Characterizing Teachers' Verbal Scaffolds to Guide Elementary Students' Creation of Scientific Explanations

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Scaffolding is a complicated construct that can take many forms, including both written and verbal forms. This research study focused on three elementary science classrooms where students were using a series of written scaffolds to guide explanation building. In each classroom, data were collected to document and study an additional type of scaffold, verbal scaffolds that the teachers provided to complement the written scaffolds. Findings suggested that some types of verbal scaffolds, such as navigational guidance, were universal and therefore cut across all three grade levels. On balance, other verbal scaffolds were more common with younger students in association with their first explanation-building science unit, such as a verbal scaffold that turned an open-ended question into a few multiple-choice options. Through the characterization of the types and range of verbal scaffolds that teachers say, both in general and in response to audience, we can gain insights to inform both curricular design and professional development toward supported explanation building across target audience, time, and topic.

A Framework for K-12 Science Education (National Research Council [NRC], 2012), the important document serving as the foundation for the Next Generation Science Standards (NGSS), outlines a new emphasis in science education on a smaller set of core content ideas and science practices for all students, including students in grades K–6. The document states, "building progressively more sophisticated explanations of natural phenomena is central throughout K–5, as opposed to focusing only on descriptions in the early grades and leaving explanation to the later grades (NRC, 2012; p. 2–25). Research in science education consistently demonstrates that as early as the onset of formal elementary-age schooling, American students are capable of sophisticated scientific reasoning such as constructing explanations about focal science content (Metz, 2008; NRC, 2007). Several research groups have designed curricular units that focused on guiding students to construct scientific explanations as a means to promote deep conceptual understandings of focal science content. For example, Linn, Shear, Bell, and Slotta (1999) guided seventh and eighth grade students' explanation building about the causes for the onset of deformities in frogs as a means to deepen conceptual understanding of selected concepts in genetics, biology, and chemistry. On balance, nearly all of the recent studies that focused on guiding explanation building selected a target audience of students in the secondary years of schooling (grades 7–12 in the United States). Therefore, while these studies have provided a foundation for how curriculum developers and researchers might guide middle and high school students in explanation-building activities, (e.g., Chin & Osborne, 2010; McNeill & Krajcik, 2008), they do not provide specific guidance for how to support elementary students' explanation building. This article addressed this gap in the research through a research study designed to examine the range and types of verbal supports teachers provide to guide elementary school students in explanation building around concepts in biodiversity and ecology.

Conceptual Framework

Extending Prior Work With Explanations

Our work builds from several research studies that have explored different approaches to guiding students' written development of evidence-based explanations. These studies draw on the work by Brown and Campione (1990) and others who argue that guiding students to write explanations leads to deeper conceptual understandings of science concepts because it challenges students to evaluate, integrate, and elaborate on their knowledge in important ways (e.g., McNeill, Lizotte, Krajcik, & Marx, 2006). Chin and Osborne (2010) provided empirical evidence for the use of question prompts, contrasting views, argument diagrams, and evidence statements in guiding secondary students toward more productive argumentation.

The notion of scaffolding, with regard to teaching and learning, was first introduced in the context of tutoring. It described the ". . . process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts" (Wood, Bruner, & Ross, 1976, p. 90). Over time, scaffolds can be minimized or removed so that the student are encouraged to generation more aspects of the work on their own. Later, this idea of one-on-one scaffolding was connected to Vygotsky's (1978) sociocultural perspective on learning and development, and it was expanded to include the idea of a teacher using a range of tools, such as language (both written and verbal) to scaffold the learning of a whole class (Palinscar & Brown, 1984; Stone, 1998).

Several science education studies focus on the types of online and written scaffolds that are particularly useful for guiding scientific inquiry and complex reasoning (Krajcik, Blumenfeld, Marx, & Soloway, 2000; Quintana et al., 2004; Reiser, 2004). These authors describe scaffolds that can reduce the complexity of the task by, for example, (a) sequencing the task for easier management, (b) providing componential guidance such as boxes for the different parts of a scientific explanation, (c) providing navigational guidance to help students monitor their progress, and (d) providing content-specific hints and prompts to guide students to distinguish salient from irrelevant variables.

Despite a set of studies by different research teams focused on written scaffolds and explanation building, we recognize that we would be naïve to assume that the written scaffolds are the only important form of scaffolding, or even the most important guidance, that might be associated with strong learning outcomes on posttests. We propose that studies, even our own, that study only written scaffolds are inevitably over simplifying the set of cognitive supports that are assisting students in constructing scientific explanations. This realization led us to our current work to review literature that discusses teacher talk and teacher verbal supports that provide guidance to students (Scott, 1998).

