FOSTERING SECOND GRADERS' SCIENTIFIC EXPLANATIONS USING EDUCATIVE CURRICULUM MATERIALS: A BEGINNING ELEMENTARY TEACHER'S PERSPECTIVE AND PRACTICE

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Abstract: Teaching science as explanation is fundamental to reform efforts but is challenging for teachers, especially new elementary teachers, for whom the complexities of teaching are compounded by high demands and little classroom experience. Despite these challenges, few studies have characterized the knowledge, beliefs, and instructional practices teachers need in order to overcome these difficulties and the role that educative curriculum materials—or curriculum materials intended to promote teacher learning in addition to student learning—might play in facilitating their learning about explanations. To address these gaps, this study describes one beginning elementary teacher's perspective and practice for giving priority to explanations when she is provided with educative curriculum materials that aim to support her in fostering explanations. Analyses showed that the teacher developed new understandings and practices for fostering students' explanation construction when using the educative curriculum materials. However, despite these advancements, she continued to prioritize learning science content above the importance of building explanations in her goals and practices, in part because she did not see explanation construction as a strategy for facilitating students' understanding of science and as an educational goal in its own right. The paper concludes with recommendations for designing educative curriculum materials and teacher education programs.

Reforms in science education highlight the need to promote scientific literacy among all students and suggest that students can become part of an informed citizenry by having the opportunity to learn science through inquiry (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC], 1996). Developing evidence-based explanations is one fundamental component of inquiry-oriented science. Teaching science as explanation shifts the goal of learning science from acquiring a collection of facts about natural phenomena to developing a deep understanding of the natural world. However, teachers encounter numerous challenges in helping students develop evidence-based explanations (Newton, Driver, & Osborne, 1999). New elementary teachers are especially in need of support due to their limited science subject matter knowledge and lack of teaching experience.

In order to overcome these challenges, many teachers need to develop new knowledge, beliefs, and instructional practices for guiding students' explanation construction (Haefner & Zembal-Saul, 2004; Newton et al., 1999). Recent research in science education has shown that *educative* curriculum materials, which include learning supports for both students *and* teachers, are one potential vehicle for supporting teachers' learning about science as explanation (McNeill & Krajcik, accepted).

Even though educative curriculum materials may help teachers learn about inquiry, few studies have actually characterized the knowledge, beliefs, and instructional practices that teachers need to possess in order to foster specific inquiry practices. Additionally, few studies have examined how teachers use educative curriculum materials in their practice and what they can learn from them, especially with regard to fostering explanations. This study addresses both of these gaps by examining how one beginning elementary teacher thinks about and engages her students in developing scientific explanations when she is provided with educative curriculum materials that are intended to support her in learning about this inquiry practice.

Theoretical Framework

Teaching Science as Explanation

To support new insights about how students learn science, standards documents call educators to develop students' understandings and abilities with regard to scientific inquiry (AAAS, 1993; NRC, 1996). Inquiry environments iteratively engage students in asking scientific questions, designing and conducting investigations to answer those questions, and constructing and communicating explanations. By investigating their everyday world, students use reasoning and thinking skills, in addition to scientific knowledge, to find solutions to real-world problems.

One essential feature of classroom inquiry is the practice of generating evidence-based explanations (Driver et al., 2000; NRC, 2000; Sandvoal, 2003). Drawing from Toulmin's (1958) argumentation framework, explanation construction has be defined as the practice of stating claims that account for how or why a phenomenon occurs and using evidence and reasoning to support these claims (e.g., Bell & Linn, 2000; McNeill, Lizotte, Krajcik, & Marx, 2006; Sandoval, 2003; Zohar & Nemet, 2002). Thus, teaching science as explanation shifts the focus away from "getting an answer" to "using evidence and strategies for developing or revising an explanation" (NRC, 1996, p.113).

Generating explanations enables students to enhance their understanding of scientific concepts (Bell & Linn, 2000; Coleman, 1998; Zohar & Nemet, 2002). It also helps students develop greater insight into the nature of scientific knowledge and its methods of scientific investigation (Bell & Linn, 2000; Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999; Sandoval, 2003). Engaging students in this practice also enables students to participate in one of the core practices of the scientific community (Driver, Newton, & Osborne, 2000). For these reasons, teaching science as explanation is essential for students' learning of and about science. Therefore, this study seeks to better understand the ways in which explanation construction can be fostered among students.

The Role of Teachers in Fostering Explanations

Although engaging in scientific explanation is an important learning goal, using data as evidence to support a scientific claim is no easy task (Bell & Linn, 2000; McNeill et al., 2006; Sandoval, 2003). However, limited research findings have shown that even elementary school children can develop explanations when provided with support (Abell, Anderson, & Chezem, 2000; Coleman, 1998; Herrenkohl & Guerra, 1998; Lehrer, Carpenter, Schauble, & Putz, 2000). Research has investigated the role of various tools and artifacts in scaffolding this inquiry practice (e.g., Bell & Linn, 2000; Coleman, 1998; Herrenkohl et al., 1999; McNeill et al., 2006; Reiser, 2004; Sandoval, 2003). Teachers play a pivotal role in structuring and facilitating students' learning from scaffolding by working synergistically with curricular materials, instructional activities, and learning technologies (Tabak, 2004). Teachers are essential for making new ideas and cultural tools of the scientific community available to students (Driver, Asoko, Leach, Mortimer, & Scott, 1994). They also play a key role in encouraging students to defend and evaluate their assertions in light of data (Abell et al., 2000; Geddis, 1991). Teachers can help students articulate their explanations more fully by discussing the rationale behind scientific explanation, modeling how to reason from data, and making the tacit structure of explanations explicit (McNeill & Krajcik, accepted). Moderating interactions, probing students' theoretical positions, translating between students, and assessing students' explanations are other crucial pedagogical practices teachers use to foster explanations (Crawford, 2000; McNeill & Krajcik, accepted).

Even though teachers can play a key role in helping students construct evidence-based explanations, they typically place little emphasis on the role of evidence in their science teaching. For example, some teachers make authoritative assertions without having students examine evidence in support of these claims (Geddis, 1991). This often occurs because teachers possess limited understandings of how explanations are developed and evaluated (Haefner & Zembal-Saul, 2004) and lack the pedagogical skills needed to help students make sense of data and generate explanations (Geddis, 1991; Newton et al., 1999). In addition, some teachers fail to see constructing scientific explanations as an educational goal in its own right (Sadler, 2006).

In addition to these challenges to teaching science as explanation, *new elementary* teachers face additional constraints that often prevent them from meeting the high demands of inquiry-based instruction (Davis, Petish, & Smithey, 2006). Due in part to their lack of teaching experience, many new elementary teachers possess little specialized pedagogical content knowledge for science teaching (Abell & Roth, 1992), that is, knowledge of the difficulties that students face in learning specific science concepts and the ways to represent the subject matter to help students understand these ideas (Magnusson, Krajcik, & Borko, 1999). They also have limited and often unstable understandings of their students, their role as science teachers, and their philosophy of teaching (Abell, Bryan, & Anderson, 1998; Bullough & Knowles, 1990). Additionally, new elementary teachers tend to possess weak subject matter knowledge (Cochran & Jones, 1998), often due to the high demands of having to teach topics from multiple science disciplines as well as various subjects other than science. Classroom management issues and pressures to conform to established school norms also decrease teachers' motivation to teach science (Abell & Roth, 1992; Appleton & Kindt, 2002; Bullough & Knowles, 1990). As a result, some new elementary teachers decide to move away from lessons that incorporate inquiry or choose not to teach science at all during their first years of teaching. New elementary teachers thus need support in order to promote their success as inquiry science teachers.

In order for teachers to overcome challenges to teaching science as explanation, they need to develop new knowledge, beliefs, and instructional practices for giving priority to explanations (Avraamidou & Zembal-Saul, 2005). Specialized knowledge and beliefs for fostering explanations comprise one fundamental aspect of pedagogical content knowledge (PCK) for scientific inquiry (Zembal-Saul & Dana, 2000), which includes knowledge and beliefs of how to "help students understand the authentic activities of a discipline, the ways knowledge is developed in a particular field, and the beliefs that represent a sophisticated understanding of how the field works" (Davis & Krajcik, 2005, p.5). Specialized knowledge, beliefs, and practices for fostering explanations entail an understanding of why engaging students in explanations is important to scientific inquiry and how to help students make sense of data and generate explanations based on evidence (Avraamidou & Zembal-Saul, 2005).

Even though researchers have argued that the development of specialized knowledge, beliefs, and practices for fostering explanations is important, few studies have actually investigated these characteristics (Davis et al., 2006; Keys & Bryan, 2001), especially at the elementary level. To address these gaps, this study aims to examine elementary teachers' understanding of what it means to teach science as explanation, their ideas about the role of explanations in their own science teaching, and the difficulties they encounter when putting explanation into practice.

