tell us, what did you guys do, what were you trying to figure out, and what do you now know from what you did?" Lana responded by describing her group's procedure as the *story* of what they did experimentally, and noted their observation that there was still water in the bottom of the bottle. Lana's narrative followed the experimenters rather than the phenomenon itself, and consequently, she did not note the drops forming at that top of the bottle or explain the implications of this finding; that water evaporates up. Mrs. Charles, however, felt it important to direct the students' attention to this phenomenon, and held up Lana's bottle for the class to see: "It looks like [the height of water] went down a little bit, but there's a lot of moisture up at the top, kind of like what Joe was saying with his, there's moisture at the top, can you guys see it?" Mrs. Charles tried to draw the class's attention to the drops accumulating at the top of the bottle and questioned Lana to help her generalize from her results.

Mrs. Charles' questioning post-experiment was much more scaffolded in year 2 than in year 1. The ways in which Mrs. Charles helped Lana's group notice observations and draw conclusions about relationships were representative of her interactions with every group. As such, conclusions and generalizations didn't emerge from the students' independent reasoning about the experiments in year 2, but rather from Mrs. Charles as she played a more prominent role in guiding her students. The scaffolded questions Mrs. Charles offered in year 2 were not scripted in the curriculum or promoted in PD; these guiding questions were instead Mrs. Charles' adaptive follow-up to the students' difficulties. Although Mrs. Charles' follow-ups addressed students' thinking in the moment, her moves during hours 3 and 4 seem to push for the use of resources that year 2 students were not already bringing into the classroom (e.g., generalizing from experimental evidence, controlling variables). In subsequent hours, Mrs. Charles relaxed her own objectives and instead explored how the resources her students were already drawing upon (e.g., descriptive narratives, coherence seeking, everyday experiences as a source of evidence) were productive facets of scientific inquiry.

Hour 5—Students bring in personal experiences to make sense of phenomena. After students shared aloud and then drew pictures of what they learned from their experiments, Mrs. Charles reconvened the whole class and asked students to share their ideas: "Alright, who's ready to talk? Who's ready to tell us what they notice [from all of the experiments conducted] and what they think that tells us? What did you notice...?" One student, Katie, shared her observation that more water formed on a bottle stored outside than on one stored inside the classroom and suggested that it might be because of the warmer temperature outside. Although Katie began with an account of how one variable (bottle location/ambient temperature) affected condensation, students quickly shift the discussion from experimental observations to personal experiences related to evaporation:

1	Mrs. C:	We have this idea of water droplets [forming] faster when heat is there, because she used what the water bottle looked like inside [the classroom], versus what it looked like outside. What else can you say from what you observed? What else can you say? This is the tough part, I'm not going to hand an answer to you. You have to observe the world around you, make sense of it. What does it tell you? Lacy, what does it tell you?
2	Lacy:	Well, I was thinking because sometimes it rains, and sometimes there still is water on the sidewalk, it's not all dried up. ''Cause'' like, when I'm at home and it rains, the next morning, there's still water on the sidewalk, and there's water on my slide. And then when in the afternoon, I come back, like it's gone
3	Mrs. C:	So what does that tell you?
4	Diana:	I remember something in my yard. In my front yard, whenever we leave for school, it's like all wet, because the moist air. There's huge puddles and I'm like, ''Did it rain last night?'' But it's really just from the morning
5	Zander:	Fog
6	Diana:	Yeah, it's like fog.
7	Mrs. C:	You put words in her mouth, Zander. So it's damp in the morning, and then what?
8	Diana:	It's really cold, it's just really wet, and when my car, my mom's car, it's really wet, also. Sometimes you don't wipe it off, and when I come home, it's gone. Except, but it leaves like dirty on my mom's car, it leaves dirty droplets of water, because
9	Mrs. C:	So [writing] damp in the morning, afternoon dry?
10	Diana:	Yeah
11	Mrs. C:	How does what we've been doing out there help us make sense of what's going on? What do you *think* based on what you saw? Robert?
12	Robert:	When you look at the drops of liquids, that they're all different, that can't help us. But if you just do plain water, it will hit the cap, it will hold it up and leave it on top. But, when you close the—if you don't have a cap, you don't really see it, because it's like, it's going up, and it's coming out of the bottle. Whereas it's just-like, the water coming out of the other
13	Mrs. C:	So you have this problem with closed versus open container caused a different outcome; what you saw was different? Okay. Holly?
14	Holly:	I have a question from before. Say you have dirty clothes, and you give them to your parent to wash them. And you put it in the washer, and then you get it wet, and you put it in the dryer. Where does it all go, does the dryer, did it dry it or does it evaporate?