Teachers' Talk and Verbal Supports to Guide Science Inquiry

In this article, we define and study verbal scaffolds as the range of ways teachers verbally guide the construction of evidence-based explanations, both in addition to and along with provided written scaffolds in the curricular materials. Reform-based approaches to science inquiry emphasize the importance of the role of teachers as facilitators who ". . . orchestrate discourse among students about scientific ideas," (NRC, 2000, p. 22). A reasonable body of literature exists that explores the ways teachers can help to make scientific inquiry, including explanation building, accessible to students. van Zee and Minstrell (1997) examine the types of questions and responses teachers use to prompt high school students to think deeply about their own and their peers' responses. In this work, van Zee and Minstrell (1997) study the effectiveness of guides that help students compare approaches or validate a consensus with evidence. McNeill and Krajcik (2008) studied instructional practices that teachers used to first introduce scientific explanation to middle school students, such as "making the rationale of scientific explanation explicit" or "defining scientific explanation" and its components. In a subsequent paper, these authors discuss the synergistic use of written scaffolds and pedagogical practices to guide fruitful explanation building among middle-school students (McNeill & Krajcik, 2009). These researchers suggest that teachers' verbal supports may come in many different forms including: (a) sequencing tasks for easier student management, (b) using questions to breakdown difficult tasks into smaller pieces (similar to componential guidance), (c) highlighting key ideas about a concept, or (d) making connections to students everyday lives by providing examples and analogies (Krajcik et al., 2000).

Herrenkohl and Guerra (1998) utilized student roles as a means of peer support for the generation of predictions and explanations. In their studies, students were assigned different roles including intellectual roles or "thinking practices" and audience roles. Intellectual roles provided students with metacognitive guidance about what to share and explain during discussions. Audience roles offered a complementary purpose through the use of student prompting through reflective questions such as, "What is your prediction? What did you find out? Did your results support your theory?" (p. 448). Other studies similarly utilize teacher, peer, or self-prompted metacognition to engage in and encouraging meta-talk through the explanation-building process (e.g., Herrenkohl, Tasker, & White, 2011; Leinhardt & Steele, 2005). Collectively, these studies suggest that verbal scaffolds emphasizing either cognitive or metacognitive support and that are presented in conjunction with written curricular scaffolds may provide valuable reflection and support for elementary-age student participation in the procedural and cognitive aspects (Fleer, 1992) of scientific discourse and practices, such as generating scientific explanations.

Building on this literature base, we designed our study to characterize the range of verbal scaffolds teachers spontaneously provided in a set of elementary classrooms where students were working with an eight-week, inquiry-based curricula emphasizing written scaffolds for explanation building. We were interested in collecting data from a purposeful sampling of elementary classrooms to provide an empirical base as to how, if or when elementary teachers introduce and guide complex ideas like "making a claim" and "providing supporting evidence" with students who are just embarking on explanation construction activities for the first time. In addition, we were interested in gathering data to determine whether or how teachers might differentially utilize verbal scaffolds for younger late-elementary students (e.g., fourth graders) as compared to slightly older students (e.g., sixth graders).

Research Questions

Because there are some suggestions but no agreed-upon measures of verbal scaffolds documented in the literature and virtually no discussion of verbal scaffolds for elementary science, we adopted an exploratory study approach "to identify or discover important categories of meaning and to generate hypotheses for further research" (Marshall & Rossman, 1999, p. 33). We adopted a constant comparative analysis research approach (Glaser, 1965; Patton, 2002) in order to engage in cycles of coding and analysis. A constant comparative analysis approach permitted the systematic identification and characterization of the range of verbal scaffolds our sample teachers were using along with the written scaffolds in the curriculum. For example, a first pass through the teacher transcript data would reveal a particular type of verbal scaffold. When we observed a similar meaning unit in other transcripts, we revisited and discussed both transcript cases and the corresponding codes in light of each other in order to determine whether codes needed to be combined or new codes were needed to capture both similar and different characterization of their verbal supports. These cycles of coding and analysis continued until coders reached consensus. In this manner, the constant comparative approach supported our ability to gather details of both the kinds and frequency of verbal scaffolds used by our sample of fourth, fifth, and sixth-grade teachers. The research questions explored were:

1. What types of verbal scaffolds did teachers provide when guiding late elementary students to develop scientific explanations about focal science content?
2. In what ways did teachers' verbal scaffolds differentially complement written scaffolds presented in the inquiry-focused curricular programs?

Method

A major goal of The Center for Essential Science is to develop and evaluate replacement curricular units focused on guiding fourth through 10th graders in explanation building, prediction building, data collection, and analysis of focal science concepts in the life and environmental sciences. Our work is anchored in a learning progression framework, which focuses on the development and evaluation of sequential learning goals in science or mathematics that (a) builds on what we know about how children learn, (b) spans multiple years and age bands, and (c) focuses on the development of complex thinking about a small number of focal topics (NRC, 2007). In our work, our learning progression serves as a template for the sequence and definition of learning goals across multiple, consecutive curricular units, assessments, and professional development modules. Prior to this study, our research team developed a learning progression with two dimensions: a content dimension encompassing concepts in biodiversity and ecology across fourth, fifth, and sixth grades and a science practices dimension encompassing the creation of scientific explanations.