More specifically, this study examines teachers' specialized knowledge, beliefs, and practices for fostering explanations as they use and enact *educative* curriculum materials. Educative curriculum materials include embedded features that are intended to support teacher learning, in addition to student learning (Ball & Cohen, 1996; Davis & Krajcik, 2005). Such materials provide opportunities for teachers to learn about and adopt reform-oriented practices as well as to make informed decisions about how to evaluate, adapt, and use the materials. Educative supports can serve as a form of scaffolding for teachers.

The role of scaffolding has often been examined within the context of supporting student learning (Herrenkohl et al., 1999; McNeill et al., 2006); however, this notion can be extended to teachers as well. Educative features embedded in curriculum materials can scaffold teacher learning by providing teachers with expert guidance that enables them to engage in instructional practices that they would not be able to do independently and that fades across the set of curriculum materials to enable teachers to perform these practices on their own (Schneider, Krajcik, & Blumenfeld, 2005). Additionally, curriculum materials, in particular, may play a unique role in scaffolding teacher learning because they are intimately connected to teachers' daily work and thus can situate their learning in their own practice (Putnam & Borko, 2000), provide ongoing forms of support (Ball & Cohen, 1996; Collopy, 2003), and support reform initiatives on a large scale (Schneider & Krajcik, 2002).

Though conceptualizing educative features as scaffolding may be fruitful, research studies have just begun to investigate the types of educative features that may be beneficial in fostering teacher learning (Schneider & Krajcik, 2002; Schneider, 2006; Smithey & Davis, 2004). Therefore, much still needs to be learned about the kinds of educative features that can effectively support the development of teachers' knowledge, beliefs, and practice before studies can investigate the effects of fading the supports over time. This study contributes to this work by examining how educative features synergistically support teachers' learning about teaching science as explanation.

Purpose of the Study & Research Questions

To better understand teachers' specialized knowledge, beliefs, and practices for giving priority to explanations when provided with educative curriculum materials, this study describes one new elementary teacher's perspective and practice for fostering explanations and how educative materials support her learning about teaching science as explanation. We use the term 'perspective' to describe the teacher's knowledge and beliefs. Teachers access a blend of both knowledge and beliefs when they talk about their teaching, making it difficult, if not impossible, to distinguish between the two (Magnusson et al., 1999). The research questions guiding this study include the following: When provided with educative curriculum materials that are intended to support teachers in fostering students' explanations, (1) what is a new elementary teacher's perspective on the role of scientific explanations in her own science teaching? and (2) what is a new elementary teacher's practice like for giving priority to explanations?

This study is significant because it deepens our understanding of new elementary teachers' knowledge, beliefs, and practice for fostering explanations and elucidates their struggles in integrating this inquiry component into their own practice. These improved understandings offer important insights to curriculum developers and teacher educators into the types of experiences they can create to foster new elementary teachers' development of knowledge, beliefs, and practices for teaching science as explanation. By providing a concrete example of classroom practice, this study serves as a vehicle for conceptualizing the ways in which teachers give priority to explanations in their science teaching when using educative curriculum materials, which in turn provides a foundation for the design of larger scale studies.

Methods

Research Design

In this study we used qualitative methods to develop a single case study (Yin, 1994). The purpose of developing a case study was to develop rich descriptions of one elementary teacher's perspective and practice with regard to explanations and to use these descriptions to consider implications for teacher education and the design of educative curriculum materials. This design allowed us to study the teacher's interactions with educative materials as she was fully immersed within the complexities of the classroom setting and to develop an in-depth understanding of the reasoning underlying her actions. Even though a single case study does not enable us to form generalizations about beginning elementary teachers and the role of explanation in their classroom practice, the descriptions in this study do shed light on an unexplored area of research by illuminating the characteristics of a particular case with regard to one aspect of inquiry-based instruction and the role that educative materials played in supporting this inquiry practice. These descriptions provide other researchers with a deeper understanding of what to look for when they study this specific aspect of teacher knowledge and beliefs in larger scale studies and how to design educative curriculum materials to support teachers in enacting inquiry-based instruction.

Research Participant

We selected Catie (a pseudonym), a third-year second grade teacher, to participate in this study. Catie was a female, white teacher in her mid-twenties and thus was typical of new elementary teachers with regard to gender, race, and age. However, Catie was atypical from her peers because of her strong emphasis on having her students learn science content and her strong reflective disposition (Abell et al., 1998). Moreover, Catie viewed herself as a science teacher, not as a generalist, as most elementary teachers view themselves (Meadows & Koballa, 1993). She participated in many professional development opportunities to develop her science teaching. She joined the National Science Teachers Association, a science teaching professional organization, and began a masters degree program in science education.

Catie was a participant in a longitudinal study exploring new elementary teachers' learning about science teaching. In this larger study, she taught several units from the CASES website, an online learning environment that provides new elementary teachers with educative curriculum materials intended to help teachers develop an understanding of inquiry-oriented science teaching (http://cases.soe.umich.edu; see Davis, Smithey, & Petish, 2004). In this study, Catie enacted the CASES plant unit; this was her first time teaching this unit. She received no additional professional development along with the materials.

Instructional Context & Curriculum Materials

This study took place in a second-grade classroom at a parochial school in southeast Michigan. The class consisted of 30 second-grade students, mostly from the same socio-economic and ethnic background (i.e., white, middle class families). At the start of the study, Catie was teaching a unit on animals that she had designed. She drew from a variety of resources in developing this unit. She enacted the animal unit before teaching the CASES plant unit, which was her final science unit of the school year.

The educative curriculum materials for the plant unit included teacher materials and student worksheets. The unit was designed to engage K-2 grade students in a 6-week extended inquiry on plants, with each week of instruction containing two to four days of instruction. This unit consisted of seven lessons that engaged students in making observations and using their observations as evidence to form written explanations. The materials defined an explanation as a scientific claim supported by evidence drawn from prior experiences, observations, experimental data, and/or reading material. For example, in explaining how a cocklebur is dispersed, students were asked to state a claim, such as, "A cocklebur is dispersed by animals," and to back up their claim with evidence, such as, "I think this seed moves in this way because it has hooks, and seeds with hooks stuck to my sock during the sock walk." The materials provided students with detailed questions and sentence starters to facilitate their explanation construction. Lesson topics within the materials included the location of seeds, grouping of seeds, seed dispersal, seed parts, plant usage, plant growth requirements, and an open investigation exploring student-generated questions. Table 1 includes a list of lessons from the plant unit, the date they were taught, and a description of the inquiry tasks that were included in each lesson plan description.

Table 1
Summary of Lessons as Written in Plant Unit

	Lesson and Date	Description of Inquiry Tasks
1	Finding Seeds, 5/3/05	Form predictions, make and record observations of seeds in fruits, and build evidence-based explanations.
2	Grouping Seeds, 5/5/05	Make and record observations, group seeds based on different criteria, and build evidence-based explanations.
3	Seed Dispersal, 5/10/05, 5/12/05	Make and record observations of a cocklebur and form predictions. Make and record observations of seeds collected on a walk and form predictions. Design their own seed and build evidence-based explanations about how it moves.
4	Seed Parts, 5/16/05	Form predictions, make and record observations of seed parts, and build evidence-based explanations.
5	Sunlight Investigation, 5/17/05, 5/19/05, 5/23/05, 5/26/05	Set-up experiment to see if plants need sunlight, form predictions, make and record observations over several days, and build evidence-based explanations.
6	Plant Investigation, 5/17/05, 5/19/05, 5/23/05	Extended plant investigation driven by student questions. Set-up experiments, form predictions, make and record observations, and build evidence-based explanations.
7	Plant Usage, 5/31/05	Take field trip to farm or grocery store. Build evidence-based explanations.

The plant unit was designed to support teacher learning, in addition to student learning, specifically with regard to explanations. Guided by the design heuristics developed by Davis and Krajcik (2005), four types of educative features were developed. First, the materials contained narrative "images of inquiry," which are fictional vignettes about how a teacher addresses a specific challenge in his or her practice by reflecting on and adapting curriculum materials to address the particular need (Smithey & Davis, 2004; Davis & Krajcik, 2005). In the plant unit, the narratives described how a teacher named Peg engaged her students in different inquiry practices, with an emphasis in some stories on how she helped her students use evidence to develop scientific explanations. Second, responses to "Why?" and, "How?" questions were developed in order to provide teachers with general rationales for why certain aspects of explanation construction are important and general suggestions for how they might integrate such aspects into their own practice (Davis et al., 2004). Third, lesson-specific supports were embedded within the lesson plan description; these supports provided rationales for lesson-specific instructional approaches that aimed to foster students' explanations and examples of scientific explanations that students might give to particular lesson questions. These lesson-specific supports also provided examples of students' alternative ideas about explanations and suggestions for how to deal with those ideas. Finally, examples of student answers to assessment questions and descriptions of how the answers counted as scientific explanations were embedded within each lesson assessment. These examples were intended to guide teachers' thinking about the kinds of scientific explanations students might make in each particular lesson. Table 2 includes examples of these four types of features that aimed to help teachers give priority to explanations in their science teaching