During this dialog, Mrs. Charles tried to guide the students to make connections between the experiment and the phenomena: ''Use what we're observing now to help us think.'' She capitalized on a student's conclusion that was based on the effect of changing a variable: ''We have this idea of water droplets [forming] faster when heat is there, because she used what the water bottle looked like inside [the classroom], versus what it looked like outside.'' Lacy deviates from this experiment-centered form of inquiry by bringing up her own experiences with water evaporating on the sidewalk. Rather than direct Lacy back to the experimental findings, Mrs. Charles tried to prompt Lacy to make conclusions about what her personal experience tells her (line 3), and other students immediately began to add their own personal experiences to the conversation. By bringing in personal stories, Lacy, Diana, and Holly nominate real-world observations as meaningful sources of evidence. Diana in particular references temperature in relation to water (''it's really cold, it's just really wet''), indicating that she is using her personal experience to address Mrs. Charles' previous question about the effect of ambient heat on evaporation. Rather than direct the students back to their findings from the recent round of experimentation, Mrs. Charles prompted the students to generalize from their experiences, implicitly elevating personal experience to a valid form of evidence. Later, when Mrs. Charles did attempt to direct the conversation back to experiments (line 11), Holly posed a question about moisture in a clothes dryer and the discussion then began to follow the phenomena of drying.

Hour 5+—Discussions about real world experiences emerge as a normative inquiry practice. During another discussion at the end of that same day, the class began responding to a real-life experience that Megan described: when her dad takes a cold shower in the morning, the bathroom mirror fogs up a little, and then when she takes a warmer shower after him, the bathroom fogs up much more. (See Table 1, Year 2 EEs for transcript excerpt.) These students had recently conducted experiments, just as the students in year 1 had, but year 2 students made sense of phenomena through personal experience rather than experimental findings. In this excerpt, both Rita and Megan included the personal details of their stories, complete with characters, settings, and plot; however, the purpose of their sharing was similar to that of year 1—to support a generalized claim about evaporation. Rita's story was the support (and possibly inspiration) for the claim that cold showers do not cause mirror condensation. Similarly, Megan's and Wendy's anecdotes suggest that larger rooms (or open doors) cause there to be less condensation on the bathroom mirror. Holly reconciled Rita's and Wendy's contradictory experiences by nominating room ''structure'' as the dominant factor in determining how much condensation forms on the bathroom mirror. Much like Tiffany in year 1, Holly identified an inconsistency and offered a solution; however, Holly drew on personal experiences voiced in the discussion instead of proposing a follow-up experiment as Tiffany had. Each student's contribution helped to shape the scientific inquiry norms that eventually became dominant in the classroom.

The following day, after a brief review of the previous experiments and findings, the students began proposing and discussing real-world experiences related to evaporation, such as what happens to the moisture in a wet towel over time, why goggles on a wet head get foggy, and why the shower fogs up. Within the next three 1.5-hour class periods, the students considered various phenomena and developed explanations for multiple phenomena: where moisture on the carpet goes when something spills on it, where moisture from blown dry hair goes, where steam in the bathroom goes, how fog forms in the air and on windows from our breath, the difference between cold and hot evaporation, and the connection between evaporation and humid weather. Although Mrs. Charles occasionally scaffolded experimentation throughout the rest of the module, she also supported and engaged in sense-making grounded in EE. Multiple times Mrs. Charles even shared her own personal anecdotes about evaporation.

Comparing and Contrasting Years 1 and 2. As evidence from the classroom suggests, Mrs. Charles began both years with the same opening question about the puddle and followed up in similar ways during the first two hours of class. She facilitated discussion, encouraged students to narrow down the list of possible explanations for the disappearing puddle, asked students what they wanted to explore, and supported the development of students' own experiment designs. The year 2 students pursued different experiments than year 1 students because their own ideas and explanations differed, not because Mrs. Charles intentionally led students to explore different phenomena in the second year. During discussions in both years, students shared ideas and brainstormed what variables might affect the puddle. The students then developed independent experiments, some more structured than others, to explore their own ideas.

In many ways, the first few hours were quite similar. Why, then, did different inquiry practices emerge and become stable each year? We argue that because Mrs. Charles provided the space for students' ideas to take center stage, differences in the students' epistemological resources and inclinations each year—their implicit expectations about what type of activity and reasoning is appropriate in the context of classroom science—significantly contributed to the divergent normative activities. Just after completing their first round of experiments, Mrs. Charles asked the students to generalize from their experiment what they now know: ''So what do you guys think you learned from what you did?'' (year 1) and ''What were you trying to figure out, and what do you now know from what you did?'' (year 2). In year 1, the discussion focused on how different empirically testable variables affected evaporation. Students readily drew conclusions from their experimental findings, and offered causal explanations. These students drew on many concrete and epistemological resources to construct these explanations. Underlying and supporting this normative classroom practice were epistemological resources associated with experimental knowledge construction; that ''seeing is believing'' and that a phenomenon can be deconstructed and analyzed by identifying causal variables, holding all but one variable constant, and testing cause and effect. When Mrs. Charles asked how the class might explore an idea, the year 1 students responded with proposals for new experiments. As a result, the class seamlessly transitioned into a student-directed second round of experimentation to answer questions generated during the interpretation of the previous round's empirical findings. The module continued in a similar way with a third and fourth round of experimentation.

