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The Importance of Engaging K–5 Students in Scientific Explanation

How can you support K–5 students in making sense of science ideas? How can you support students in constructing scientific explanations using evidence? Consider the following vignette from Mrs. Kyle's first-grade classroom.

> *Mrs. Kyle's first-grade class had been learning about magnets. The class wanted to find out the answer to the question, Are some magnets stronger than others? In an assessment of prior knowledge, many students indicated that they believed larger magnets were stronger than smaller ones. The students helped design three different tests about the strength of magnets. They used magnets of different sizes and shapes, and Mrs. Kyle intentionally*

included a small, but very strong, bar magnet. The tests included investigating the number of paper clips each magnet could pick up (the clips were in plastic bags of 25), the number of chained paper clips that could be attached to a magnet, and the distance at which a magnet could attract a paper clip. After completing their tests of the different magnets and recording their observations, the first-graders gathered in a circle for a science talk to discuss their results.

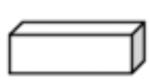
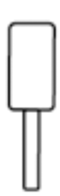
> *Mrs. Kyle: What are the results of our tests to find out if some magnets are stronger than others?*
>
> *Sam: The bar magnet was the strongest.*
>
> *Mrs. Kyle: Were you surprised by that?*
>
> *Sam: Yeah, because it was the smallest.*
>
> *Mrs. Kyle: How do you know that the bar magnet was the strongest, Sam?*
>
> *Sam: The bar magnet could hold eight paper clips in a chain, the horseshoe magnet could only hold four paper clips, and the wand magnet could hold six paper clips.*
>
> *Mrs. Kyle: Did anyone else notice the same thing?*
>
> *Lauren: Yes, the bar magnet held the most in our group.*
>
> *Joe: That's not the same as our group.*
>
> *Mrs. Kyle: What did you find?*
>
> *Joe: We found that the bar and the wand magnet both held eight paper clips in a chain.*
>
> *Mrs. Kyle: What about the horseshoe magnet?*
>
> *Joe: It held four, so it wasn't that strong.*
>
> *Mrs. Kyle: What about the number of paper clips that were lifted? Did you find that the bar magnet was the strongest in that test?*
>
> *Olivia: Yes, the black bar magnet could lift the most, and then the wand, and then the horseshoe.*
>
> *Mrs. Kyle: Do other groups agree with Olivia's results?*
>
> *Several students: Yes!*
>
> *Mrs. Kyle: So what would you say about the magnets?*
>
> *Olivia: The bar magnet was the strongest.*

This vignette highlights important aspects of what it means to do science in elementary schools. Students worked to understand magnets and they were guided by a question about the strength of magnets. The teacher intentionally created a situation that challenged students' naïve ideas about larger magnets being stronger than smaller ones. Students designed and conducted tests to compare the strength of three magnets, and they recorded data/observations in their science notebooks (see Figure 1.1). Now students have come together as a group to share and discuss those observations. But what does it mean to engage students in scientific explanation? Let's extend the scenario and consider how the nature and purpose of the discussion changes from reporting results to constructing claims from evidence.

> *Mrs. Kyle: Let's go back to our question: Are some magnets stronger than others? How would you answer that?*
>
> *Nate: Yes.*
>
> *Mrs. Kyle: Can you put your claim in a sentence, Nate?*
>
> *Nate: Some magnets are stronger than others.*
>
> *Mrs. Kyle writes the statement on a chart that has the question at the top: Are some magnets stronger than others? Beside the word* claim *she writes, "We found that some magnets are stronger than others."*

FIGURE 1.1

Strength of Magnet Data Table

Magnet Type	1	2	3
	Number of paper clips lifted	Number of paper clips in chain	Distance magnet pulled a paper clip
Horseshoe 	25	4	3 cm
Bar 	125	8	8 cm
Wand 	75	6	6 cm

Mrs. Kyle: What is your evidence for that, Nate?

Nate: Ummmm, the black magnet could lift more paper clips.

Mrs. Kyle: Can you look at your charts and give me some numbers to support Nate's claim?

Alison: Well, the black bar magnet lifted 125 paper clips, the wand magnet lifted 75, and the horseshoe only 25.

Mrs. Kyle: How does that go with our claim?

Alison: It tells us that the bar magnet is really strong and the horseshoe is not that strong.

Mrs. Kyle: And what does that mean?

Alison: It tells us that some magnets are stronger, like the bar magnet.

Mrs. Kyle: Should we include that as evidence for our claim?

Most of the class: Yes!

Mrs. Kyle writes on the chart: "Our evidence is that the bar magnet lifted 125 paper clips and the horseshoe magnet lifted 25, so the bar magnet is stronger than the horseshoe magnet."

Mrs. Kyle: Did we find the same evidence at our other stations?

Lauren: Yes, we found that the black bar magnet could hold more in a chain than the other magnets.

Joe: Except the wand magnet was the same for my group.