Table 2

Types and Examples of Educative Supports for Giving Priority to Explanations

Support Type	Examples of Supports from Plant Unit
Narrative "Images of Inquiry"	Peg's 1st graders loved the sock walk. They were talking excitedly when they got back to the classroom and eagerly began removing seeds from their socks. However, when they began drawing their ideas about how their seeds moved, the students found this difficult. They could come up with ideas about how seeds travel, but Peg noticed that their ideas weren't connected to specific seed features. So Peg decided to introduce her students to the term "evidence." Each student chose 1 seed and gave their opinion (or claim) about how it traveled. Then, the class asked the person what their evidence was. The student then had to point to a feature on the seed that supported his or her claim. This established an important ritual in their classroom -- supporting explanations with evidence -- that will be important throughout this unit. It also helped guide students through this difficult task.
General Support	Why should students draw conclusions based on evidence? • Engages students in working and thinking like scientists (For example, in science, opinions are judged by how strongly they are supported by evidence. Students often think any opinion is as valid as any other.) • Facilitates problem solving skills & inquiry abilities. • Facilitates understanding of content. How can I help students draw conclusions based on evidence? Encourage students to draw conclusions based on evidence by… • working with peers to analyze the data collected during an investigation • using the data as evidence when drawing conclusions • asking questions like, *What data should we keep? What patterns exist in the data? What explanations account for the patterns?*
Lesson-Specific Support	Asking WHAT and WHY questions helps students form explanations. WHAT questions prompt students to state their opinion or to make a CLAIM. For example, students might say, "Seeds come from apples." This explanation is not complete, however. Students also need to give some sort of EVIDENCE to support their claim. WHY questions prompt students to use prior experiences, observations, experimental data, or reading material as EVIDENCE for their claim. For example, students might say, "I think seeds come from apples BECAUSE I once ate an apple and saw little black seeds inside it." In these ways, find opportunities to ask your students WHAT they think and WHY they think what they do in order to help them make complete explanations.
Supports for Assessment in Student Worksheets	The questions that will be asked on the assessment include the following: • Where do seeds come from? *(Possible Answer: Students might make the CLAIM that seeds come from fruits and vegetables.)* • During your seed activity, what did you do or see that makes you think this? *(Possible Answer: Students might suggest that they know seeds come from fruits and vegetables BECAUSE they found seeds inside both apples and pumpkins during the activity. Thus, this question prompts students to use their observations as EVIDENCE to support a claim.)*

We did not attempt to disentangle the effects of specific supports in the educative curriculum materials on Catie's perspective and practice. Instead, we examined how the various features within the educative materials synergistically supported, or failed to support, Catie in fostering students' explanations. This design limited the types of assertions we could make about the effectiveness of individual educative features. However, this study provides insight into the role the materials played overall in Catie's enactment of the plant unit.

Data Collection

The primary data sources for this study included field notes of classroom observations collected during the animal and plant units and three audio-taped, semi-structured interviews with Catie (approximately 50-70 minutes each). Secondary data sources included student artifacts as well as various other documents capturing aspects of Catie's practice. Table 3 summarizes the connections between the data sources and the research questions as well as the hypothesized outcomes for each research question.

Table 3
Analysis Structure for All Data Sources

Analysis Questions	Data Sources						Hypothesized Outcomes
	Observations	Interviews	Student Work	Lesson Plans	Daily Logs	Reflection	
RQ1. What is a new elementary teacher's perspective on the role of scientific explanations in her own science teaching, when she is provided with educative curriculum materials that are intended to support her in learning about this inquiry practice?							
1a. How does Catie define explanation?		X			X		Teacher espouses definition recommended in materials.
1b. How does Catie view the importance of having her students construct explanations?		X		X			Teacher views explanation construction as important and gives several reasons why.
1c. What are Catie's learning goals for her students?		X		X		X	Teacher wants students to develop *evidence-based* explanations for each lesson.
RQ2. What is a new elementary teacher's practice like for giving priority to explanations, when she is provided with educative curriculum materials that are intended to support her in fostering those explanations?							
2a. What generalized practices does Catie frequently employ in her science teaching, and how do they relate to fostering students' explanations?	X	X			X		Teacher's generalized practices support students' explanation construction.
2b. What specialized practices (if any) does Catie use for giving priority to explanations?	X	X	X		X	X	Teacher engages in several practices to support students' explanation construction.
2c. How do Catie's assessment practices and views shape the kinds of explanations students make?	X	X	X				Teacher wants students to develop evidence-based explanations on assessments.

We observed four lessons from the animal unit and used these observations to better understand what instructional practices Catie used with her students in teaching science and the role that explanations played in her science instruction before enacting the plant unit. Additionally, we observed five lessons from the plant unit. These observations enabled us to characterize Catie's use of the educative materials, any adaptations she made to the lessons, and the specialized practices she used to give priority to explanations during instruction.

In addition to classroom observations, we also interviewed Catie three times, once during the animal unit and once during and after the enactment of the plant unit. Interview questions centered on Catie's learning goals and instructional practices during the animal and plant units, assessment views and practices, and feedback on lesson activities and worksheets from the plant unit. During these interviews, we avoided using the terminology presented in the educative curriculum materials (e.g., claim, evidence, explanation) to allow Catie to freely express her ideas without feeling like she had to adopt the ideas/language presented in the plant unit. However, when she did use these terms, we asked Catie to elaborate on her ideas in order to make the meaning behind these words transparent during our conversations. Appendix A includes the protocols used in these interviews.

We also gathered a variety of other artifacts and documents to complement the data collected from the field notes and teacher interviews. We collected student work from the plant unit, including the students' pre-/post-tests and lesson worksheets. We also collected two daily logs capturing Catie's self-report of features in her instructional practice. (Catie had completed daily logs before as part of the larger study of which this one is a part and thus was familiar with their structure and content.) We also collected worksheets and assessment tasks from the animal unit and a teacher lesson reflection in response to feedback questions given midway through the plant unit enactment. Appendix B includes the questions used in the teacher lesson reflection. Finally, Catie had highlighted sections of lesson plans from the plant unit and jotted notes in the margins to help her better use the materials. Therefore, at the conclusion of the study, we also asked for and collected copies of her marked-up lesson plans.

Data Analysis

In analyzing the data, we developed several analysis questions to elaborate upon our two main research questions. These questions emerged from key themes in the data and are outlined in Table 3. We used these questions to guide the development of a coding scheme that reflected the predominant themes in the data. The research literature also informed the development of a coding scheme by drawing our attention to possible themes in the data. The coding scheme was developed through an iterative process of uncovering emergent themes related to each analysis question, coding the data with regard to these themes, modifying the themes as appropriate, and recoding the data with a revised coding scheme (Miles & Huberman, 1994). After multiple iterations of analysis and revision of themes, we developed a finalized coding scheme and recoded all the data using it.

After identifying themes and patterns in the data, we generated preliminary assertions for each analysis question based on the data and tested their viability by seeking both confirming and disconfirming evidence from multiple data sources (Erickson, 1986). We then triangulated data sources to support the most robust assertions (Johnson, 1997; Krefting, 1991). We were also able to triangulate against data from the larger longitudinal study of which this was a part (e.g., Forbes & Davis, in review). A single case study was then constructed to describe Catie's perspective and practice with regard to fostering students' explanations. To enhance the validity of the study, a second independent rater coded a subset of the data (15%) using the same coding scheme. We achieved over 90% interrater reliability and subsequently resolved all disagreements through discussion and clarified the coding key accordingly. We also discussed emerging findings at regular meetings with impartial colleagues; this peer review process provided further feedback on our emergent themes and contributed to the credibility of the assertions in the case study (Lincoln & Guba, 1985).

Results

This section characterizes Catie's perspective and practice with regard to helping her students construct explanations, while enacting educative curriculum materials that were intended to support her in fostering those explanations. In characterizing Catie's perspective on explanations, we first describe how Catie defined the concept of explanation and then describe how she viewed its level of importance in her practice. Next we describe her learning goals for her students during the plant unit. In characterizing her teaching practices, we describe some of Catie's generalized instructional practices and how they relate to fostering students' explanations as well as some of her specialized practices for giving priority to explanations. We conclude by detailing the ways in which Catie assessed her students' explanations and describing her perspective on why some of her students developed inaccurate explanations.

Catie's Perspective on the Role of Explanations in her Science Teaching

How does Catie define explanation? Even though the educative curriculum materials defined an explanation as a claim supported by evidence, it was uncertain whether Catie would define explanations in the same way. Therefore, the data was analyzed to determine how she defined this concept, whereby two themes emerged. Catie broadly defined explanation as a response that provides clarifying details and as a response that includes a general reason why students think their answer is right. However, after teaching the plant unit, Catie articulated a more sophisticated perspective, defining explanation as a response that contains students' observations as evidence in support of a claim. These themes are described below.