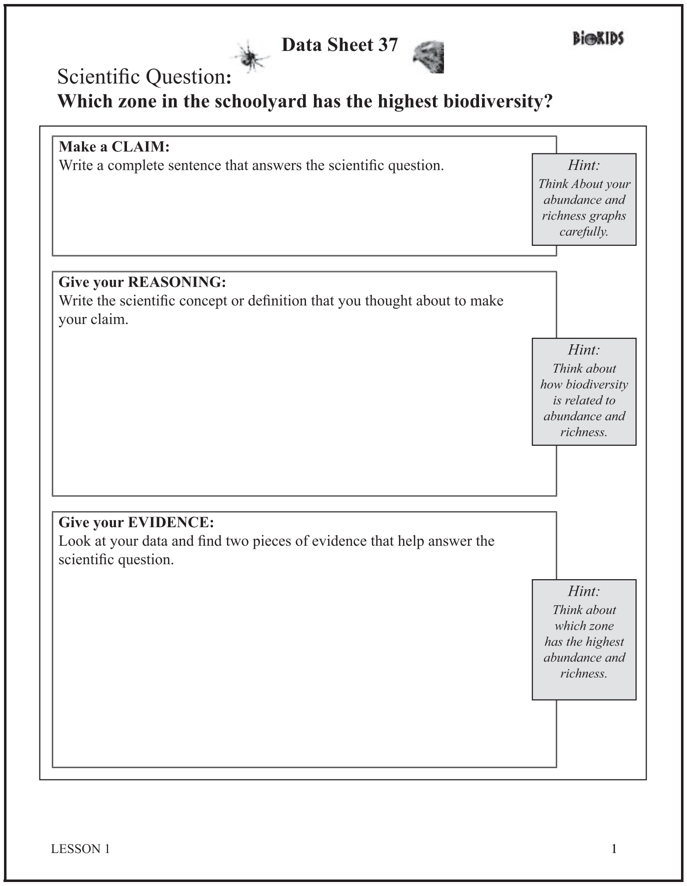
The curricular units consist of eight weeks of activities that ground students' learning in data collection about local organisms, emphasize repeated exposures to ecology and biodiversity content, and provide repeated practice with written guidance to the development of scientific explanations. As the curricular units were enacted within several classrooms within a large, urban district allowed us to observe how the curriculum lent itself to modification to fit the needs of students with a diversity of learning needs and backgrounds. For example, we saw the curriculum translated into Arabic and Spanish to support students' with different language and cultural backgrounds in guided knowledge building and explanation construction.

One of the most challenging aspects of our work was the development of a set of written scaffolds that were embedded in our curricular units and designed to guide fourth, fifth, and sixth graders' first construction of evidence-based explanations about focal content. In this work, we adopted a definition for scientific explanations that is modified from the definition of argumentation in Toulmin (2006), that was used in our earlier work (e.g., Songer, Kelcey, & Gotwals, 2009), and that is similar to the model used by some other researchers (e.g., McNeill et al., 2006). In our definition, a scientific explanation contained three components, each of which are defined as follows:

1. A claim. A claim is a complete sentence that answers the scientific question,
2. Two pieces of evidence. Evidence are data that support the claim and that address the scientific question, and
3. Reasoning. Reasoning is a scientific concept or definition that links the claim to the evidence and that supports the scientific question.

Each student completed eight weeks of scaffold-rich explanation construction activities. The student workbooks for each grade contained several opportunities to practice explanation building as follows: seven scaffold explanations in fourth grade, nine scaffold explanations in fifth grade, and 10 scaffold explanations in sixth grade (Songer, 2006; Songer et al., 2009). The written explanation hints and prompts were developed and revised through several rounds of empirical evaluation, including a set of studies that evaluated the effectiveness of consistent support or faded support over the eight-week curricular unit (Lee, 2003). Previous research results evaluating students' abilities to develop explanations under various guided conditions were strong. In one recent study focused on written scaffolds for explanation-building with sixth graders, students demonstrated significant student achievement gains on both multiple choice and open-ended explanation-building tasks, with achievement gains particularly strong on the explanation-building tasks in associated with a variety of content foci in the life sciences (Songer et al., 2009). For more information on the learning progression and the achievement results, see Songer et al. (2009) or Songer and Gotwals (2012).

Within the student notebooks, the written scaffolds came in two forms: (a) explanation-construction scaffolds and (b) content scaffolds. Explanation-construction scaffolds consisted of response boxes and sentences that defined the component of the explanation, such as the definition of evidence. Content scaffolds guided students to the particular location (e.g., a data table) or resource that was the source of the data serving as claim, evidence or reasoning. Figure 1 presents a sample fifth grade data sheet that contains both explanation-construction (larger boxes) and content (gray boxes) scaffolds. In all activities, the scientific question at the top of the page was matched to the content standards required for our target audience.



Data Sheet 37

BioKIDS

Scientific Question:

Which zone in the schoolyard has the highest biodiversity?

Make a CLAIM:

Write a complete sentence that answers the scientific question.

Hint:

Think About your abundance and richness graphs carefully.