Mrs. Kyle: You're right, Joe. Can we still say that the bar magnet was stronger than the horseshoe with the evidence from your group?

Joe: Yeah, I guess—the bar magnet did hold more than the horseshoe.

Lauren: I think that we should write that about the bar magnet.

Alison: That would be more evidence.

Mrs. Kyle: I'm going to add that as more evidence. How many did the bar magnet hold in a chain?

Lauren: Eight, and the horseshoe held only four.

Mrs. Kyle adds to the chart: "We also found that the bar magnet could hold eight paper clips in a chain and the horseshoe could only hold four."

Mrs. Kyle: So we have written a claim to answer our question and we used evidence from our tests to support our claim. Who would like to read what we wrote for the class to hear?

Although sharing results is an important aspect of doing science, the second part of the vignette illustrates *moving beyond* results to constructing an explanation from evidence. More specifically, after results have been shared, the teacher guides students to propose a claim by returning to their original question about the strength of magnets. Students propose a claim—*Some magnets are stronger than others*—and consider their observations in light of that claim. In doing so, the class is able to support the claim by using multiple sources of evidence. How can you incorporate these kinds of scientific practices and talk with your students? This book will support you in exploring this question and provide you with research-based strategies for engaging K–5 students in constructing, communicating, and critiquing scientific explanations. In Chapter 1, we provide a rationale for engaging children with scientific explanation, share samples of written explanations, address the importance of intentionally connecting science and literacy, describe the benefits of engaging in scientific explanation for both students and teachers, and preview what to expect of students at different grade levels when it comes to scientific explanations.

Why Teach Children to Construct Scientific Explanations?

Fundamentally, science is about investigating and explaining how the world works. Scientists do not use a single "scientific method," but they do ask questions that frame their investigations of the natural world, have criteria for what data to collect and how to minimize human error, and rely on evidence derived from data to inform the development and critique of explanations. Similarly, young children are known to be naturally curious about how the world works. They explore enthusiastically, observe carefully, and ask important questions, such as *Why do some insects blend in with their environment but others have bright colors that get them noticed?* Until recently, the ability of children to engage in scientific practices and reasoning was underestimated, which in many cases translated to limited science learning opportunities in elementary school settings. Issues related to science in elementary grades are well documented and range from a lack of materials and high-quality curricula to an overwhelming emphasis on fun, hands-on activities that pay greater attention to "snacks and crafts" rather than big ideas in science. However, new research on young children's development provides compelling evidence that regardless of socioeconomic level, they come to school with rich knowledge of the natural world and the ability to engage capably in sophisticated reasoning and scientific thinking (Duschl, Schweingruber, & Shouse, 2007). But why focus on scientific explanations?

There are a number of important reasons for engaging elementary students in scientific explanation. Constructing and critiquing evidence-based explanations engages students in authentic scientific practices and discourse, which can contribute to the development of their problem-solving, reasoning, and communication skills. These abilities are consistent with those characterized as twenty-first century skills necessary for a wide range of current and future occupations

(Krajcik & Sutherland, 2009; National Academies, 2009). Constructing scientific explanations can also contribute to students' meaningful learning of science concepts *and* how science is done. Both components are necessary for scientific literacy and evidence-based decision making in a democratic society. As illustrated with the initial vignette, inquiry science is not only about collecting data and sharing results. By participating in the language of science, through talking and writing, students make sense of ideas and explain phenomena as they negotiate coherence among claims and evidence. This meaning-making process is essential to science learning and is supported through the construction of scientific explanations.

As mentioned previously, when science is actually taught in elementary school classrooms in the United States, the predominant approach has become hands-on activities, which can minimize the importance of big ideas and meaning making. There is much evidence to support this claim; however, the most striking may be the Trends in International Mathematics and Science Study (TIMSS) Video Study. This international comparison of science teaching at the eighth-grade level revealed that although U.S. lessons involved students in activities, the lessons placed little or no emphasis on the science concepts underlying those activities. More specifically, 44 percent of U.S. science lessons had weak or no connections among ideas and activities, and 27 percent did not address science concepts at all (Roth et al., 2006). In contrast, there were significant gains in science learning among students whose teachers were prepared to attend to a coherent science content storyline in their instruction. A coherent science content storyline focuses attention on how the ideas in a science lesson/unit are sequenced and connected to one another. Such storylines also concentrate on lesson activities to help students develop a "story" that makes sense to them (Roth et al., 2011). Our work with teachers in K–5 classrooms suggests that emphasis on scientific explanation and attention to developing a coherent content storyline are complementary efforts that can support student learning (Roth et al., 2009; Zembal-Saul, 2009). These ideas will be used later in the book to guide the planning process for science instruction.

Finally, in a recent synthesis of research from fields including science education and educational psychology, the National Research Council report, *Taking Science to School* (Duschl et al., 2007), and the companion document for practitioners, *Ready, Set, Science!* (Michaels, Shouse, & Schweingruber, 2008), make a strong case for the importance of science in elementary school classrooms. Those authors conceptualize proficiency in science around four interconnected strands (pp. 18–21).