In the first and third interviews, Catie completed a daily log on the most recent lesson she had taught. In the daily log, she selected several items that she thought best characterized what her students had done in class. For both of the lessons, Catie said her students had "made sense of data or evidence," "used evidence in responding to questions," "developed explanations based on evidence," "connected explanations to scientific knowledge," and "communicated explanations." In clarifying why she had selected particular items, Catie explained what she had meant by having her students "develop explanations based on evidence," saying,

> If they give me an answer, for example, then I say, 'Well, tell me more,' or, 'I don't understand exactly. Elaborate. Expand on that.' That would be developing their explanation, like making it more understandable to the person they're telling. 'Give me some more words to describe what you're thinking about.' (Interview 1, 4/28/05)

Catie saw an explanation as a detailed response that allows students to expand on their thinking. However, she did not specify what these details would entail.

During the study, Catie also defined explanation as a response that includes a general reason why students think their answer is right. For example, in explaining her responses to the daily logs, Catie emphasized this idea that an explanation provides some sort of reasoning for why students think their idea is right. She said,

> I don't necessarily look for the right answer as much as I look for, 'If you've given me a yes or no, answered the question, have you given me a reason why you think it's that way?' (Interview 3, 6/7/05)

Here, Catie clarified that an explanation needs to include some sort of reasoning. However, she did not specify what this reasoning would entail. Catie explained that in an explanation she wants her students to describe why they think something happened a certain way, thereby providing a general reason why they think their claim or answer is right.

At the end of the plant unit enactment, a different perspective with regard to explanation emerged. In the third interview, Catie began to talk about an explanation as not just any detailed response but, more specifically, as a response that includes students' observations and actions in support of a particular answer or claim. She said,

> [An explanation is] giving a more detailed answer so if somebody else wasn't there doing the experiment with you or was reading it out at home, that they would understand what it was that you did, what it was that you saw, and could understand why you came to the conclusion that you did without being in the setting that you were in. (Interview 3, 6/7/05)

Catie began to articulate a more refined definition of an explanation by unpacking her ideas about what it means to have students give a "detailed answer." She clarified that these details include students' observations and actions and that they are used as evidence to explain why students arrive at the conclusion that they did.

Additionally, at the end of the plant unit enactment, Catie became more explicit about her ideas about what it means to have students give "reasoning" in their explanations. For example, in evaluating some of her students' explanations from the Seed Dispersal lesson, Catie explained that she wanted her students to provide descriptions of what they had seen on their seed so that she could see their reasoning for the answer they gave:

> 'What have you done or seen?' like, I see that they give some reasons why … you know the last one, 'It got there by animal fur.' 'It's pointy so it will stick on the animal.' That kind of an answer is a good reason. That tells me that they've looked at the picture, that there's some aspect or characteristic of that seed that's given them a thought in their head that this is the right reason. (Interview 3, 6/7/05)

Here, Catie specified that having students "give a reason" in an explanation meant having them use their observations as evidence for a claim. These excerpts show that Catie's understanding of explanation became more refined by the end of the plant unit enactment as she became more explicit about what it means to give a "detailed answer" or "reasoning" in an explanation. In these ways, Catie's perspective on explanation became more closely aligned with the educative curriculum materials.

How does Catie view the importance of having students construct explanations?

Even though the educative materials emphasized building explanation as an important inquiry practice, it was uncertain whether Catie would also view it as important in her teaching of the plant unit. The analysis of the interview data and the jottings in her lesson plans showed that Catie did view this inquiry practice as important for two reasons. She explained that having students build explanations helps her elucidate students' understanding of the content and helps students practice clearly communicating their ideas to others. However, even though Catie recognized these benefits, she never saw this practice as helping her students learn the science content. These themes are discussed below.

In her lesson plans from the plant unit, Catie discriminately marked up certain sections in the materials, including the materials lists, teacher preparation, lesson plan directions, and science background information. In addition to these markings, Catie highlighted ideas pertaining to fostering explanations in all of the lessons except one. In several lessons Catie highlighted the questions she planned to ask her students, often underscoring both the content-based questions as well as the questions that prompted students to give evidence for their answer. For example, Catie highlighted the sentences, "Write how they think [the seed] travels" and "WHY they think it travels in this way." Additionally, Catie highlighted several lesson-specific supports that were intended to help her foster evidence-based explanations. Catie could have easily skipped over these supports because they were set off by italics; however, Catie not only read these sections but also highlighted phrases within them that she thought were important. For instance, Catie highlighted the sentences, "Asking WHAT and WHY questions helps students form explanations…[Find opportunities to ask your students] WHAT they think and WHY they think." By taking the time to highlight sections related to fostering students' explanations, Catie emphasized the idea that she viewed this inquiry practice as important.

In the interviews, Catie expressed this same idea and highlighted several reasons. First, Catie explained that having students engage in this inquiry practice is important because it benefits her as a teacher by helping her determine if her students understand the science content. For example, she said, "It's important always to get the reason why because when you think, oh yeah, they've got it. 'Uh uh, you thought wrong'" (Interview 3, 6/7/05). Having her students explain their reasoning in their explanations enabled Catie to know if her students had understood the science content or not. Catie also explained that she always looks for her students' reasoning because a simple yes or no response is inadequate for her to gauge whether her students understand the concepts in the lesson.

Second, Catie explained that having students build explanations benefits her students. For example, she described explanation construction as a way for her second graders to clarify what they are thinking so that others can know how they arrived at the conclusion that they did:

> Sometimes the kids will say things to me and I have no idea what you're saying at all. 'I don't understand. Can you give me some other words to describe what you're thinking about?' I mean that's not even only in science but in other things as well. 'Give it to me in a sentence. I don't know what you're saying or, give me some more words to help because I'm not sure what you're talking about.' (Interview 1, 4/28/05)

By encouraging students to expand on their thinking and use details to develop an explanation, Catie explained that students are able to elaborate on their thinking and practice clearly communicating their thoughts to others. Additionally, Catie not only viewed this inquiry practice as important in science but even stressed its importance in other subjects as well.

Catie conveyed in many ways the idea that constructing explanations was important to her in teaching the plant unit. In the lesson plans, Catie highlighted ideas related to fostering explanations, and in the interviews, explained how this inquiry practice benefited both her and her students. However, despite these benefits, Catie never mentioned the idea that she could use this inquiry practice to help her students develop an understanding of the science content.

What are Catie's learning goals for her students? It was uncertain whether Catie would uphold the same learning goals that were espoused by the educative materials, that is, to develop both students' understanding of the science content and ability to construct explanations. Therefore, the interview transcripts and lesson reflection were analyzed to uncover Catie's learning goals for both the animal and plant units. The data analysis revealed that during the animal unit, Catie's learning goals emphasized only science content, but during the plant unit, they began to emphasize a dual focus on content and explanations for some lessons. However, for others lessons in the plant unit and in the unit assessment, Catie emphasized only science content in her learning goals, because she viewed constructing explanations as appropriate only when students were engaged in experimental work. These themes are explored below.

Throughout the animal unit, which Catie taught directly before the plant unit, Catie's learning goals placed a great deal of importance on scientific knowledge with no emphasis on having her students build explanations. For example, she said, "The main goals for the kids were to understand the differences between animals with bones and animals without bones; to understand the main groups of the animals like mammals, birds, whatever. And their habitats and adaptations" (Interview 1, 4/28/05). Here, Catie's learning goals for the animal unit lessons detailed *what* she wanted her students to know without any emphasis on having her students explain *how* they had come to know it.

Additionally, for the animal unit assessment, Catie placed a great deal of importance on learning science content with no emphasis on having her students build explanations. The study guide that she designed consisted of a list of vocabulary words with definitions and examples, and the test she gave included only matching, identification, and true/false questions. Catie explained that "there was a lot of memorization [on the animal unit test] so [the students] would know the vocab because that's one of the main things in science" (Interview 3, 6/7/05). Therefore, before teaching the plant unit, Catie's learning goals stressed the importance of learning science concepts with no emphasis on learning to build scientific explanations.

However, in three lessons from the plant unit, Catie's learning goals began to emphasize the importance in having her students not only develop an understanding of the content but also use their observations to build scientific explanations. For example, in the Seed Dispersal lesson, Catie wanted her students to understand how seeds are dispersed and to have them use their observations of seed features to explain how specific seeds moved. She said, "I wanted them to be able to look at a seed and analyze its characteristics, which help to make it move. I wanted them to understand the way of movement was and how we could tell that from the seed's characteristics" (Lesson Reflection, 5/19/05). Similarly, in the Sunlight Investigation lesson, Catie wanted her students not only to know that plants need sunlight but also to use their observations to explain how they know this. She said, "I wanted them to use what they saw happen to their plant as evidence for giving the answer of yes or giving the answer no [about whether plants need sunlight or not]" (Interview 3, 6/7/05). Therefore, for several lessons in the plant unit, Catie's learning goals were consistent with the educative curriculum materials because she aimed to provide opportunities for her second graders to build evidence-based explanations, in addition to learning the science content.