In year 2, however, when Mrs. Charles prompted the students to articulate what they learned from their first round of experiments, the discussion transitioned rather quickly from school experimentation to personal experiences. This transition was not instigated by the instructor, but arose from the students and their comments. In other words, the students renegotiated the direction of the discussion, shifting it towards explanations of everyday phenomena. Compared to year 1 students, students in year 2 drew on similar concrete resources to construct explanations of evaporation, and as such, even came to similar understandings about evaporation and condensation. For example, both classrooms debated whether the water went up into the air or down into the ground to deplete the puddle. However, the year 2 students approached the task of understanding evaporation by making comparisons and analogies to experiences they had encountered in everyday life. Although year 2 students very likely had resources for controlling variables and experimentally testing conjectures, in the context of the water cycle module, they repeatedly approached scientific discovery as an opportunity to consider their own experiences of the world around them, using anecdotes and agreed-upon common knowledge to co-construct an account of phenomena related to the water cycle. Year 2 students drew on epistemological resources that reflected a connection between everyday experiences and scientific sense-making, a way of knowing that was reinforced in some of the students' previous year of schooling, and in other classrooms and subjects throughout the school year. Following the initial round of experimentation in year 2, most of the remaining time in the module focused on discussing and explaining phenomenon proposed by participants (e.g., condensation inside swimming goggles) as opposed to independent rounds of experimentation (Figure 1).

Consistency in Mrs. Charles' Classroom Objectives

In both years, Mrs. Charles created a science classroom where the students' ideas took center stage. From the initial opening question about a puddle, she facilitated discussions and encouraged experimentation based on the questions students posed about various topics related to evaporation. The data from debriefing sessions and stimulated recall interviews with Mrs. Charles revealed a consistency in her self-stated science goals for her students. When Mrs. Charles' classroom behaviors are interpreted in light of her self-reported goals and intentions, it becomes evident that any differences in her classroom behaviors in the two years nonetheless stem from consistent broader goals. Specifically, Mrs. Charles (a) valued and tried to promote experimentation, observation, and discussion; (b) embraced a flexible approach to instruction that was responsive to students' ideas; and (c) desired that her students develop intellectual autonomy (i.e., that students investigate and judge ideas themselves rather than disregard their own logic and sense-making when encountering ideas from authority figures). These objectives were explicitly expressed by Mrs. Charles during both years of debriefs and PD meetings, and are consistent within her classroom practice (see Table 2 for examples).

Key phrases and strategies Mrs. Charles repeated in her classes coincide with claims made outside of the classroom. In both years Mrs. Charles often encouraged students to talk to each other rather than to her. For example, when students disagreed or wanted to contribute to someone's idea, Mrs. Charles responded by redirecting them to their peers: ''Talk to him. I didn't say it.'' or ''I don't know! Talk with your group.'' Mrs. Charles stated in class and in her interviews that she wanted students to listen to each other so that they could ''refine their thinking.'' When facilitating discussions, this goal was evident in her instructions to the students: ''Your attention is on who's presenting. How is it helping your idea, how is it making you change your idea, how is it maybe confirming your idea?''

One common way Mrs. Charles promoted experimentation was to use the phrase ''How do you know?'' to follow up a student's conjecture or claim. Mrs. Charles posed this kind of question frequently during both years; below is one example from each year:

> *Year 1*—Mrs. Charles: Okay, so we have a puddle, and we have water vapor. So now I'm going to throw out a tough question: ''How do you know its water vapor? How do you know?''
> *Year 2*—Mrs. Charles: We've got this idea that evaporate went up. Then we said, how do we know it goes up? What did we figure out, and what did we use during the week last week to help us decide that it went up, that the water, the puddle, evaporated up? What did we use and how did we know, Cindy?

Mrs. Charles promoted experimentation and observation during the module by prompting students to devise ways to test their ideas. For example, in year 1 Mrs. Charles responded to Parker's conjecture about surface area (see Year 1: Hours 3 and 4) by encouraging the class to ''do that'' and ''explore'' that idea: ''So surface area. How would you go about doing that? How might you want to explore that idea to make sure that your thinking is accurate?'' Mrs. Charles asked similar questions when year 2 students offered explanations (see Table 1, SE, Year 2). These repeated classroom phrases (''How would you test your thinking? What would you *do*? What do you want to explore?'') may appear to be superficial strategies when taken alone, but are consistent with Mrs. Charles' debrief statements about what she hoped to achieve in her classroom (Table 2). She wanted her students to value experimentation as a key way of verifying scientific knowledge and generating new questions. As Mrs. Charles expressed in interviews, it was not sufficient for students to know how to conduct an experiment; her ultimate goal was for her students to ''want'' to actively ''do'' and ''explore'' scientific phenomena rather than passively accept what they read in books or heard from the ''smart kids.''

Mrs. Charles recognized that year 2 students did not respond to her prompting for experimentation in the same way as year 1 students. Mrs. Charles talked about these differences,

Table 2
Transcript examples from debrief and interviews of Mrs. Charles approach to science, responsiveness, and goals for students.