- *Strand 1: Understanding Scientific Explanations* means knowing, using, and interpreting scientific explanations for how the natural world works. This requires that students understand science concepts and are able to apply them in novel situations, as opposed to memorizing facts.
- *Strand 2: Generating Scientific Evidence* requires knowledge and abilities to design fair tests; collect, organize, and analyze data; and interpret and evaluate

evidence for the ultimate purpose of developing and refining scientific models, arguments, and explanations.

- *Strand 3: Reflecting on Scientific Knowledge* involves understanding how scientific knowledge claims are constructed, both in scientific communities and the classroom. Students should recognize that scientific knowledge is a particular kind of knowledge that uses evidence to explain how the natural world works. They also should be able to monitor the development of their own thinking over time and in light of new evidence.
- *Strand 4: Participating Productively in Science* refers to norms of participation within the classroom community. For example, students should understand the role of evidence in presenting scientific arguments. The aim is to work together to share ideas, build explanations from evidence, and critique those explanations, much like scientists do.

An emphasis on evidence and explanation is not only overwhelmingly captured in the strands of science proficiency but it is also consistent with the framework for K–12 science education (National Research Council [NRC], 2011), national science education standards and reform documents (American Association for the Advancement of Science [AAAS], 2009, 1993, 1990; National Research Council [NRC], 2000, 1996). *A Framework for K–12 Science Education: Practices,Crosscutting Concepts, and Core Ideas* is one of the three fundamental dimensions of science education (NRC, 2011). (NRC, 2011) is engaging students in scientific practices, which includes constructing explanations from evidence and participating in argumentation. The *National Science Education Standards* (NRC, 1996) recognize the centrality of inquiry in science learning, emphasizing that students should "actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills" (p. 2). The content standards for abilities necessary to do scientific inquiry explicitly state that K–4 students should "use data to construct a reasonable explanation" and "communicate investigations and explanations." In addition, K–4 students should "think critically and logically to make the relationship between evidence and explanation" and "recognize and analyze alternative explanations." The *Benchmarks for Science Literacy* (AAAS, 2009) also include a similar focus on explanations and justifying claims.

The companion document to the *National Science Education Standards,* titled *Inquiry and the National Science Education Standards,* elaborates on inquiry as a content standard and describes five essential features of classroom inquiry that vary according to the amount of learner self-direction and direction from the teacher. These features include (1) learner engages in scientifically oriented questions, (2) learner gives priority to evidence in responding to questions, (3) learner formulates explanations from evidence, (4) learner connects explanations to scientific knowledge, and (5) learner communicates and justifies explanations (NRC, 2000, Table 2.6, p. 29). In this book, our approach to engaging students in scientific explanation addresses all four strands of proficiency, as well as the essential features of classroom inquiry, and will be illustrated through examples drawn from classroom science teaching.

Scientific Explanations in the Classroom

Our interest in students' construction of scientific explanations originated from research and professional development efforts with teachers participating in school–university partnerships and the education majors who interned in their classrooms. Two of the authors, Carla Zembal-Saul and Kimber Hershberger, first began their work specifically with elementary school science. The project was known as *TESSA: Teaching Elementary School Science as Argument* (Zembal-Saul, 2009, 2007, 2005) and the goal was to support teachers in scaffolding students in the process of using talk and writing tasks to negotiate the construction of evidence-based arguments in science. The use of the term *argument* in the TESSA project was based on the adaptation of Toulmin's Argument Pattern (Toulmin, 1958) and was intended to highlight the use of claims, evidence, and justification (the basic structure of an argument) in talking and learning science. Teachers and university faculty associated with TESSA worked to develop many of the strategies that are shared in this text. The other author of this book, Katherine (Kate) McNeill, and her colleague Joseph Krajcik began their work in a similar project with middle school teachers over ten years ago (McNeill & Krajcik, 2012). More recently, Kate has begun working with elementary school teachers on how to support younger students in scientific explanation in writing and talk (McNeill, in press; McNeill & Martin, 2011).

Both projects align with the framework for scientific explanation used in this book. In order to illustrate a scientific explanation, the following examples come from Kimber Hershberger's (third author) grade 3 classroom where students were investigating simple machines. Over the course of 6 weeks, the class tested levers, inclined planes, and pulleys to develop claims about the relationship among distance moved by the load and applied force. Students had used the structure of claims supported by evidence in prior science instruction.

In the first writing sample (Figure 1.2), Karen has drawn and labeled a representation of the class demonstration in which she, one of the smallest children in the class, was able to lift the teacher by using a lever. Below her drawing, she wrote a claim that responded to the question the class was investigating: "We can use a lever to lift teacher if we put the fulcrum closer to the load." Karen documented her observations, which she used as evidence to support her claim.