However, like the animal unit, Catie's learning goals for some of the plant unit lessons emphasized only the science content, even though these lessons were intended to emphasize both learning concepts and developing explanations. For example, for the Seed Parts lesson, Catie emphasized only content learning goals for her students, saying, "I was hoping that the students would understand that there are three main parts and what their names are (embryo, food supply and seed coat). I wanted them to understand the function of each and why it was necessary to have these parts" (Lesson Reflection, 5/19/05). In this lesson, Catie wanted her students to only learn the names of the seed parts and their functions, not engage in the scientific practice of building explanations. Consequently, Catie deemphasized the importance of having her students make observations of the different seed parts and use their observations to understand each part's function, which were learning goals espoused by the educative curriculum materials.

Additionally, for the plant unit assessment, Catie explained that she wanted her test only to assess *what* science content her students had learned, not *how* they had come to know it. For example, she described the kinds of questions she wanted to include on the unit test, saying,

> I think I would probably have a diagram so they would be able to label simple parts like the petals of the plant or the roots of the plant or the root hairs and I'd give them a word box and all that, and like asking them what are the things that makes the plant living that

> would be important for them to have and, to give them a couple of pictures of seeds and ask them how they travel. (Interview 3, 6/7/05)

Here, Catie's ideas for a unit test included assessing her students' knowledge of plant parts, living things, and modes of seed dispersal but not students' ability to build explanations.

Additionally, in commenting on whether she would use our post-test as her unit test, Catie indicated that she liked the content-based questions but not the questions that asked students to explain their ideas. She explained her reasoning for this response, saying, "I think that those kind of questions, like, 'What have you done or seen [that makes you think this]?' is more important when you're doing an experiment but not necessarily on a test" (Interview 3, 6/7/05). This excerpt uncovers why for the unit assessment Catie believed it was only important for her second graders to demonstrate an understanding of the science content.

In sum, during the animal unit, Catie's learning goals only emphasized science content, but during the plant unit, they began to incorporate a dual emphasis on learning content and building explanations, showing consistency with the goals in the educative materials. However, for some of the lessons and the unit assessment in the plant unit, Catie only emphasized the importance of having her students understand the science content. She explained that having students build explanations was only relevant when students were engaged in experimental work.

Summary. Initially, Catie broadly defined the practice of explanation construction, but by the end of the plant unit, had developed a more refined understanding that was more closely aligned with the educative materials. Additionally, Catie believed that having students construct explanations was important for herself and her students, but she never connected the idea that this inquiry practice could help her students learn science content. Finally, unlike the animal unit, Catie began to adopt learning goals that aimed to help students develop both their conceptual understanding as well as their ability to build explanations. This dual emphasis was consistent with the educative materials. However, some of Catie's learning goals in the plant unit still only emphasized the importance of having her students learn science content. Catie explained that having students form explanations is important but only when conducting experiments.

Catie's Practice & the Role of Explanations During the Plant Unit Enactment

Having explored Catie's espoused perspective, we now turn to her practice. First, we describe Catie's main generalized instructional practices and how they relate to fostering students' explanations. Second, we detail her specialized practices for giving priority to explanations. Finally, we conclude by describing how Catie assessed her students' explanations and her reasoning for why students developed inaccurate explanations.

What generalized practices does Catie frequently employ in her science teaching, and how do they relate to fostering students' explanations? In analyzing the field notes and interview transcripts, two generalized instructional practices emerged as central to Catie's science teaching: reading books and reviewing science concepts. Catie even engaged in these instructional practices during the plant unit, which did not specifically emphasize these practices. During the units, Catie used these practices to foster students' understanding of science content but not their ability to build evidence-based explanations. These practices are discussed below.

During the plant unit, Catie incorporated a reading component that was not originally part of the educative materials. She read several trade books (fiction and non-fiction) to her students on a variety of topics, including seed dispersal, germination, and roots. She also had her students read about plants in their textbooks. Catie saw reading as a valuable component to the plant unit, in addition to the hands-on activities. She said, "I think [the plant unit] went really well. There was enough experiment but there was also enough book reading" (Interview 3, 6/7/05).

Catie also frequently read to her students during the animal unit, as evidenced by classroom observations and interview transcripts. She read from the textbook, in addition to several trade books, to help her students learn about living/nonliving things, camouflage, habitats, and vertebrates/invertebrates. Catie mentioned, "We usually start by reading whatever's in the text because the stuff for animals in the text was really good" (Interview 1, 4/28/05).

In explaining why she uses text in her science instruction, Catie explained that reading helps her students develop an understanding of science concepts. For example, in the second interview (5/17/05), Catie explained, "I've read [the students] that one [book] about how a seed travels. I mean they love when I read the books to them because they really pick up on the information, the pictures and things." In this passage and others, Catie explained that reading books is an effective method for helping her students learn about science, especially when the books are written in "kids' language" and illustrated with pictures (Interview 1, 4/28/05).

The following passage about the Seed Parts lesson further illuminates this idea that Catie used books to help her students understand the science content. She said,

> I'm not exactly sure if they understood the different [seed] parts and why it's necessary. We really talked at length about the seed coat and how it's important for it to protect the seed. Like this embryo and food supply, I'm sure one of the books I have will have something in there about that we can read about. (Interview 2, 5/17/05)

Catie explained that many students failed to learn the names of the different seed parts and their functions from the lesson activity that had students dissect a seed. As a result, Catie wanted to find a book to share with her students because she felt confident that it would enable her students to obtain this understanding. Thus, Catie used text during both the plant and animal units to help students learn the science content. However, she did not use text to foster students' explanations.

The use of repetition emerged as a second prominent practice during both the animal and plant units. Catie frequently used this instructional practice to review science concepts with her students. For example, on multiple days following the Seed Parts lesson, Catie reviewed the three parts of a seed—food supply, embryo, and seed coat—and their respective functions with her students. (The following transcripts of classroom discourse are drawn from the field notes and may not be an entirely comprehensive representation of the discussion that evolved.)

> Catie: Can anyone tell me what happened to the lima bean when we soaked it in water?
> S1: The seed coat came off.
> Catie: Okay, the seed coat fell off.
> S2: It cracked open.
> Catie: Okay, what else did we notice?
> S3: The food supply.
> Catie: And what else was inside? *(Students offer their best guesses.)*
> S4: A word that starts with an E.
> Catie: Yes, it does start with an E. *(After more guessing, one student remembers.)*
> S5: Embryo.
> Catie: What did I tell you that it is?
> S5: It is the root.
> Catie: Okay, part of it will turn into a root. It's that baby what? *(Students don't remember.)* It's the baby plant, remember? So we are hoping that the seeds will shed their seed coats so we can see their embryos. (Field Notes, 5/19/05)

A few days later, a similar exchange was observed.

> Catie: What did we notice in our experiment with the lima beans soaked in water?
> S1: The seed coat fell off.
> Catie: Okay, the seed coat came off.
> S2: It got bigger.
> Catie: The seed got bigger…
> S3: They were more smooth.
> Catie: The seeds felt smooth. What part of the plant was growing? What was that part called?
> S4: Embryo.
> Catie: And what did I say the embryo was?
> S5: The beginning of a new plant. (Field Notes, 5/23/05)

Like other review sessions, Catie provided students with the opportunity to learn the science content but not to practice building explanations.

The interview transcripts provide further evidence that Catie used review sessions primarily to help her students learn science concepts. For example, in the third interview, Catie clarified why she reviewed plant and root parts with her students—interestingly, concepts that were not part of the educative materials but instead from books she had read to her students.

> It's just that whole idea of repetition, repetition, repetition, like a flash card. If you see it enough times, if you hear it enough times, you'll remember… It's better for them to be inundated with it over multiple times. Like we went over the different parts of the plant today and what is this part of the root called and what's that part called. And more and more kids every time are able to tell me the parts and what their names are so more or less that is a very good indication to me of how many kids are getting it and how much more we need to review. (Interview 3, 6/7/05)

This passage shows that Catie used repetition to help her students learn key science ideas.

Reading books and reviewing science concepts were two main generalized instructional practices that emerged during the teaching of both the animal and plant units. These practices provided students with the opportunity to learn key scientific ideas but not to learn how to build explanations. Because these two practices played a frequent role in Catie's science teaching—even during the plant unit which did not emphasize these practices as originally written—and facilitated students' learning of science content, Catie's classroom instruction tended to place a strong focus on helping students understand science concepts.

What specialized practices (if any) does Catie use for giving priority to explanations? Even though the educative materials included teacher learning supports for fostering explanations, it was uncertain whether Catie would engage her students in building explanations during the plant unit, especially since her main instructional practices tended to focus only on science content and her learning goals did not always include explanations. Analysis of the field notes, interview transcripts, and student artifacts revealed that Catie did engage her students in building scientific explanations throughout the plant unit. In doing so, three specialized practices for giving priority to explanations emerged. Catie used the questions in the student worksheets, whole class discussion, and general and specific prompts to scaffold her students' explanation construction. These practices are described below.

Classroom observations revealed that unlike the animal unit, Catie provided opportunities for her second graders to build explanations during the plant unit. She engaged her students in developing both oral and/or written explanations during all of the lessons in the unit, as advocated by the educative curriculum materials. She even had her students build explanations in the Seed Parts lesson and the Plant Investigation lesson, even though her stated learning goals for these lessons had only emphasized the science content.