	Year 1	Year 2
Promoted Student-directed experimentation: Mrs. Charles' goal of student autonomy is intertwined with her ideas about what science is: she highlights and promotes experimentation as the key way for students to generate and verify scientific knowledge themselves. Science is an empirical process rather than an authority-dictated set of facts	Its, did this [experiment] work or didn't it? If it didn't work, what can you do to change it? . . .Its ''okay, so that didn't work, what does that tell you?'' What can you change on it [experiment] to get something different? You don't have to know everything. You just have to figure out how can I go find it. . . .Back up what we found out. Experiment and play with it. We can actually find it and prove it to ourselves that what they are saying is accurate. So that's where I want to go with them	I know in my head I kept [thinking], ''I want them (year 2 students) to get to this point of trying something.'' Of doing it [an experiment]. . . .Of saying it's okay to go play with an idea they have and seeing if it works or not. . . .In science terms, test something out. . . .Going and proving it and disproving it to yourself. . . .By doing a test, doing an experiment of some kind. Because it might be that idea that spurs on that discussion and takes that one a little bit further, clears up this idea
Responsiveness to Students' Thinking: Mrs. Charles exhibited a flexible approach to instruction that is responsive to students' ideas	It's that flexible piece. . . .When do you give up and when do you not? If [the class discussion is] so meaty, do you continue it? And, oh god, what if I don't go on to the next piece? But it's the richness that goes on in the classroom. Learning *that*—that's kind of where teaching is. You have to be flexible	So as you're going around the room, you're constantly on your toes, evaluating, listening, and thinking. What's the next best step for this group of students? Are there some things that are out there that are great ideas? . . .But putting it back to them, and letting them making some decisions, and have some say in it
Goals for Students: Mrs. Charles desired that her students develop intellectual autonomy (i.e., that students can investigate and judge ideas themselves rather than disregard their own logic and sense-making when encountering ideas from authority figures)	Letting some groups go and research and bring it back, and, ''well, what did you find out?''. And sharing, and how does that fit with what we already learned? Does it cause us to have any more questions? Or does it put things to rest? Or are we now still, even more confused than we were to begin with? And I think that, for them, its realizing that the more you are confused, the better it is because you are going and searching for questions and answers. As soon as you think you know it all, they like to sit back and they don't push themselves to learn	[I want to change students' way of thinking about the science to move them]—toward taking anything that comes their way, and going, ''Well, I don't have to take somebody's word for it, I don't have to take the book's [word for it]. I can just go prove it to myself. I can go get the knowledge myself. I don't have to just—Oh, it's true because [a smart student] said it''

unprompted, during PD meetings concurrent with her year 2 implementation of the module. During an interview several months after the module implementation in year 2, Mrs. Charles reflected on the changes she had seen in her students over the year. She stated that her year 2 class did not initially think about or value testing ideas to generate and verify scientific knowledge: ''Whereas my room [year 2] wouldn't even think about going to an experiment, it was all, 'let's just discuss all this.' Now all of a sudden [later in the school year] they are saying, 'That's something we could test, right? Can we go test that now?' And you say, 'Okay sure; go right ahead.''' This statement not only shows that promoting experimentation and observation was a central objective for science both years, but it also reveals a high level of responsiveness; Mrs. Charles' goals for her students and vision of acceptable classroom science were flexible enough that she was willing to foster and build upon the productive resources for reasoning about phenomena that students brought to the discussion.

Although Mrs. Charles' ultimate goals for her students—intellectual autonomy and facility conducting experiments and interpreting results—did not seem to change from one year to the next, her responsiveness to students' ideas and a flexibility in her approach to inquiry resulted in a different enactment of inquiry each year. In year 2, she released her objective of experimentation and allowed the students to extensively discuss phenomena they were curious about. By building upon the resources that year 2 students brought into the classroom, Mrs. Charles validated the students' ideas and the students became personally invested in seeking answers to their own questions. In year 2, Mrs. Charles attempted to focus her students on drawing conclusions and generalizations from the first round of experiments (see Year 2, Hour 5). After some effort to center the discussion on the experiment results, she allowed the students to redirect the discussion toward personal experiences and wonderings. Mrs. Charles did not continue pushing the class to develop testable questions, but instead waited for the opportunity to emerge from a student. When it did (see Table 1, SE, Year 2), she capitalized on it by leading the whole class through an experiment. In light of Mrs. Charles' interviews, we believe her intent was not simply to enact that experiment, but to help her students develop an appreciation for empirical investigation. Mrs. Charles reported that by the end of the year, these students began to value experiments as a key way to verify scientific knowledge.

Although we see a consistency over the two years in Mrs. Charles' objectives, we are not arguing that Mrs. Charles did not change as a result of PD. We acknowledge that she have may have improved her ability to hear or appreciate the science in students' ideas or improved her content knowledge. However, we wish to emphasize that although Mrs. Charles may have expanded in her views of science, such changes do not account for the substantial differences we see in the inquiry norms and activities that emerged in her classroom in years 1 and 2. The interactions and negotiations between Mrs. Charles and her students each year accounts for the differences we observed.

Discussion

The classroom data presented in the previous section are indicative of the instantiations of scientific inquiry that occurred in the two consecutive years of Mrs. Charles' classroom. In year 1, students spent a significant amount of time planning, implementing, and debriefing experiments in pursuit of using empirical evidence to support their ideas and distinguish between competing claims. In year 2, the class spent much more time reasoning about puddle-related phenomena in terms of their experiences from everyday life, and as a community worked to develop a theoretical explanation of evaporative processes. In both classes, students engaged in the pursuit of ''finding something out,'' an enterprise that several researchers identify as essential—yet challenging—for beginning science learners (Kuhn & Pease, 2008). For this study, we set out to account for how the differences in the normative inquiry practices emerged and became stable each year. We propose that the two different instantiations of scientific inquiry were not merely the artifact of teacher intent, as traditional conceptualizations of teacher change would suggest. Rather, they were the outcome of a complex dynamic between the teacher and students, engendered by (a) the students' unique intellectual and epistemological resources each year, (b) a broadness in Mrs. Charles' goals for her students and a flexibility in her ideas about what classroom science can and should look like, and (c) the curriculum and PD designed to promote sensitivity and responsiveness to student thinking. Each of these influences is elaborated upon below.