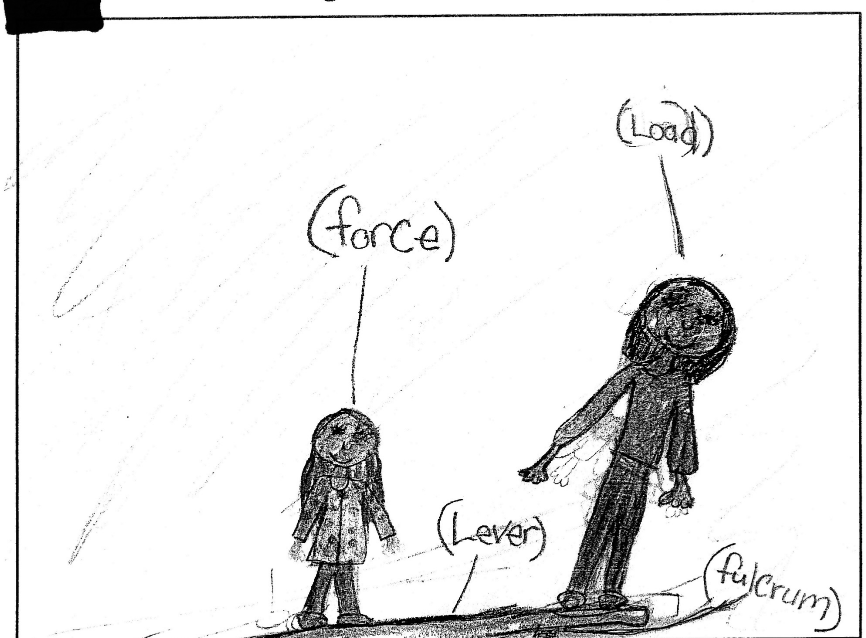
The second writing sample (Figure 1.3), also from Karen, is from a few weeks later in the unit on simple machines. For this investigation of inclined planes, the teacher designed a science notebook entry page that included the question, a data table for recording observations, and space for an explanation in which she prompted students to include claims, evidence, and scientific principles. Notice that Karen labeled the components of her explanation. It is evident in Karen's claim that she understood the relationship between reducing the force applied to lifting the load and increasing the distance of the inclined plane over which the force is applied to move the load. She wrote, "When you use inclined [plane] you use a greater

FIGURE 1.2

Karen's Explanation for How to Lift a Teacher by Using a Lever

How can you lift a teacher?

[redacted]



Explain what you learned about lifting heavy objects. (Use evidence from our experiments to support your ideas.)

We can use a lever to lift teacher if we put the fulcrum closer to the load. → When we used a bard (lever) and put a brick (fulcrum) close to the teacher (load) the student (force) was able to lift the teacher with a little effort.

distance but it takes less force to move the load." Karen also used data from her observations to compare the force needed for a straight lift (5N) to that needed to move the load to the same height using an inclined plane (3N); however, she did not include in her explanation the height to which the load was being moved (19 cm) or

FIGURE 1.3

Karen's Explanation for Inclined Planes

How do inclined planes help us to do work?

How high are we lifting the load? 19cm 7in

How much force does it take to lift the load straight up? 500g 5N

	Distance of Board	Trial #1	Trial #2	Trial #3	Trial #4	Average
B	91 cm 36 in	200g 2N	200g 2N	200g 2N	200.5g 2.5N	200g 2N
S	46 cm 18 in	300g 3N	300g 3N	300g 3N	300g 3N	300g 3N

Explanation: (Claim, Evidence and Scientific Principles)

Inclined planes help us to move a load by reducing the effort or force we use but they increase the distance.

Claim: When you use inclined you use a greater distance but it takes less force to move the load.

Evidence: Our data shows that it takes 5N to lift the load straight up and it takes 3 N of force to move the load using an inclined plane.

the distance across which the load was moved using the inclined planes (91 cm and 46 cm). She attempted to justify the connection between her claim and evidence by writing on a separate index card: "Inclined planes help us to do work by overcoming the force of gravity to move a load over a distance using less force." Although her justification was not robust, Karen did mention overcoming gravity (one of the scientific principles identified by the class).

Would it surprise you to know that Karen is a Title I student who struggled with academic writing? We selected samples of her work because they demonstrate the kinds of improvements that students are able to make in terms of writing explanations when norms of talking and writing scientifically are emphasized during science instruction. These changes can take place over short periods of time when consistently scaffolded by the teacher. For example, after discussing the components of scientific explanation as a class, Ms. Hershberger made a chart and hung it in the room for students to refer to during science talks and when writing explanations. She also emphasized the questions that students were attempting to answer through investigations by posting them in the room and including them on science notebook entry pages. These kinds of strategies are essential for supporting all students in constructing scientific explanation, especially younger students, students with linguistically diverse backgrounds, and students with special needs.