To help her students use their observations in constructing scientific explanations, Catie participated in several specialized practices. First, for all but one lesson, Catie engaged her students in developing written explanations using the questions in the student worksheets. Catie described the usefulness of these explanation questions, saying

> As far as the experiments go, that question, "What have you seen or done that makes you think this way?" does help them to think about what it was that we did so that they have a better explanation. That seemed to be a reoccurring thing and it gave them more practice in explaining their reasoning and by the time we were halfway through [the unit] they were more comfortable doing that it seemed, so that was a good reoccurring question that was in there. (Interview 3, 6/7/05)

Additionally, most students answered the explanation questions in the worksheets and at least one student in every lesson (often more) developed a complete, accurate explanation. Below are examples of student explanations (with sentence starters in brackets) developed during the unit.

> [My seed depends on] animals and people [to move]. [I think my seed can move in this way because] I made it with sticks to make it stick to other things. (Student response from Seed Dispersal lesson, 5/12/05)

> [Do plants need sunlight?] Yes. [I think this is the answer to my question because] the plants that did not get sunlight are crumbled. (Student response from Plant Investigation lesson, 5/26/05)

These student explanations show that Catie used the questions in the student worksheets to structure students' explanation construction.

Second, in addition to helping students develop written explanations, Catie also provided opportunities for her students to communicate their explanations in whole class discussions. For example, at the end of some lessons, Catie had her students share their explanations as a class. She said, "We went through each question, and I read it to them and said, 'Now put down your answer.' We did all of the questions like that and then we went back and reviewed each of them separately again" (Interview 3, 6/7/05). Catie also added a whole class discussion to an activity that she had added to the Seed Dispersal lesson, which did not initially include an explanation component. This modification provided students with the opportunity to connect their observations of seeds to their claims about how they thought specific seeds traveled. This critical incident shows that Catie recognized that this activity was incomplete, thereby adding a discussion component to help her students make sense of the science. Thus, Catie not only used whole class discussions to help her students construct explanations but did so for an activity that was not initially designed with an explanation component.

Catie's third specialized practice for giving priority to explanations entailed rephrasing the questions in the student worksheets by using general and specific prompts. With regard to general prompts, Catie often followed up explanation questions by asking students to use describing words and/or to explain their reasoning for the answers they gave. For example, as Catie walked her students through the questions in the Sunlight Investigation lesson, she reminded students to use reasoning to explain why they thought plants needed sunlight or not:

> "'Do plants need sunlight?' We want to write that down in number one. Don't forget your capital and question mark…All right take a look at number two. 'What do you think is the answer to your question?' I want you to take a minute to think about the answer to the

question, 'Do plants need sunlight?' Yes or No, but also give a reason why you think yes or no…" (Field Notes, 5/17/05)

In addition to using general prompts, Catie also used specific prompts with the worksheets to help her students think about what specific kind of evidence they needed to use to support their claims. For example, Catie described some of the ways in which she provided specific support for students during the Sunlight Investigation lesson, saying,

> We reminded ourselves of the question that we were trying to answer [Do plants need sunlight?] and when they wrote it down, I said, 'Think about what happened from the very beginning when you had your plant to the very end and what kind of changes it went through and what you saw happen to it.' (Interview 3, 6/7/05)

In this excerpt, Catie talked about using specific prompts to focus students' attention on their observations of their plants, thereby helping her students use their classroom observations as evidence in support of the claim that plants need sunlight.

In the interviews, Catie illuminated her reasoning behind using general and specific prompts to expand on the questions in the student worksheets, saying, "The kids will read so quickly over them that they won't understand what the question is asking them, so a lot of times I'll read the question to them and then I'll rephrase it so that they understand what it's asking them to do" (Interview 3, 6/7/05, lines 364-371). Here, Catie explained that these prompts help her students stay on track and focus their thinking as they develop their explanations. For these reasons, Catie scaffolded students' explanations by helping them expand upon their thinking as they used their classroom observations as evidence for their claims.

In sum, Catie used three specialized practices to engage her students in building scientific explanations during the plant unit. Catie used the questions in the student worksheets to guide students' thinking about how to develop their explanations. She also provided opportunities for students to communicate their explanations in whole class discussions, even integrating a discussion for an activity that did not initially have an explanation component. Finally, Catie used general and specific prompts with the student worksheets in order to help students understand the questions and to think about them in more productive ways.

How do Catie's assessment practices and views shape the kinds of explanations students make? In assessing students' written work, Catie tended to focus on whether students understood the content rather than on whether they successfully used evidence in their explanations. When asked to examine the inaccuracies in students' explanations, Catie explained that these errors were due to students' physical exhaustion or indifference, rather than due to a lack of understanding or weaknesses in her practice. Consequently, Catie provided few opportunities for her students to develop better explanations. These themes are explored below.

In another study drawing on the student data from the plant unit, we analyzed the written explanations that students had developed by assessing the accuracy and completeness of their claims and evidence (Beyer & Davis, 2006). Accuracy was defined as information that was relevant to the lesson and scientifically correct. Completeness was defined as statements that required no inference on the part of the reader (e.g., logical connections made between ideas). The results from this analysis indicated that only about half of the second graders (55%) stated accurate and complete claims, and even fewer students (19%) provided complete and accurate evidence. Therefore, even though Catie engaged in several practices for fostering explanations, most students still struggled with this inquiry task.

Even though students' explanations often were incomplete and inaccurate, classroom observations showed that the ways in which Catie assessed her students' work often precluded her from giving her students' individual feedback. Catie explained, "Usually I collect [the worksheets] and just quickly leaf through them. I don't look at them really closely but just to make sure that they got the idea, that they did fill them out, and that most of their answers were correct" (Interview 1, 4/28/05). Catie likely had little time to focus on assessment because she had 30 second graders in her class and the responsibility of teaching many other subjects. Nonetheless, Catie's assessment practices did not provide her with many opportunities to help her students develop better explanations. Thus, many students' inaccurate responses remained uncorrected, and perhaps unnoticed.

When Catie did examine her students' work in the ways described above, she often looked to see if her students had developed an accurate understanding of the science content. For example, Catie noticed that on the post-test students continued to have an inaccurate understanding of how particular seeds are dispersed in nature, saying, "I was actually surprised at the end about how the seeds traveled. A lot of them still thought that [the cocklebur] traveled by wind" (Interview 3, 6/7/05). In addition to recognizing that students sometimes possessed an inaccurate understanding of science concepts, Catie also acted upon her detection of misunderstandings by finding ways to help her students better understand the content. For example, as mentioned previously, Catie read a book to her students to help them learn about the different parts of a seed, after some students had failed to learn these ideas during the activity in the Seed Parts lesson. However, Catie never mentioned or demonstrated that she recognized when students had developed inaccurate *explanations*. For example, she never talked with students about the inaccuracies of their evidence in their explanations. Therefore, Catie tended to perceive students' struggles with learning the content but not their struggles with building explanations. Consequently, the ways in which Catie examined students' work provided few opportunities for her to help her students develop better explanations.

Finally, to see if Catie was able to recognize the inaccuracies in students' explanations, we asked her to critique some of her students' explanations during the third interview. In reflecting upon her students' work, Catie was able to recognize several weaknesses in the kinds of evidence that her students provided. However, Catie gave several reasons for why she thought her students had developed poor explanations, which did not open up opportunities for her to help her students develop better explanations:

> Sometimes in the afternoon they just don't want to work so some of the kids just don't. They're so used to getting through their work so quickly that they don't want to have to sit there and write an explanation to me. 'I wanted it to.' 'I filled up the line. Isn't that good enough?' (Interview 3, 6/7/05)

In this excerpt and others, Catie explained that students tended to give incomplete, inaccurate explanations due to apathy and/or physical weariness after a long school day, legitimate concerns for second graders. However, in providing reasons for students' poor quality of work, Catie never attributed these inaccuracies to students' possible weak understandings of the content or of the practice of making explanations or to possible weaknesses in her own instruction. As a result, Catie's reasons for students' inaccurate explanations restricted the opportunities she had to help her students improve their explanations.

In sum, Catie did not provide individual feedback on students' written explanations, and when she did examine students' work, she tended to recognize and respond to students' erroneous content responses, not their inaccurate explanations. Finally, when asked about the inaccuracies in students' explanations, Catie reasoned that students developed poor explanations due to physical exhaustion and lack of interest, not from a lack of understanding or need for more support. Therefore, Catie's assessment practices and views did not provide her with many opportunities to help her students develop accurate and complete explanations.

Summary. Reading books and reviewing science concepts were two main generalized practices that emerged as fundamental in Catie's science teaching. Catie used these practices to help her students develop their understanding of the science content but not build explanations. However, during the plant unit, Catie did engage her students in the explanation-building activities suggested in the educative curriculum materials and even adopted three specialized practices for fostering explanations. Finally, even though Catie fostered explanations in her classroom, her assessment views and practices provided her with few opportunities to help her students develop accurate and complete explanations, often resulting in having students' written explanations remain uncorrected and perhaps unnoticed.