Differences in the Nascent Inquiry Resources of the Students

The interview evidence indicates that Mrs. Charles did not intentionally lead the classes towards different inquiry practices (see Consistency in Mrs. Charles' Objectives above). Instead, Mrs. Charles' responsive classroom moves allowed the experiences and resources of the students to contribute to the image of scientific inquiry realized each year. The year 1 students showed an interest in and resources for formulating testable questions, designing and implementing empirical investigations, and generalizing from experimental results. These students had recent practice working on science fair projects, and as such, brought to the classroom resources pertaining to valuing empirical evidence to prove the validity of their conjectures. Their questions and wonderings about the puddle remained focused on the role of variables throughout the module, and they readily took up opportunities to design and conduct experiments.

Year 2 students, on the other hand, had not discussed science fair projects prior to this module. Instead, 30% of these students took 4th grade science from a teacher who was part of our PD project. Our data from other classrooms indicate that these students engaged in sustained inquiry discussions prior to and outside Mrs. Charles' classroom; students generated their own ideas and theories about how the world works based on their personal experiences. While considering the puddle in Mrs. Charles' class, the students tended to describe ideas in terms of personal experiences and stories which became the context of the class discussions. Even reports of experiments hinged on personal narratives of what students did and saw during their experiments. As such, prevailing inquiry activities centered on discussions about scientifically relevant and personally meaningful questions.

Examining how the two classes transitioned after the first round of experimentation helped to illuminate how the two classes diverged during the module. In year 1, variables that affect a puddle were in the foreground of the discussion from the first day of the module. Even before the first round of experiments, the students proposed a variety of variables that would affect a puddle: whether the puddle was on asphalt or dirt; whether the puddle was in the country or city; what time of year was the puddle seen; how many cars would be able to drive over the puddle, etc. An emphasis on testable variables that affect a puddle became the focus of the first round of experimentation. Year 1 students responded to Mrs. Charles' questioning (''What did you learn from what you did?'') by abstracting from the experimental results various claims about evaporation. When a student posed an explanation, such as Parker proposing surface area as a variable affecting the rate of evaporation, the other students responded by offering ways to test that idea. These students were drawing on epistemological resources associated with empirically testing conjectures.

In year 2, although variables played a prominent role in the initial discussion, the variables proposed were embedded in the students' personal experiences rather than in testable propositions. The students reasoned about water-related phenomena by making connections to contexts they were familiar with. They also formulated insightful contextualized questions (e.g., Where does the water in a clothes dryer go?) to explore and challenge their own conclusions and generalizations. Through such questions, students came to value and refine their ability to raise issues that were of interest to their classmates and that warranted further exploration (van Zee et al., 2001). In many instances these questions formed the basis for Mrs. Charles' next moves. The continual, spontaneous generation of substantive questions reflects students' active engagement in and ownership of what they were learning (Berland & McNeill, 2010; van Zee et al., 2001). Although both years 1 and 2 students used resources for drawing analogies, reconciling inconsistencies, and reasoning causally and mechanistically, the year 2 students brought in epistemological resources for making connections to everyday life, while the year 1 students primarily drew on resources associated with empirically investigating causal factors. This is not to say that year 1 students did not make connections to everyday life or that year 2 students could not design and perform experiments. However, the inquiry norms that became established in each classroom, along with the teacher–student negotiation of norms that occurred in the first few hours of each module, appeared to result from different combinations of resources offered up by participants in each year.

In addition to their divergent responses to experimenting, year 1 and 2 students interpreted Mrs. Charles' common questions and prompts differently. A question frequently asked by Mrs. Charles—''How do we know?''—provides an interesting case in point. The question emerged naturally in year 1 early in the module during a small group conversation when Mrs. Charles was asking the students what made them change their mind and accept an explanation offered by one member of the group. The invitation to consider the question ''How do we know'' or the suggestion that an idea might be testable was readily taken up by these students. By the end of the module, however, this phrase became accepted by both the students and the teacher as meaning ''design an experiment to test that idea.'' The students were not interpreting the question at face value any longer, but rather, the question became an invitation to design a physical experiment to convince oneself and others of a causal claim. This interpretation of the question epitomizes how the teacher and students came to a common understanding of ''doing science'' as designing and performing experiments to test ideas.

This same phrase—''How do we know?''—in year 2 did not elicit the same type of responses as it did year 1. In year 2 the students responded with stories or anecdotes drawn from personal experience (e.g., blow dryers, bathroom mirrors). They tried to reason about and account for phenomena by grounding it in what they knew from their everyday lives. Variations of the students' response, ''I know because something similar happened to me'' does not lead to the same strategies (i.e., isolation of variables, empirically testable designs) seen in year 1. Interestingly, in year 2, Mrs. Charles became more prone to ask ''What is happening there?'' This may be an adaption to her students' tendency to draw on scenarios and experiences that already happened rather than design and implement new ones. Additionally, Mrs. Charles began posing personal experiences of her own as prompts for discussion, such as ''Why is moisture collecting on the outside of my soda cup?'' In this way, Mrs. Charles and the students negotiated and co-constructed the acceptable way to reason about and develop explanations for phenomena.