Give your REASONING:

Write the scientific concept or definition that you thought about to make your claim.

Hint:

Think about how biodiversity is related to abundance and richness.

Give your EVIDENCE:

Look at your data and find two pieces of evidence that help answer the scientific question.

Hint:

Think about which zone has the highest abundance and richness.

LESSON 1

1

Figure 1. Sample student sheet from the fifth grade unit illustrating explanation construction (big rectangles) and content scaffolds (gray boxes).

Sample

The sample was 161 students in grades four through six and their six teachers in a large urban public school district within the midwestern United States. This district provides education for over 90,000 students in grades PK to 12. This urban district had a large minority student population with approximately 88% African American students. Almost 78% of the student population was economically disadvantaged according to the district profile (District Website, 2010). Two teachers from each grade level were selected using criterion sampling to be participants in this study (Patton, 2002). Teacher selection criteria included: (a) the teacher had at least one year of experience teaching this curricular unit in the past, (b) the teacher was actively completing the fourth, fifth, or sixth grade curricular unit with her students leading up to the lessons we wished to study, and (c) the teacher was using the curricular unit as her primary resource to teach instead of heavily modifying or using outside resources often to teach related topics. In each classroom, the individual teachers made all of their own decisions about how and when to teach the district-mandated science content. In other words, even though the six teachers were all following the same curricula, the research team granted complete autonomy to teachers for all pedagogical decisions.

One teacher, Teacher B, taught both fourth and fifth grades, resulting in six classes of students taught by five different teachers. Video records were collected of each teacher guiding students to construct a scientific explanation in response to the same scientific question in each grade. Grade levels, teachers, number of students per grade, scientific questions and parts of the scientific explanation addressed in this lesson are available in Table 1.

Each explanation building data sheet took approximately 150-minute class period to complete. Researchers observed and taped the teachers' discussions and lessons of the day of

Table 1
Simple Descriptors for Video Records

Grade	Teachers	*n*	Scientific Question and Activity in Observed Lesson	Parts of Explanation
Fourth grade	A and B	52	Data Sheet 14: "*Is the animal you collected an insect?*" Students use their observations of an animal they collected from their schoolyard to determine whether or not their animal is an insect.	Claim Evidence
Fifth grade	B and C	46	Data Sheet 32; "*Which zone in the schoolyard has the highest biodiversity?*" Students use the data they collected in their schoolyard to determine which zone has the highest biodiversity) Data Sheet 37: "*Which Michigan habitat has the highest biodiversity?*" Students use provided data in the form of bar graphs to determine which Michigan habitat has the highest biodiversity [Figure 1]	Claim Evidence Reasoning
Sixth grade	D and E	63	Data Sheet 15: "*What will happen to the number of johnny darters in the river if the water becomes very muddy and dark?*" Students look at their ecosystem diagram to determine what biotic and abiotic factors would be impacted by a muddy river.	Claim Evidence Reasoning

completion of the explanation building data sheet, as well as the days preceding and following the day she was guiding the students through the data sheet we were studying. Depending on the teacher, some enactments took more or less than the 150-minute class period. Our research team also collected samples of student notebooks so student responses could be reflected upon in follow-up interviews with the teachers. Video cameras were focused on capturing the teachers' actions and verbal talk throughout the day's activities. The camera was placed at the back of the classroom as the teacher addressed the full class. When the teacher traveled to small groups, the camera traveled with the teacher to capture the teacher's verbal interactions with the smaller groups of students.

Data Analysis

Coding steps. Video records of each teaching enactment were transcribed and analyzed by members of the research team. The constant comparative method (Glaser, 1965) was utilized to code and analysis all transcript data. This process consisted of three steps:

1. Identifying and comparing incidences applicable to each starting category (e.g., start codes),
2. Implementing cycles of iterative coding toward integrating categories and their properties, and
3. Organizing final list of codes and examples.

Since the researchers were familiar with the curriculum and how it was enacted, an initial "start-list" of codes describing possible verbal scaffolds were identified and revised through several iterations of coding (Miles & Huberman, 1994, p. 58). The start-list included codes about reading particular hints directly from the written worksheets and codes about using analogies. The transcripts were divided into "meaning units," at the sentence and paragraph level, and codes were applied to these units to describe the different verbal scaffolds the teacher was using to guide students' construction of scientific explanations. For example, a meaning unit could be the following segment of transcript:

> Teacher E: Shalen, read the scientific question.
> S: What would happen to the number of johnny darters if the water in the river becomes very muddy and dark?
> Teacher E: What happens to the johnny darters if the water in the river becomes very muddy and dark? (Teacher E, classroom video 1:03, 12/17/2009)

This segment could be coded as "orienting to the scientific question." The next teacher comment made up another meaning unit that was coded as "orienting to the hint" for claims:

> Teacher E: Look at the hint. Look at the hint. Trey, read the hint for me. The gray box on the side. (Teacher E, classroom video 1:30, 12/17/2009)