Throughout this book, we highlight strategies that can help different types of students successfully engage in constructing scientific explanations. Many of the strategies that work well for particular groups of students, such as English language learners (ELLs), are the same teaching strategies that work well for all students (Olson et al., 2009). The academic language of school science can be challenging even for native English speakers because of the specialized meanings of words (e.g., *matter, property, adapt,* etc.) and the unique features of science discourse (e.g., *the role of evidence*) (Gagnon & Abell, 2009). Consequently, we integrate our discussion of strategies for different learners throughout the book since they can be beneficial tools for all students.

Connecting Science and Literacy through Scientific Explanation

Since 2001 and the No Child Left Behind legislation, increased emphasis has been placed on helping *all* children develop literacy skills—reading, writing, speaking, and listening. In this political climate, science is not always seen as central to the education of elementary children, and often disappears from the school day to accommodate literacy instruction. However, a number of educators have argued that intentionally connecting science and literacy can enhance the learning of both (Hand, 2008; Hand & Keys, 1999). This may be something you are already attempting to do in your classroom. Inquiry-based science can provide a meaningful context for literacy activities in that it creates a motivating purpose for students to use language to negotiate meaning and figure out something new about the way the world works. Previous research suggests that inquiry-based instruction can successfully support ELLs in learning science content and language, particularly when instruction takes into consideration students' cultural and linguistic backgrounds (Lee, 2005). In this book, our view of literacy is not confined to reading books about science content; rather, our focus is on talking, writing, and listening actively in science in ways that support negotiating and analyzing evidence-based claims.

Regardless of whether students are talking or writing explanations, language plays an essential role in learning science. When students are engaged in constructing, communicating, and critiquing science explanations, they make their thinking public (Bell & Linn, 2000; Michaels et al., 2008; Zembal-Saul, 2009). Talking about their thinking requires students to process their understandings as they attempt to articulate their ideas. Once that thinking has been made visible, peers can consider whether their understandings are consistent with or different from the ideas on the table, and they can ask clarifying questions. In addition to weighing one's ideas in light of those of others, making thinking visible also supports the establishment of social norms for talking and writing science in the classroom. For example, if a teacher consistently prompts for evidence to support claims, students in the class begin to recognize the need to use supporting evidence and to offer it without prompting. Another variation is that students start requesting evidence from one another to support claims. Finally, when science meaning is negotiated publicly, teachers can monitor both individual and group understanding. Put another way, constructing explanations from evidence provides the teacher with important assessment information about what students are understanding and how they are reasoning. In Chapter 4, we focus on establishing norms of participation in classrooms that engage students in constructing explanations from evidence, as well as the role of talk as a vehicle for teachers to monitor and assess student thinking and learning.

In our work in elementary classrooms, talking and writing science explanations are complementary activities. Sometimes we engage students in talking about their ideas first (e.g., predictions) in preparation for an investigation in which they will document observations in writing in their science notebooks, which will later serve as evidence for scientific claims. Other times we have students attempt to identify patterns in evidence and/or draft an initial claim in writing before gathering for a science talk in which we collectively construct claims from evidence. In order to monitor the thinking of the learning community over time and support the development of a coherent content storyline, we have developed scaffolds for talking and writing explanations, as well as strategies for mapping scientific explanations throughout a unit of study. These approaches will be shared in Chapters 4 and 5.

One approach to connecting the development of literacy skills and inquiry-based science instruction includes the use of science notebooks. There are a number of existing frameworks for science notebooks and writing in science, several of which we find particularly useful (Fulton & Campbell, 2003; Norton-Meier et al., 2008). In this text, we will describe our use of science notebooks in several chapters, placing specific emphasis on their role in engaging students with scientific explanations.

Benefits of Engaging Students in Scientific Explanation

As discussed previously, there are a number of important reasons to engage your students in scientific explanations that are consistent with contemporary thinking about science education in elementary grades and that attempt to improve scientific literacy. In addition, there are benefits to both students and teachers (McNeill, 2009; McNeill & Krajcik, 2008a; McNeill et al., 2006), which we will describe in more detail here. Benefits to students include understanding science concepts, participating in scientific practices, using evidence to communicate convincingly, and learning about the nature of science.

Understanding Science Concepts

When constructing evidence-based explanations, either through talking or writing, students use data/observations from their investigations and scientific ideas to answer questions about the physical world. This process can be seen as one of making sense of science concepts and applying them in flexible ways to new situations and is consistent with current perspectives on proficiency in science, particularly the strand that emphasizes knowing and using science explanations (Duschl et al., 2007; Michaels et al., 2008). Examining data for patterns and seeking coherence among claims and evidence are powerful thinking tasks that require students to reason scientifically. Such scientific reasoning can result in deeper understanding of science ideas as connections are made across the content storyline of a unit. For example, remember the earlier third-grade lessons on simple machines, when students made the connection between reducing the applied force and increasing the distance needed to move the load? Those children were observed relating that connection to simple machines studied later in the unit, such as inclined planes and pulleys. More specifically, the students not only recognized the connections but they also used the fact that the relationship held up in light of the other simple machines they studied. This suggests that those students were developing a meaningful understanding of the relationship and were able to apply that understanding in novel situations.