Flexibility in Mrs. Charles' Ideas About Classroom Science

In both years' debriefs and meetings, Mrs. Charles described science in broad terms, as a process that involves iterations of both experimentation and experience-based reasoning. We believe this breadth in her view of science allowed for a certain flexibility in what Mrs. Charles accepted as classroom science. Because, for her, the essence of science involved a general way of reasoning about and exploring the world, Mrs. Charles tolerated substantial variance in the specific classroom activities that counted as science. Rather than holding her students to specific criteria—like following the "scientific method" (e.g., hypothesis, procedure, analysis, conclusion) or using specific components in an argument (e.g., claim, data, warrant, backing)—Mrs. Charles pushed for a student-driven exploration of natural phenomena.

In year 1, as we have shown, students asked questions, proposed explanations, and took up Mrs. Charles' invitations to empirically investigate phenomena. In year 2, while students reasoned mechanistically about phenomena, the inspiration for ideas and evidence used to evaluate conjectures were more often taken from everyday experiences rather than collected in designed experiments. Mrs. Charles adapted to this alternate instantiation of science that year 2 students pushed for in two ways. First, she continued to scaffold opportunities for year 2 students to collect relevant empirical evidence. Second, she took up the students' proclivities for drawing on their personal experiences by engaging in and facilitating their discussions. Mrs. Charles even contributed her own personal stories as context for scientific discussions. In many ways, the year 2 realization of science was compatible with Mrs. Charles' view of science and her goals for her students: the students *discuss* their ideas about evaporation, and even "push back" against the ideas of their classmates and teacher, using their real world experiences as justification and evidence. Year 2, however, lacked much of the *experimentation* and *autonomy* that Mrs. Charles valued and repeatedly mentioned in debriefs and interviews. In fact, in an interview at the end of year 2, Mrs. Charles explained her choices and tensions when facilitating inquiry:

> Had the second year sat there and said, 'Well, let's go get different things and try it,' I would have sat there and said, 'Let's do it.' So more, because it didn't come from them necessarily. I don't want to sit there and [say], 'Okay, let's experiment on this.' Cause, it's that Catch 22; how much do I insert into their mouths and how much do I take from them? How much do I guide them to it, versus how much do I corral the discussion and just keep it moving and herding it?

Both a responsiveness to students' ideas—their concrete *and* epistemological resources and *ways* of thinking—and a flexibility in how classroom science can look contributed to an environment where students co-constructed the image of classroom science.

Mrs. Charles' "Responsiveness" Resulted in Different Instantiations of Science

We found that in both years, Mrs. Charles saw "the science" in different types of student contributions and responded in a way that built on the inclinations and resources of the students. In turn, students from each classroom had space to bring in their own ideas, experiences, and reasoning in a way that reflected their perspective of what science is, and consequently a different sort of scientific inquiry was realized in each classroom. An overview of the last days of the module during both years is provided below to further illustrate how a responsive classroom community led to different overall expectations and inquiry activities each year.

In year 1, during the last hour and a half of the module, Mrs. Charles summarized for the students all of the ideas they had generated about the puddle and recited several lingering questions that the class had posed. Most of the questions involved variables affecting evaporation (e.g., How does ground temperature affect evaporation? How does wet, dry, or humid air affect evaporation? How does color of the surface under the water affect evaporation?). Other questions were more general in nature (e.g., How does water change from liquid to gas? Are oceans and rivers evaporating?). After reviewing where the class had arrived since pondering the original puddle question, Mrs. Charles asked the students, ‘‘So where do you want to go today? What do you want to find out about?’’ A few students posed new questions, and some posed new experiments they wanted to try. The day ended with students working in small groups developing questions and experiments related to weather phenomena, the topic of the next unit in Mrs. Charles’ curriculum.

In year 2, during the last hour and a half of the module, Mrs. Charles also restated where the students had arrived with respect to water evaporating from the puddle, and, like year 1, she asked the students to consider where this knowledge could lead them or what it could help them to understand. In contrast to year 1, however, the class proceeded by working communally on a theoretical explanation for moisture in the air, an explanation they had been building together for several days. The discussion transitioned to how clouds form, and one student described a phenomenon he had experienced the previous day with his soda cup. Mrs. Charles suggested that the class could experiment with his idea: ‘‘We could play with that idea and experiment with it, and come to an understanding of it.’’ As was typical for this class, the students did not take up Mrs. Charles’ prompting. Much of the activity for the remainder of the day consisted of discussion with students grounding their ideas and explanations for cloud formation in personal experiences (e.g., humidity and fog in Florida, flying in an airplane through clouds in the air, etc.).