In the second step, codes evolved after each iteration of review of the transcripts and having the raters discuss the emerging codes and codebook. For example, our start-list code for "reading the hint" was divided into two subcategories: (a) the teacher read the hint verbatim from the worksheet, or (b) the teacher oriented students toward the

Table 2
Types and Frequencies of Verbal Scaffolds by Grade

Scaffold Type	Example	4th	5th	6th
1. Orienting to hint	There is a hint right here, "think about your animal and if it has the same characteristics as an insect," you need to answer that question. (Ms. A)	-	/	X
2. Clarifying terms	Before students were able to discuss the interactions among different components of an ecosystem, Teacher E prompted them to clarify their understanding of the term ecosystem: "What is an ecosystem? Let's go back. What's an ecosystem, Tia?" (Ms. E)	/	/	X
3. Writing format	Students were writing short phrases for the parts of their scientific explanation and Teacher B used writing format scaffolds to remind them to provide complete sentences: "It still has to be a sentence, you can't just write, no sections, no body sections, no head. It still has to be a sentence." (Ms. B)	X	X	/
4. Formatting sentence content	Is that kind of like a general idea? You guys gave me real specific things, you went way past general. You named organisms, you name how they would be affected. Bring it back down to something real general. When this happens, that happens. When this changes, it affects that. (Ms. E)	/	/	-
5. Directing to necessary content	The teacher guided students to provide evidence that muddy water would block sunlight and affect organisms that need sunlight to survive in an ecosystem. She guided students to think about the needs of plants so they could make this connection: "So, what would . . . okay, Charles . . . If it's a plant, what do they need to grow? What do plants need to grow?" (Ms. D)	X	X	X
6. Answer options	"Just answer the question 'yes what I collected is an insect' or 'no what I collected is not an insect' and stop" (Ms. A)	/	-	-

X = 10–20 instances; / = four to nine instances; - = fewer than four instances.

hint by reminding them where they could read about it. In the third step, codes were grouped into categories and subcategories that shared similar meanings, resulting in pattern codes that implied themes across the data (Miles & Huberman, 1994). Efforts were made to find both confirming and disconfirming evidence for emerging themes.

Addressing reliability. During the coding process, two of the authors coded two transcripts to initially revise the start-list of codes. Check coding was completed through a process of discussion among coders when differences occurred, and subsequent updates to the codebook through addition, deletion, combination, rename, or redefinition of codes. After a resulting codebook was realized, both researchers coded the remaining four transcripts separately. After full coding, the coding practices and results of both coders were compared again, and differences were discussed until agreement and clarification of the codebook was reached. The researchers recoded the entire data set together with the final codebook to ensure that they were applying the codes appropriately and consistently (Miles & Huberman, 1994, p. 64).

Results and Discussion

Range and Frequency of Verbal Scaffolds

In response to our first research question "what types of verbal scaffolds did teachers provide when guiding late elementary students to develop scientific explanations about focal science content" our qualitative analysis revealed six conceptual categories of verbal scaffolds demonstrated by our teachers. Table 2 presents each of the six conceptual categories, a representative example of each category, and general information about the frequency of each type detected in our fourth, fifth, and sixth grade observations.

Orienting to hint. The first type, orienting to hint, involved the teacher helping students to focus on the various content scaffolds (e.g., written hint boxes) on their data sheets. Content hint boxes began with the phrase "think about . . ." to help draw student attention to the science concepts they should draw on to write their claim, evidence or reasoning while constructing their scientific explanation. Teachers in our study oriented students to the content hint boxes in different ways, such as having a student read the hints out loud to the class or using the hints themselves to turn into questions for the students. For example, one teacher said, "There is a hint right here, 'think about your animal and if it has the same characteristics as an insect,' you need to answer that question" (Teacher A, classroom video 10:35, 5/24/2010).

Another teacher simply directed students to read the hint: "Look at the hint. Look at the hint. Trey, read the hint for me. The gray box on the side" (Teacher E, classroom video 1:30, 12/17/2009). And yet another teacher used the hint as a jumping-off point for a series of questions that she felt would guide the students:

> T: Look at the hint. Read the hint for me, Tia.
> S: Think about how the biotic and abiotic components interact.
> T: Okay, let's make sure we understand. What is biotic? What does that mean? (Teacher D, classroom video 8:42, 2/1/2010)

Clarifying terms. Clarifying terms referred to a scaffold where the teacher paused the discussion from moving forward until she had helped the students review their understanding of terms that were necessary for them to either make sense of the written scaffolds or to come up with other appropriate parts of a scientific explanations. For example, Teacher B anticipated the importance of students understanding the terms abundance and richness as essential pieces of the larger concept of biodiversity prior to analyzing graphs to determine which Michigan habitat had the highest biodiversity:

> Teacher B: Okay, what's biodiversity?
> S: (hard to hear . . .)
> Teacher B: It's the combination of both, right? So if that's the combination of both, and wetlands had a combination of both, wouldn't that be our answer, our reason why we picked that? What does biodiversity really mean? Anybody else need any help?
> Teacher B: Do you know what biodiversity is? What's biodiversity? The total (s/he points at the graphs and word) . . . abundance, AND, richness, so that's biodiversity.
> So, which one had the highest of abundance (points to graph), "wetlands" and which one had the highest richness, "wetlands."
> Wetlands. So biodiversity is what, total (points)
> S: Abundance and richness. (Teacher B, classroom video 17.32, 6/1/2010)

Writing format. The third type of verbal scaffold, writing format, referred to the verbal support teachers provided to guide students on how to structure the written responses to each part of the explanation. For example, Teacher B said, "it still has to be a sentence, you can't just write, no sections, no body sections, no head. It still has to be a sentence" when guiding her students to make a scientific claim that was a complete sentence (Teacher B, classroom video 22.17, 6/1/2010). This category of verbal scaffolds was not necessarily defining the parts of an explanation. Rather, it was directing students to complete responses that were customary norms of the curricular activities.

Formatting sentence content. In contrast, formatting sentence content were specific verbal scaffolds that helped simplify more difficult open-ended instructions. In this type of verbal scaffold, teachers simplified a difficult written scaffold by reworking it into a more structured verbal scaffold. Examples included cases where teachers provided students with the start of the sentence the students were to complete or teachers translated an open-ended instruction into a fill-in-the blank statement to guide their students' development of that part of the explanation. In one example, Teacher E used sentence starters to guide students into transforming more specific responses into appropriately general statements associated with the reasoning component of a scientific explanation:

> Teacher E: Is that kind of like a general idea? You guys gave me real specific things, you went way past general. You named organisms, you name how they would be affected. Bring it back down to something real general.
>
> When this happens, that happens . . .
>
> When this changes, it affects that . . . (Teacher E, classroom video 19:01, 12/17/2009)

Similarly, Teacher C provided a case of formatting sentence content scaffolds to help her students focus their answers through a fill-in-the blank format as follows:

> Teacher C: In biodiversity you have to think about richness and abundance together, right, and so you have to give me an answer, well, which zone has highest biodiversity. So I think that is fine, but you need to tell me the rest of it . . . I think that zone blankitty-blank, whatever you think, and where are you going to look for it? (Teacher C, classroom video 22:11, 5/10/2010)

Directing to necessary content. The fifth category, directing to necessary content, involved specific kinds of direction by teachers so that students could more easily determine which aspects of the content information or data was most important for their explanation building. In one example of this category, Teacher D was leading a class discussion to guide students to design an explanation to address the question, what would happen to the johnny darters if the river got muddy? In her verbal discussion, Teacher D directed students to focus on the conditions that would develop if the river was muddy. To achieve this goal, Teacher D initiated a series of questions that directed students to the necessary content.

Answer options. The sixth category, answer options, were the instances when the teacher provided two or more possible answer choices for students, and then prompted students to choose one to use for their response. This was a high scaffold category, as we observed this guidance as acting much like structuring an open-ended response into a multiple-choice question. This scaffold type occurred when students were confused about what to provide relative to a very specific written scaffold, such as a written scaffold related to the development to a claim to address the question, is the animal you collected an insect? Teacher A addressed the confusion among her students by providing an answer options verbal scaffold that narrowed the range of choices of possible claims:

> Teacher A: You're going to answer the question, yes it is or no it's not. Don't tell me because, why or anything else like that at this point. Just answer the question "yes what I collected is an insect" or "no what I collected is not an insect" and stop. (Teacher A, classroom video 10:27, 5/24/2010)

Verbal Scaffolds to Complement Written Scaffolds

Our second research question focused on the ways in which teachers' verbal scaffolds differentially complement the written scaffolds. In other words, we were interested in analysis to determine patterns in the type or frequency of verbal scaffolds used by teachers in the different grade levels. This analysis was conducted in order to further characterize the range and amount of customization of verbal scaffolds relative to their particular target audience, context, and written stimulus materials. As our data represent only a small sample of the total verbal scaffolds used by our teachers in association with the complete curricular unit, we do not intend to over generalize our results beyond the instances and teachers in this sample. Nevertheless, Table 2 and the subsequent discussion suggested some potentially interesting trends.

One of our first observations was that certain types of verbal scaffolds tended to be used similarly across grade levels, while others tended to be more frequently observed at either younger or older grades in our sample. One type of verbal scaffold, directing to necessary content, was observed in similar amounts by all of our teachers. As students needed to draw on data and information they may have collected days before working on their data sheets, directing to necessary content became a helpful role to guide student thinking. Even if students had worked with similar material in earlier construction of explanations, our results suggest that directing to necessary content was important. For example, some of the sixth grade written worksheets asked students to refer to multiple data sources in the gathering of evidence for their explanations, and teacher verbal scaffolds were observed as a guide to the correct previous resources.