Participating in Scientific Practices

The ability to construct and communicate evidence-based explanations relies on being able to design and conduct fair tests and to collect, organize, analyze, and represent data appropriately—all essential scientific practices (Michaels et al., 2008). This kind of problem solving is essential to twenty-first century learning. Students can benefit greatly from reasoning logically about how best to collect data given the questions they have. For example, when kindergarten students recognize that during a seed investigation they need to change one variable (e.g., planting lima beans in dry soil versus wet soil), observe one key result (e.g., lima bean growth), and keep everything else as similar as possible (e.g., amount of soil, placement in the classroom, etc.), they have developed the basis for thinking about fair tests. However, as illustrated through the opening vignette, this aspect of scientific practice must contribute to the ultimate aim of using those data to construct scientific explanations to the questions under investigation. Science lessons in K–5 often culminate with students sharing their observations. Unfortunately, lessons usually do not take that next step to include the construction of evidence-based explanations, which limits opportunities to engage students in this essential scientific practice.

Using Evidence to Communicate Convincingly

Science answers questions about the way the natural world works, and gives priority to the role of evidence in supporting scientific claims. When students communicate their thinking by proposing claims and supporting them with evidence, they benefit from participating productively in the norms of science and scientific language—strand 4 of science proficiency (Michaels et al., 2008). Moreover, students benefit by learning a powerful form of persuasive and empirical writing. Communicating in these kinds of complex ways also is central to twenty-first century learning and can be extended to other disciplines, as well as to students' everyday lives. For example, the importance of evidence in communicating convincingly in nonscience fields may take the form of determining which product to buy or deciding how to vote on a proposition that could affect local waterways. In real-world contexts, individuals need to be critical of the evidence and evaluate whether it is appropriate and sufficient for supporting particular claims. As it relates to school science and science learning, students not only benefit from constructing explanations but also from evaluating how peers are justifying claims and using evidence. Constructively critiquing the explanations of others involves active listening and clear communication. Teachers can effectively scaffold this kind of critical thinking and talk by asking students to agree or disagree with one another as they explain their evidence. As discussed earlier in association with making thinking visible, engaging in this kind of talk requires students to reflect on, organize, and articulate their thinking, which is a characteristic of strand 3 of science proficiency (Michaels et al., 2008).

Learning about the Nature of Science

Finally, by engaging in scientific explanation, students not only learn science concepts, but they also learn about the nature of science and scientific knowledge claims. Science is a social enterprise that involves large numbers of scientists working together. They discuss and debate their ideas at conferences and through publications, such as journals and books. For scientists, evidence plays a critical role in determining which ideas to support, modify, or reject. Because they are grounded in evidence, explanations can be tested by other scientists and are subject to change. When science is represented as a static body of facts, which is frequently the case in school curriculum, it fails to represent important aspects of science—that knowledge is created socially by scientists and changes in light of new tools, observations, and discoveries. Not only does it misrepresent science to portray it as a litany of known facts to be learned, but it also can discourage students from being interested in science. For these reasons, strand 3 of proficiency in science (Michaels et al., 2008), reflecting on scientific knowledge, specifically addresses the nature of science by having students recognize how their explanations change in light of new evidence, much in the same way scientists modify their explanations.

Our purpose in connecting benefits of engaging students in scientific explanation to the strands of proficiency in science is to illustrate how this approach to science teaching weaves the strands together in powerful ways. When emphasis is placed on evidence and explanation, children can develop meaningful understandings of science concepts, consider the important role of evidence in science, recognize science as a social endeavor through which explanations are changed in light of new evidence, and participate productively in a classroom community of scientists.

Benefits of Scientific Explanation for Teachers

Although understanding the benefits to students is important, it also is helpful to consider what teachers get out of learning to teach science in ways that engage students in scientific explanation. In our research with beginning elementary teachers, several benefits were observed when they adopted a stance to teaching science that gave priority to evidence and explanation (Avraamidou & Zembal-Saul, 2005; Zembal-Saul, 2009). First, when elementary teachers started to focus on scientific explanation, they also paid more attention to science content. This finding is not surprising, given that we define the science explanations that students construct as including important concepts in science. If a teacher is to intentionally facilitate students in constructing an explanation from evidence, it requires the teacher to have a deep understanding of that explanation and the investigations that generate the evidence necessary to support it. Because many elementary teachers are prepared as generalists, it is important to have access to reliable subject-matter resources when planning for instruction. In Chapter 3, we suggest a process that will help you recognize what you need to know about the science concepts, associated investigations, and children's ideas in order to effectively teach in this way.