The differences in the direction the class took in year 2, as compared to year 1, would typically be interpreted as evidence of a shift in Mrs. Charles’ objectives, influenced both by her first year implementation and her PD experiences. However, as previously stated, we find this conclusion incomplete when accounting for the longitudinal classroom data and teacher interviews. Differences in the intellectual and epistemological resources of the students, along with a flexibility in Mrs. Charles’ view of classroom science, allowed these two classes to diverge in the normative practices of inquiry that were established. This complex pattern of interactions that occurred between teacher and students was possible because of Mrs. Charles’ responsiveness to differences in the students and what they brought to scientific inquiry.

Conclusions and Implications

Studies typically focus on changing how students do science rather than considering how their intellectual and epistemological resources influence the doing of science that emerges in a classroom. In this study, we set out to investigate the complex dynamics that produced the image of scientific inquiry ultimately realized in two 5th grade classrooms. Our data show that the students had a substantial influence on the ‘‘doing of science’’ that occurred in Mrs. Charles’ class each year. The story of the evolution of inquiry practices that became normative in years 1 and 2 highlights the extent to which a focus on the teacher overly simplifies the complexities of the classroom, and can mistakenly lead to attributing change seen in the classroom exclusively to the influence of the teacher.

With the inquiry literature primarily focused on *how* to produce sophisticated inquiry norms in the classroom (Berland & McNeill, 2010), it would be negligent of us not to compare the merits of the two different enactments of inquiry realized in Mrs. Charles’ classrooms. One might assert that the class in year 1 demonstrated a more sophisticated instantiation of inquiry because students pursued their own questions by designing and conducting experiments. This captures an important component of the nature of science: science is accountable to reproducible empirical findings (Abd-El-Khalick & Lederman, 2000; McComas, 1998). On the other hand, one could critique year 1's instantiation of inquiry because the students' divergent explorations did not ultimately feed into the larger purpose of constructing an explanatory account of evaporation and related phenomena (Chinn & Malhotra, 2002; Windschitl, 2004). While Mrs. Charles encouraged each group to share out the results of their experiments, these findings were not woven back into a collective explanation for evaporation and the water cycle in year 1. In fact, near the end of year 1 Mrs. Charles expressed dissatisfaction with what the class had accomplished thus far. In year 2, however, the class developed theoretical explanations as a community, drawing on their own personal experiences to reason about scientific phenomena. Additionally, the interweaving of real-life experiences with classroom science suggests that year 2 students might be more likely to transfer their knowledge between settings. However, experimental evidence plays a critical role in reconciling alternative scientific claims, and therefore, discourse focused only on theoretical inquiry also has its limitations.

It is not our aim here to argue that one of the classroom's instantiation of inquiry is ''better'' than the other. Science is a complex and domain-specific process that involves both experimental *and* theoretical inquiry. We instead are arguing that if we really mean to build on learners' nascent resources for reasoning about the natural world, then this means allowing students to pursue explanations for phenomena in ways that make sense for them.

For teachers and researchers, our findings provide insights into how the evolution of scientific inquiry can be shaped by both students and teachers. Most notably, our 2-year case study demonstrates how responsive facilitation of scientific inquiry allows student resources to shape the image of scientific inquiry realized in the classroom. Consequently, where one class arrives may not be where another class arrives, even under the guidance of the same teacher. While this is a simple and obvious revelation, it is nonetheless important to document and discuss in relation to PD. Teachers often strive to establish certain predetermined inquiry practices in their classrooms, and justifiably so. Relaxing control and suspending objectives can be difficult, stressful, and counterintuitive for teachers.

We believe Mrs. Charles' ability to be responsive stemmed in large part from the nature of her classroom goals and objectives. She cared deeply about her students as whole individuals, not just as science students, and wanted them to be creative, curious, independent, skeptical, active learners. Although Mrs. Charles may have expected and preferred her year 2 class to spend more time on SE, classroom time spent discussing phenomena in the context of EEs in many ways coincided with her overarching goals for her students. The PD project also emphasized the value of theoretical discussions and everyday thinking as an important component of science, making it easier for participating teachers, including Mrs. Charles, to see the hidden science in students' thinking. We believe that both of these elements—general rather than specific goals and the ability to recognize scientific value in multiple forms of activity—were vital for Mrs. Charles' ability to make use of the resources students brought into the classroom.

These findings suggest that when curriculum designers and those in PD set out to promote responsive teaching with inquiry as the goal, they must support teachers in their ability to see science as a sense-making endeavor rather than a collection of processes (e.g., following the ''scientific method,'' structuring an argument according to a formula). If elementary science curriculum designers and PD programs strive to facilitate responsive teaching, they must support teachers in broadening their notions of what scientific inquiry can and should be. Teachers must recognize the productive scientific foundations present in the resources their students bring to the classroom, and *that* should be considered the starting point for the class's inquiry practices. Although our case study shows two very different enactments of scientific inquiry, it is important to note that each module lasted less than 14 hours. Had we been able to support and track Mrs. Charles' use of responsive science curriculum throughout the entire school year, we would have expected to see slow and subtle changes in science norms as both classes converged on an instantiation of science that involves both theoretical and experimental activity. That is to say, teachers, researchers, and curriculum designers can view responsiveness both as a means of determining an appropriate and productive starting point for scientific inquiry and as a way to facilitate long-term growth in scientific inquiry practices.