Our data suggest that other types of verbal scaffolds were more commonly observed in association with the sixth grade curricular unit when compared to fourth and fifth grade observations. Both orienting to hint and clarifying terms were slightly more common with sixth grade teachers as compared to fourth or fifth grade teachers. We speculate that these slight differences can be explained, in part, because of the more complex scientific vocabulary in the sixth grade unit as compared to the fourth or fifth grade vocabulary. For example, sixth graders were expected to construct explanations by drawing on data and definitions associated with the terms biodiversity, abiotic, biotic, abundance, and richness. Fourth and fifth graders' explanation building, however, tended to focus on a fewer number of terms overall and terms with greater real world understandings, such as insect, body part, or legs.

A third set of verbal scaffolds demonstrated slightly higher frequencies by teachers of younger students. Verbal scaffold, writing format, was observed more commonly among fourth and fifth grade teachers than sixth graders. Our explanation of this outcome is that sixth graders likely needed fewer prompts about the use of complete sentences or the need for two pieces of evidence to support their claims both because their reading level was higher and because of their general familiarity with literacy norms and the explanation worksheet format. Similarly, there were more instances of verbal scaffold, answer options, and formatting sentence content, with younger students. Answer options and formatting sentence content were verbal scaffolds that simplified an open ended activity through either transformation into multiple choice-type options or providing or a sentence starter. These verbal scaffolds provided additional structure and guidance for the younger students' early attempts at explanation building. We speculate that teachers of these younger students

Table 3
Examples and Frequency of Alternative Definitions of Evidence by Grade

	D (6th)	E (6th)	B (5th)	C (5th)	A (4th)	B (4th)
			Prove it.	Give me your proof.	Proof.	Without it [evidence], you could trick me.
			How do I know that?	*Your* evidence may not be the same as your neighbor's.	*Prove* it to me.	*Prove* it to you.
					Is it true or not?	Take the data that goes with what we're looking for.
					Make certain the evidence is valid.	
Total	*0*		*4*		*6*	

recognized that some of the younger students were not ready to complete the explanation components on their own, and therefore required structured options to guide them into the correct answers.

Verbal Scaffolds That Provide Multiple Working Definitions of Abstract Terms

As mentioned earlier and illustrated in Figure 1, one of the primary design features of our curricular units was the written activity sheets that contained two types of written scaffolds: explanation-construction scaffolds and content scaffolds. In designing these scaffolds, we intentionally kept the wording and format of the explanation-construction scaffolds identical throughout the units in order to provide consistent support in the definition of claim, evidence, and reasoning within and across units. For example, all data sheets used the same instructions to guide students in generating the reasoning portion of a scientific explanation as follows: "Write the scientific concept or definition that you thought about to make your claim." In contrast, the written content scaffolds were unique to each scaffold explanation worksheet, as the content scaffolds needed to support the generation of a claim, evidence, or reasoning to match the scientific question and the specific topic area. For example, the content scaffold from Figure 1 reads, "Hint: Think about which zone has the highest abundance and richness."

Our data and analysis revealed that while all teachers used the research project definitions of claim, evidence and reasoning, our teachers supplemented these project definitions with their own alternative phrasings. For example, in order to help her fourth grade students have a rich understanding of the term "evidence," one of our fourth grade teachers used four slightly different variations of the definition of evidence in the verbal talk that we observed. These variations included, "proof," "prove it to me," "is it true or not?," and " make certain the evidence is valid." To further characterize this type of verbal scaffold that complemented the written claim, evidence, and reasoning scaffolds, we gathered information on the amount and kinds of different working definitions that different teachers generated as verbal scaffolds to complement the written scaffolds focused on explanation construction.

Our data reveal that individual teachers, including both of our fourth grade teachers, presented several different variations of their own phrasings of definitions when they are first introducing the concept of evidence. Table 3 presents a set of similar but not identical phrasings for the term evidence that our teachers generated to guide their students in constructing scientific explanations. We found it interesting that both Teacher A and Teacher B provided at least three different variations of evidence as a way to emphasize the importance of the term and to help establish a strong understanding of this term across their students and curricular activities.

Verbal rephrasing of evidence also had some similarities across teachers. For example, while at times all four of the teachers discussed alternative definitions of evidence as a form of "proof," teachers' phrasings of proof were not identical with each other, nor did individual teachers always use the same wording within their own classroom.

Table 4 presents similar but not identical phrasings for the term reasoning. The curriculum defines reasoning as "a scientific concept or definition that you thought of to make your claim." The alternative definitions used for reasoning were phrases such as "supports your claim," or "what would make you say that?" Another teacher asked students to come up with a "general idea." In this way, we believe she was trying to help her students to utilize the idea of a scientific concept as a tool for understanding reasoning. Our data also support the statement that our teachers predictably utilized more redefinitions of difficult terms such

Table 4

Examples and Frequency of Alternative Definitions of Reasoning by Grade

	D (6th)	E (6th)	B (5th)	C (5th)	A (4th)	B (4th)
	Supports your claim	Tell me the reasons why you said that.	Reason that you said that.	Find out why, what was your thinking on this.		
	General idea	Everybody's doesn't necessarily have to be the same.	Why would you even say that?	What reason?		
			What made you say that?	the proof		
			What's your *reason why?*	Why your evidence supports your claim. How we got there. Why did you choose this piece and not this piece? Why do you say this evidence proves your point? Where you got that reasoning from		
Total	*4*		*12*		*0*	

as evidence and reasoning compared to terms more easily understood, such as claim.