Discussion

Developing evidence-based explanations is no easy task, yet several studies have shown that both upper (Abell et al., 2000; Coleman, 1998; Herrenkohl & Guerra, 1998) and lower (Lehrer et al., 2000) elementary students are able to successfully engage in this scientific practice when provided with support. Researchers have designed high-quality curriculum materials to scaffold students' explanation construction (McNeill et al., 2006; Zohar & Nemet, 2002), yet teachers play a pivotal role in determining what and how students learn from such materials (Tabak, 2004). Teachers decide how curricular scaffolds are used to support student learning, when to hold students accountable for expressing and defending claims, and what new ideas and tools to give students to help them make sense of the science for themselves (Herrenkohl et al., 1999; Driver et al., 1994; McNeill & Krajcik, accepted). Because teachers play a key role in facilitating student learning, they need opportunities to improve their knowledge and abilities in fostering explanations. To better understand teachers' knowledge, beliefs, and instructional practices for giving priority to explanations, this study examined one new elementary teacher's perspective and practice for fostering explanations as she enacted educative curriculum materials that were intended to support her in learning about teaching science as explanation.

In this study, Catie placed a strong focus on helping her students develop an understanding of the science content during the animal unit with little emphasis on fostering students' explanations. For example, Catie's learning goals during the animal unit emphasized science content, at the exclusion of building explanations. She also frequently engaged in two main instructional practices, reading books and reviewing science concepts, which facilitated her students' understanding of science content but not their ability to develop scientific explanations. These findings are consistent with another study that found that teachers whose orientations toward science teaching were inconsistent with scientific inquiry tended to spend little time on the sense-making aspect of science lessons and instead tended to provide students with explanations rather than help students construct them themselves (Petish, 2004).

Even though her science teaching prior to the plant unit did not provide many opportunities for students to develop scientific explanations, Catie did begin to adopt instructional practices that engaged her second graders in building explanations during the plant unit, when she enacted educative curriculum materials that were intended to support her in learning to foster those explanations. In using these materials, Catie developed a more articulate definition of explanation, coming to view it as a response that uses students' observations as evidence in support of a scientific claim. Thus, Catie's understanding of explanation became more closely aligned with the educative curriculum materials. Additionally, in half of the plant unit lessons, Catie adopted learning goals that had a dual emphasis on content and explanations, thereby showing consistency with the goals in the educative materials. Furthermore, in her classroom practice, Catie engaged her students in developing written as well as verbal explanations by having them respond to questions in the student worksheets and using prompts and whole class discussion to guide students' explanation construction.

These findings elucidate some of the views and practices that teachers adopt when giving priority to explanations, which complements other research that has begun to identify and characterize teachers' knowledge, beliefs, and practices for specific inquiry practices (Crawford, 2000; Herrenkohl et al., 1999; McNeill & Krajcik, accepted). Many of Catie's instructional practices for fostering explanations are similar to the practices described in another study of a first-year, fifth-grade teacher (Avraamidou & Zembal-Saul, 2005). Both of these studies showed that the teachers fostered evidence-based explanations by having students develop written explanations in the form of claims and evidence, share their explanations in whole-class discussions, and respond to specific questions/prompts given by the teacher. These findings corroborate other studies that have begun to describe teachers' knowledge, beliefs, and practices for fostering inquiry-based instruction and build upon these studies by providing further insight into teachers' perspective and practice for this specific aspect of inquiry.

Additionally, these findings provide insight into the role that educative curriculum materials might play in scaffolding teachers' learning about how to foster students' explanation construction. Because Catie did not emphasize the role of explanations in her teaching prior to the plant unit but began to give priority to explanations during the plant unit, these findings suggest that the supportive features within the educative curriculum materials worked synergistically to provide Catie with opportunities to think about the role of explanations in her classroom practice and to engage her students in building scientific explanations. Providing opportunities for teachers to experience new ways of teaching by learning from and enacting curriculum materials can increase teachers' understanding of new teaching approaches and even lead to changes in knowledge and beliefs (Loucks-Horsley, Hewson, Love, & Stiles, 1998). These findings substantiate results from other studies that show that educative curriculum materials can positively impact teachers' perspective and practice about pedagogy and learners (Collopy, 2003; Petish, 2004; Remillard, 2000; Schneider & Krajcik, 2002; Schneider, 2006). However, what distinguishes this particular study from others is that the educative curriculum materials enabled this teacher to expand her perspective and instructional practices specifically for fostering evidence-based explanations, one of the most difficult inquiry practices to undertake for beginning elementary teachers (Haefner & Zembal-Saul, 2004; Petish, 2004).

Even though Catie's perspective and practice were consistent with the explanation focus in the educative materials in some respects, they were inconsistent with the materials in other ways. Throughout the plant unit, Catie tended to emphasize the importance of science content above the importance of helping her students build evidence-based explanations. Therefore, her perspective on teaching often impacted the opportunities students had for developing their own scientific explanations. For example, Catie's learning goals for some lessons in the plant unit and for the unit assessment did not include assessing students' ability to construct explanations. Instead, assessing students' understanding of the science content dominated her learning goals. Additionally, Catie engaged her students in reading and review sessions during the plant unit, even though these practices were not part of the educative materials. These practices provided opportunities for students to develop their understanding of the science content but not their ability to build explanations. Furthermore, Catie's second graders struggled to use accurate, complete evidence in their explanations, which is a common struggle even for older students (Bell & Linn, 2000; McNeill et al., 2006; Sandoval, 2003). However, in assessing her students' work, Catie only noticed their erroneous content responses, not their use of inaccurate, incomplete evidence in their explanations.

These findings show that helping her students learn the science content generally continued to play a more central role during the plant unit than helping her students construct scientific explanations, even though the educative materials emphasized the importance of this inquiry practice. As a result, Catie's perspective on science teaching sometimes deviated from the goals of the educative materials, influencing her enactment, and consequently, limiting the opportunities that students had to develop scientific explanations. This result is similar to other research that has shown that teachers' existing knowledge and beliefs about the subject matter, learning, and teaching can influence how they use educative curriculum materials and what they learn from them (Collopy, 2003; Petish, 2004; Remillard, 2000; Schneider, 2006).

Finally, this study elucidates some of the reasons why Catie's perspective and practice may have been incompatible with the educative curriculum materials. First, Catie did not appear to view the practice of building explanations as a way for her students to develop their understanding of scientific concepts. For example, Catie provided several reasons for why she thought it was important for students to build explanations. However, she never mentioned that she saw this inquiry practice as helping her students learn the science content, even though constructing explanations can help students develop a rich conceptual understanding of knowledge (Bell & Linn, 2000; Coleman, 1998; Zohar & Nemet, 2002). Additionally, in her learning goals for some lessons and for the plant unit assessment, Catie wanted her students only to develop their understanding of the science content and not to build explanations. Moreover, Catie viewed students' inaccurate explanations as resulting from physical exhaustion or lack of interest rather than from a lack of understanding of science concepts. Because Catie failed to see the practice of building explanations as a way to help students learn the science content, her views on explanation limited the role that explanations played during the plant unit and the opportunities she had to help her students develop better explanations.

A second reason why Catie's perspective and practice may have been incompatible with the educative curriculum materials is that she may not have viewed the practice of building explanations as an educational goal in and of itself. For example, Catie included this inquiry practice as one of her learning goals for some of the plant unit lessons. However, she viewed this inquiry practice only as a means to another educational end, that is, as a pedagogical strategy for helping students carry out experimental work. This perspective may have led Catie to deemphasize the importance of building explanations in some of her learning goals and to assess only her students' conceptual responses, thereby failing to notice the inaccuracies in students' explanations. This finding is similar to results in another study that examined the role of argumentation in secondary preservice teachers' science practice (Sadler, 2006). Sadler found that even though the preservice teachers viewed argumentation as a fundamental aspect in their science teaching, they tended to view it as a means to another instructional end rather than as a learning goal in its own right.

Despite these barriers to fostering explanations, changing one's teaching to reflect less of a content orientation and more of an inquiry orientation is a tall order for any teacher because knowledge and beliefs, which guide practice, are integrated within a system, which has developed over a lifetime of experiences both in and out of the classroom. Consequently, teachers' perspectives are incredibly complex and thus often very difficult to change (Bryan, 2003). Therefore, to expect Catie to make significant changes in her views and practices during the enactment of one science unit would have been unrealistic. However, in many respects, Catie did make important progress in bringing her practice more in line with reform-oriented goals. She developed a more sophisticated understanding of explanation, adopted this inquiry practice as a learning goal for some lessons, and provided opportunities for students to build their own scientific explanations.