Implications for Research in Teacher Development

As education moves towards more responsive forms of teaching, research is needed to uncover the best ways to help teachers learn to listen and respond to the substance of students' ideas (Carpenter et al., 1999; Cohen, 2004; Darling-Hammond, 1997; Jacobs et al., 2010). Our case study of Mrs. Charles contributes to this line of research because it leads us to question if we can, in fact, accurately document the evolution of a teacher's practice independent from students. Mrs. Charles played a considerable role in how each classroom came to enact scientific inquiry because she enabled student participation, allowing space for students to share, pursue, and challenge ideas and reasoning. Yet the data show that the two unique instantiations of science in years 1 and 2 emerged from an interplay between the teacher and students rather than from a significant change in the teacher's practice. Thus, our work with Mrs. Charles illuminates an important methodological concern with current research in teacher development; research accounts that focus primarily on the teacher may overlook the teacher–student interplay, and thereby provide an incomplete portrayal of the teacher's activity within one classroom *and* the teacher's growth across multiple years.

In responsive classroom cultures, understanding how a teacher's practice evolves means documenting the practices of students and teacher together over a period of time. Appreciating why a teacher may choose to probe further into one particular student's idea and not another's, or how a teacher chooses between various possible next moves, is not revealed when categorizing a teacher as belonging to a particular developmental "level". Thompson, Braaten, and Windschitl (2009) acknowledge that sometimes teachers may intentionally engage in "less sophisticated" actions because they feel it is in the best interests of their students.

Teacher Learning Progressions. Considering this argument, we have concerns regarding the current movement in teacher education toward developing TLPs (Thompson et al., 2009; Schwarz, 2009). This has become a pressing issue for us because the work presented here is from a larger study aimed at mapping out both teacher and student learning progressions in scientific inquiry. Learning progressions are described by Corcoran, Mosher, and Rogat (2009) as empirically grounded and testable hypotheses about the evolution of students' understanding of—and ability to apply—core scientific concepts, explanations, and practices. Originally, the learning progression (NRC, 2007) construct was applied primarily to students' learning of "big ideas" in science content (e.g., evolution, matter) and scientific ways of thinking (e.g., modeling, inquiry). Researchers have begun to think about TLPs for both assessing a teacher's ability to teach (Schwarz, 2009; Talbot, Briggs, & Otero, 2009) and as a tool for teachers to describe and evaluate their own progress (Thompson et al., 2009). The existing TLPs, in format, are analogous to how most student learning progressions are conceptualized: important dimensions are identified by the researchers, and initial, intermediate, and sophisticated levels are articulated and (eventually) empirically validated. For example, Thompson et al. (2009) propose a TLP for promoting scientific modeling that outlines an extensive set of dimensions and levels. They also use a reduced version of the learning progression as a PD tool for teachers to describe their current practice and steps toward change.

A notable second example of research into TLPs is the work conducted by Schwarz (2009). She identifies dimensions related to teachers' ''knowledge and practices around model-based inquiry'': knowledge of science, of learners, views of effective science teaching, lesson planning and sequencing strategies, classroom conversation norms, and the teachers' ability to work with students' ideas in conversation. Schwarz's work involves articulating and empirically validating stages within those dimensions using extant literature and data from preservice and practicing teachers. Her MoDeLS group is working on an accompanying student learning progression in model-based inquiry (Fortus, Shwartz, Weizman, Schwarz, & Merritt, 2008; Schwarz et al., 2009). While the knowledge and practices identified in Schwarz's teacher LP might be *hypothetically* related to a teacher's ability to promote sophisticated scientific modeling practices among students, the MoDeLS group addresses their teacher and student learning progressions independently and separately.

Based on our case study of Mrs. Charles, we question the value of a distinct learning progression for teachers. As previously stated, our data raise some methodological concerns with focusing primarily on the teacher. Thompson et al. (2009) recognize the challenge of documenting how a teacher progresses in her sophistication, apart from the influence of the students:

> How can the LP account for teachers' understanding of when it is appropriate to use certain practices for novice students based on context (age and experience of the students, subject matter, placement of an inquiry during a school year)? At issue is the fact that we might observe teachers purposefully doing less advanced practices with their students in attempt to lay the groundwork for more advanced practices. As is, our learning progression does not account for planned shifts in practice over time. A few of the teachers we worked with also called attention to this dilemma...

Can teacher progress be established independent of students? If student resources and progress are inseparable from understanding teacher practice, then how might we establish teacher progress? And how much classroom and interview data is really needed to make sense of the variation in a teacher's practice from one year to the next when we take into consideration the influence of the students?

We intend for our data and these questions to provoke a dialog among the community about the purpose and nature of TLPs. If TLPs are to be valuable for accounting for the increased sophistication of teachers' practices, then our findings suggest that TLPs must be inextricably linked to student learning progressions, documented by classroom activity rather than by independent measures of teacher knowledge or skill. That is, the ultimate measure and description of where a teacher is on a learning progression should include what the students are doing in the class, along with the intellectual and epistemological resources of those students, and how the teacher responds and adapts to those. A focus only on the teacher can lead to inappropriate assumptions about a teacher's change in practice, as the data from Mrs. Charles reveals (Maskiewicz & Winters, 2010). How might we translate this vision of a combined teacher/student learning progression into a tangible format beneficial to the PD community? This is just one question the LP community must consider as they define the methods for constructing and assessing TLPs.

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