Discussion and Implications

One of our early hypotheses was that even as we knew our elementary teachers were interested in tailoring verbal scaffolds to their target audience, we might observe teachers' verbal scaffolds as looking like either variations of the written scaffolds or variations of secondary teachers' verbal scaffolds observed by others. Interestingly, the verbal scaffolds we observed contained some similarities and some differences from the types of written and verbal scaffolds suggested by others' research with secondary students. Our data revealed two verbal scaffold types that show similarities to the types of secondary student written scaffolds: Clarifying terms and directing to necessary content resemble content guidance and clarification observed by others. We suggest that our study confirmed the importance of these types of verbal scaffolds across age categories and context, as directing to necessary content was observed frequently by our teachers at all grade levels, and clarifying terms was prevalent or common across all three grades.

Our work provides new insights about verbal scaffolds targeted for younger students through our observations of three of our scaffold types. The three types of verbal scaffolds that were most common with younger students were not explicitly mentioned in others' work with secondary students. These types: Writing format, formatting sentence content, and answer options represent higher levels of structure or scaffolding that might have been most beneficial for younger students. For example, answer options involved the teacher specifically rephrasing an open-ended question into one or two responses so students did not have to generate these options themselves. The observation of these three new types of verbal scaffolds suggest that there may be a set of more specific kinds of guidance and scaffolding that were observed as valuable for younger audiences just starting to learn about explanation building.

Our results that illustrate the alternative working definitions of key terms used by elementary teachers suggest important customization of verbal scaffolds to help younger students find meaning in the abstract, but important, component of the scientific explanation. For example, teachers might have used phrases like "proof" to help redefine evidence, as it is a common term that students might know from television police dramas or detective work. In this way, the teachers' verbal scaffolds could help make a bridge or a connection to students' everyday language with scientific practices. On balance, as the term "proof" has different meanings in the courtroom, field of mathematicians, and among scientists, we speculate that the same word could introduce confusion in higher grade levels when other uses of the word "proof" are introduced. Similarly, teachers may have introduced the verbal scaffold of "a general idea" for reasoning to guide students to move away from a specific instance or case and toward a "general idea." We speculate that this teacher was hoping to guide students to move beyond a particular instance toward a guiding idea or definition that could back or support relevant evidence. These observations also suggest that the written scaffolds, while structured and permanent on the page, may not be best used verbatim, where students are simply going through the motions but not grasping a more substantive definition for each component. We believe our data suggest that the written scaffolds provide a general tool for students to become familiar with the parts of the explanation, while verbal scaffolds, discussion, and prompting by the teacher and others can help students make these unfamiliar ideas their own. This use of more general tools that are used explicitly but flexibly is also discussed in the work of Herrenkohl, Palinscar, DeWater, and Kawasaki (1999) with their intellectual tools, or thinking practices, that guide students as they construct explanations.

Collectively, our results suggest that while written scaffolds provide useful guidelines for teachers and students, verbal scaffolds can help bridge between the written scaffolds and the abstract or unfamiliar scientific terms and their own lives and experiences. We see evidence in our work that the verbal scaffolds suggest a range of different kinds of supports or cognitive bridges between unfamiliar scientific terminology and ideas to more familiar ideas and practices. Our work also suggests some of the particular ways in which teachers customized their verbal scaffolds to complement written materials and tailor instruction for their younger target audience.

Our findings suggest implications for both curriculum developers and professional development design. Our work suggests particular types of verbal supports that teachers could use to guide younger students in explanation building. Curriculum developers, including ourselves, might provide a set of productive working definitions of important, abstract terms such as evidence and reasoning or examples of better or weaker analogies to guide younger students and their teachers in more productive explanation construction. Examples of how particular verbal scaffolds may lead to particular productive or unproductive student response may help teachers plan how they will use written scaffolds. For example, we envision a resource that might accompany a curricular unit that would articulate the strengths and weaknesses of particular working definitions, such as defining evidence as a "true fact" that may lead to students selecting true but incorrect evidence since not all true facts serve as appropriate evidence to support a particular scientific question. Our findings also have implications for professional development. Written materials and student work might accompany video images of interactions between the teacher and students. Teachers could follow observations with student written answers toward discussion of the ways in which verbal scaffolds may have supported or confused students.

Our work extends a dialogue on the kinds of guidance and supports we need to guide students in explanation construction around focal science topics. If we are to experience the kinds of success and understanding of science knowledge outlined in the Framework for K-12 Science Education (NRC, 2012) and the NGSS, we must extend both the dialogue and the empirical studies on explanation building toward a focus on elementary-age students or we risk falling short of the deeper conceptual learning we desire across grades, students, and contexts.

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