Second, teachers who focused on scientific explanation also began to think about classroom talk and its role in learning differently (Zembal-Saul, 2009, 2007, 2005). Not only did these teachers come to recognize the importance of talk in making meaning of science ideas, but they also began to consider disagreement as potentially productive. Initially, many of the teachers we worked with shied away from "arguments" about claims and/or evidence. However, others observed that breakthroughs in learning often happened when students disagreed with one another. For example, a common source of disagreement stems from students conducting some aspect of their testing differently across groups. Asking students to demonstrate their data-collection approach to the group and allowing for questions frequently result in students revising the test and/or coming to agreement about evidence. Negotiating effective science talks is potentially one of the most challenging practices for any teacher. In Chapter 4, we address scaffolds for classroom discourse, and in Chapter 5, we share instructional strategies that will help you be successful.

Finally, teachers in the research project who placed emphasis on evidence and explanation began to think about their role in working with small groups differently. When students are conducting investigations, it is common for teachers to visit each group, ask how students are doing, and assist with procedures. While the teachers in the project engaged in these kinds of supports, they also began listening for and documenting testable questions that emerged from the investigation and asking students about their data, the patterns they were noticing, and the kinds of initial claims they could draw from the data to respond to the question under investigation. These kinds of supports and questions are consistent with an emphasis on evidence and explanation, and they paralleled teachers' development in terms of increased attention to scientific explanation. In Chapter 4, we will provide question prompts for working with small groups during investigations. In addition, we will share strategies for organizing and representing data in ways that support young children in noticing relevant patterns in data that can form the basis of scientific claims.

What to Expect in Elementary Grades

Keep this important lesson in mind as you work to engage your students in scientific explanation. Although younger students are excellent thinkers and can readily begin to construct claims from their observations, as well as appropriately employ the language of evidence, it is not until students are older that they are ready to engage in some of the more complex aspects of this practice, such as applying scientific principles and suggesting and/or critiquing alternative explanations. As early as kindergarten, students can begin to use the term *evidence* when talking about their observations. For example, in a series of lessons about seeds and plants, kindergartners noticed that water was necessary for a seed to start growing. They observed seed changes in plastic bags with wet paper towels and in cups of damp soil. They also observed that seeds in dry soil did not change/grow. This collection of observations was used to create a claim about the role of water in seed development. Similarly, in the vignette at the beginning of the chapter, first-grade students used their observations of different kinds of magnets and the number of paper clips those magnets were able to pick up as evidence for their claim about the strength of magnets. The connection among question–claim–evidence is the most basic form of scientific explanation and is suitable for all grade levels.

As students tackle more substantial science content in grades 3 through 5, it is reasonable to consider having them use science principles to justify connections between claim and evidence, as well as consider alternative explanations. For example, in a fourth-grade lesson on adaptations, students noticed that although their hissing cockroaches shared common physical traits, they were still able to identify individual cockroaches within the group. The class constructed the claim: *Cockroaches in our group are similar, but not exactly the same.* Later, when introduced to the scientific concept that there is variation of traits in a population, students were able to use this idea to justify their claim in light of relevant evidence. As with justifying the relationship between claims and evidence, identifying and critiquing alternative explanations is more common among older students. However, this aspect of scientific explanation is quite sophisticated and not often observed in students' writing and talking.

At all grade levels, science notebooks are a useful way for students to document their tests, observations/data, and thinking over time. During science talks aimed at constructing explanations, we encourage students to bring their science notebooks with them and to refer to them during the discussion, especially when proposing evidence to support a claim. Even kindergarten children can develop meaningful notebook entries that use drawings and simple phrases to document their observations. Examples of K–5 student notebook entries will be included throughout the book.

As mentioned previously, we view talking and writing explanations as complementary activities. However, it is evident from our work with science explanations across the grade levels that co-constructing claims from evidence through science talks is an essential scaffold for learning, especially in the early grades. Norms for participating in the language of science should be made explicit to students and reinforced whenever possible. By actively listening to one another during science discussions, students develop an understanding of what counts as evidence and how to use that evidence to develop and support scientific claims. We often ask young students to record their observations and use them during science talks, but we rarely ask students to write scientific explanations before talking about their observations and identifying initial patterns in the data that serve as the basis for claims. As students become more familiar with developing science explanations and become more proficient writers, more responsibility for writing explanations individually can be transferred. The dynamic interplay between talking and writing scientific explanations is addressed throughout this book.

Check Point

In this chapter our goal was to introduce you to the potential of placing emphasis on scientific explanation in grades K–5. Samples of students' written work and examples of science talks were used to illustrate how engaging in scientific explanation can help all children learn science concepts and participate in the language of science. We demonstrated how scientific explanation is aligned with national standards and reform documents in science education. More importantly, we showed how engaging in this significant practice contributes to students' meaning making and literacy development, including students with culturally and linguistically diverse backgrounds and special needs. In addition, we provided some initial insights regarding what to expect at various grade levels. At this point, we hope you are curious about the framework and how to use it in your classroom. In subsequent chapters, we will describe the framework for scientific explanation in detail and provide examples of students' explanations across grade levels and content areas, share strategies for generating evidence and for supporting students in talking and writing explanations, and propose approaches for planning instruction and assessing student work. Taken as a whole, this book is intended to help you effectively engage all students in the complex scientific practice of explanation building.