Conclusion and Implications

Several studies have shown that fostering evidence-based explanations is a difficult task for many novice teachers (Haefner & Zembal-Saul, 2004; Petish, 2004; Sadler, 2006) and even for some experienced teachers (Herrenkohl et al., 1999; McNeill & Krajcik, accepted). However, research findings have revealed that even new elementary teachers are able to demonstrate aptitude in teaching science as explanation when provided with support (Avraamidou & Zembal-Saul, 2005). This particular study used educative curriculum materials as one form of support for helping one beginning elementary teacher give priority to explanations in her science teaching. In this investigation, the educative materials were useful in supporting certain aspects of Catie's perspective and practice by helping her develop a more sophisticated understanding of explanation as well as specialized practices for engaging her students in interpreting collected data, making meaning out of them, and using them to construct and communicate explanations.

By deepening our understanding of the views and practices that new elementary teachers might have with regard to this inquiry practice, these findings offer important insights to curriculum developers, as well as teacher educators, about the types of experiences they can create to foster beginning elementary teachers' knowledge, beliefs, and practices for supporting inquiry-oriented instruction. However, more studies are needed to examine the ways in which teachers understand the concept of inquiry and incorporate inquiry into their science instruction, especially with regard to explanations (Davis et al., 2006; Keys & Bryan, 2001). Because teachers' instructional practices significantly affect the opportunities students have to learn about explanations (Herrenkohl et al., 1999; McNeill & Krajcik, accepted), this research is imperative in order to help teachers successfully address the goals of current reform efforts that characterize science as argumentation and explanation (NRC, 1996; 2000).

Additionally, even though the case of Catie shows that educative curriculum materials can provide new elementary teachers with the opportunity to develop new understandings and practices for giving priority to explanations, there is still room for improvement to support teachers' learning about this inquiry practice. For example, during the study, Catie's existing perspective and practice about science teaching minimized her potential to foster her students' evidence-based explanations and thus to fully adopt the goals of the educative materials. Her emphasis on science content at the expense of helping students build their own explanations possibly precluded Catie from seeing how this inquiry practice could help her students understand the science content as well as why this inquiry practice was a learning goal in its own right. Catie needed additional support to help her modify her perspective and practices to enable her to develop a richer understanding of explanations and how to foster them. Thus, the features built into the CASES educative curriculum materials were insufficient for meeting Catie's needs.

Understanding the struggles that teachers face when giving priority to explanations is important for curriculum developers and teacher educators. New elementary teachers need support in developing teaching perspectives that are consistent with scientific inquiry and that highlight explanations as a key instructional focus (Petish, 2004; Sadler, 2006). For example, this study shows that beginning elementary teachers need access to specific educative curricular features and/or learning activities that can help them see how the practice of building explanations can help students develop a deep understanding of the science content. They also need opportunities to see that building explanation is a learning goal in and of itself and not just a means to another instructional end (Sadler, 2006).

By better understanding what *types* of educative features foster particular aspects of teacher learning, curriculum developers can incorporate the most promising supports and researchers can begin to investigate how supports within educative materials can be faded over time in order to help scaffold teachers' increasing expertise about fostering students' explanation construction. Curriculum developers, however, face the tension of providing teachers with sufficient support yet not inundating them with too much information (Davis & Krajcik, 2005). In addition, it is challenging to design a meaningful sequence of scaffolding for teachers within educative curriculum materials since teachers do not necessarily follow a particular sequence within a coherent set of curriculum materials. Teacher education learning activities can provide further support, for example, by giving preservice teachers the opportunity to learn about and experience science as argument and explanation (Haefner & Zembal-Saul, 2004; Sadler, 2006).

In addition to developing their knowledge and beliefs about explanation construction as an inquiry practice, teachers also need support in engaging their students in building explanations (Herrenkohl et al., 1999; McNeill & Krajcik, accepted). For example, curriculum developers and teacher educators might provide teachers with examples of student responses to help them see the range of explanations they might receive from their students. They might also provide commentary along with these examples of strong and weak explanations to help teachers critique the different components of a scientific explanation and to help them develop an understanding of what counts as complete and accurate evidence (McNeill & Krajcik, accepted; Remillard, 2000). Additionally, in developing curricula and/or activities for teacher education programs, designers and educators might also provide new elementary teachers with ideas about instructional strategies to help them foster their students' explanations, such as discussing the rationale behind scientific explanation, modeling how to construct an explanation, and explicitly defining the components of an explanation for students (McNeill & Krajcik, accepted). Furthermore, providing teachers with rationales behind these instructional approaches might help them understand the importance of scaffolding students' learning about this inquiry practice, thereby helping them support their students in developing accurate and complete explanations (Davis & Krajcik, 2005). Obtaining an improved understanding of productive rationales and instructional strategies for supporting inquiry-based instruction will help teacher educators and curriculum developers understand what sorts of knowledge, beliefs, and practices that preservice and inservice teachers need in order to help them overcome the challenges of learning about and adopting explanation-building practices.

Finally, more curriculum implementation studies, in general, are needed in order to investigate the role that educative curriculum materials might play in supporting teachers' learning about effective science teaching (Schneider & Krajcik, 2002; Schneider, 2006) and about explanations, more specifically (McNeill & Kracjik, accepted; Petish, 2004). These studies need to provide teachers with the opportunity to practice new curricular ideas and to reflect upon these experiences, in order to provide teachers with the opportunity to increase their understanding of reform-oriented practices and modify their beliefs about teaching and learning

(Loucks-Horsley et al., 1998). More specifically, additional studies need to examine the effects of particular curricular features in supporting teachers' knowledge, beliefs, and practice with regard to fostering explanations and to investigate how different types of educative features can support different types of teachers (Davis & Krajcik, 2005) or be faded over time. Beginning teachers and experienced teachers are likely to need different kinds of support as well as elementary and secondary school teachers. Finally, future research also needs to investigate the ways in which educative curriculum materials can support a larger sample of teachers. This would allow researchers to begin to develop generalizations about the ways in which the content and form of specific educative features influence teachers' learning and practice.

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Appendix A

Interview Protocols

Interview 1

Questions about the animal unit

1. Can you tell me what were some of the main learning goals you had for your students?
2. What were some of the activities that helped you meet these learning goals?
3. In this unit, how did you assess whether your students had learned these things?
4. Do you usually do a test at the end of a unit?
5. What resources did you draw from to prepare this unit?

Questions about Bird's Beak lesson from the animal unit

1. What was your specific purpose in doing this activity?
2. How did you assess whether your students had learned the things you wanted them to learn?
3. What kind of general criteria would you use to grade your students' answers to the question in these worksheets, and why do you think these things are important?
4. Tell me what kinds of answers you would hope students give on each worksheet, what you like/dislike about each worksheet and why, and what changes you would make and why?
5. Do you think some questions push students' thinking more than others, and if so, which ones and why?
6. I noticed you marked X on the daily log. What does X mean to you? Can you give me an example of when you did X? [E.g., X = using evidence, developing an explanation]

Lesson Plan Modification: Design questions that you think are important for students to answer at the beginning, during, or at the end of the lesson? Why have you chosen these questions?

Interview 2

Questions repeated for Finding Seeds, Grouping Seeds, Seed Dispersal, & Seed Parts lessons

1. What was your main learning goal for your students for this lesson?
2. What questions do you like in these lesson worksheets and why?
3. What questions would you (or did you) change and/or omit, and why?

Interview 3

General feedback questions on the plant unit

1. How do you think the unit went overall? Did anything take you by surprise?
2. Have you taught this unit before? Would you teach it differently in the future?
3. How did you use the teacher's manual?

Questions about the Sunlight Investigation lesson from the plant unit

1. What would you want your students to learn by the end of this lesson?
2. How did you assess whether your students had learned these things?
3. Do you think the questions in the assessment at the end of the lesson were helpful or were there some questions you didn't care for?
4. Can you think of anything more you'd want to add to the investigation?
5. I noticed you marked X on the daily log. What does X mean to you? Can you give me an example of when you did X? [E.g., X = using evidence, developing an explanation]

Questions about assessment

1. In this unit, how did you assess what your students had learned?
2. [If tests mentioned, ask: Why do you give tests? Do you design your own tests? In giving a test over the plant unit, what kind of questions would you include?]

3. Did you find the pretests useful? Why or why not?
4. Do you think the posttest makes for a good unit test? If not, what additions and/or changes would you make to the posttest so you could use it as a unit test?

Questions about student worksheets

1. Were there any types of question in the worksheets that you thought pushed students' thinking more than others? If so, which ones and why?
2. What kind of general criteria would you use to assess your students' answers? Why do you think these things are important?
3. In looking at student data: What answers did you hope your students would give to these questions? How would you evaluate each of the responses your students gave?

Lesson Plan Modification: Design questions that you think are important for students to answer at the beginning, during, or at the end of the lesson? Why have you chosen these questions?

Appendix B

Questions for Teacher Lesson Reflection

Questions repeated for Finding Seeds, Grouping Seeds, Moving Seeds, & Seed Parts lessons

1. What kind of answers did you hope your students would give by the end of this lesson? (In other words, what did you want your students to be able to do or say by the end of this lesson?)
2. What specific question(s) from the worksheets—if any—do you think helped you assess whether your students had learned these things or not? How did these questions help you?
3. Were there any other questions (NOT in the worksheets) that you asked (or would ask) in order to find out what your students had learned?