Study Group Questions

1. Discuss the similarities and differences between science lessons that are merely *hands-on* and those that engage students in scientific explanation.
2. After reading this book and trying some of the approaches with your students, you become interested in developing a greater emphasis on scientific explanation in your science teaching. How will you justify your decision to your principal? Craft a convincing argument to recruit one of your colleagues to try it with you.
3. It has been suggested that connecting literacy activities to inquiry-based science instruction can enhance the learning of both by creating a meaningful and motivating context. Describe at least one way you can create this kind of connection with your students.
4. Before moving on to the chapter describing the framework for scientific explanation, what questions do you have about teaching with an emphasis on scientific explanations? About how engaging students in scientific explanation supports their meaningful learning? About assessing students' explanations? Others?

2

A Framework for Explanation-Driven Science

How can you support the development of scientific explanations in your teaching? What does a scientific explanation look like in science talks and in science writing? Consider the following vignette from Ms. Marcus's second-grade classroom.

> *Ms. Marcus was starting a unit on light and asked her class to look for shadows in the classroom. The students were surprised that they could find shadows in the room and even more surprised when they realized that when they pulled the blinds, the lights in the room still made shadows. They wanted to know if other sources of light would make shadows. With the help of their teacher, the students set up light stations to see if they could make shadows with a variety of sources of light, including a black light, a flashlight, a candle, a desk lamp, and a television. After investigating the shadows of different light sources, the class gathered in a circle for a science talk.*

Ms. Marcus: What did you observe as you went around to our light stations?

Paul: All of the lights made shadows!

Ms. Marcus: Did that surprise you?

Paul: Yeah, I really didn't think that the candle would make a shadow.

Ms. Marcus: What did you notice about the shadow at the candle station?

Jamie: The candle made the best shadow.

Ms. Marcus: Do other people agree with Jamie?

Lisa: Yeah, but really they all made pretty good shadows.

Ms. Marcus (pointing to a sentence strip): Our question was "Can we make shadows with any kind of light source?" How can we answer that question?

Alex: Any kind of light will make a shadow.

Ms. Marcus: Do you think we can make that claim from our investigations?

Mark: Well, not really since we didn't test <u>all</u> kinds of lights.

Alex: But, if we did I think they would make a shadow.

Mark: You're probably right but since we didn't check, I think we should say: Light from different sources makes shadows.

Ms. Marcus: So is that the claim should we write on our KLEW chart?[1]

Most students give the sign for yes.

Ms. Marcus: What is our evidence?

Lisa: We tested different kinds of lights and they all made shadows.

Mark: I think we should say which lights we tested.

Ms. Marcus: How would you like to write it?

Mark: We tested a black light, flashlight, desk lamp, candle, and TV, and they all made shadows.

Jamie: On the white paper.

---

[1]KLEW is a modification of the reading comprehension strategy, KWL. The acronym allows us to map the following ideas over time: what students think they *know* about a science question or topic (K), what they are *learning* stated as claims (L), what *evidence* they are using to support each claim (E), and what new questions or *wonderings* they have (W). We have found that these charts can serve as an important scaffold for supporting students in scientific explanations. We will discuss them in more detail in Chapter 5.

Ms. Marcus (writes): Light from different sources makes shadows. Our evidence is that we tested a black light, a flashlight, a candle, a desk light, and a TV, and we saw that they all made shadows on the white paper.

Maria: We should add because light travels in a straight line.

Ms. Marcus: How do we know that?

Lisa: We tested it with red Jello™ and a laser light, and we saw the light going in a straight line.

Ms. Marcus: Why is that important?

Maria: Cause that's why we get shadows.

Ms. Marcus: Can you say more about that?

Maria: The light travels in a straight line until something blocks it and that makes a shadow.

Ms. Marcus: That's our scientific reasoning. I'm writing: We saw the shadows because the light was traveling in a straight line until our objects blocked it. Is that okay?

Maria: Yeah, good.

In this vignette, the second-grade class was negotiating an explanation for the question, *Can we make shadows with any kind of light source?* The students discussed their ideas about which light sources make shadows and backed up those claims using evidence from their investigations. Ms. Marcus used questions and other strategies to support her students in engaging in this complex scientific talk.

How can you help your students participate in scientific explanations? In this chapter, we discuss a framework (i.e., claim, evidence, reasoning, and rebuttal) to support students in explanation-driven science in both talking and writing. Throughout the chapter we revisit the vignette from Ms. Marcus's classroom to illustrate the different components of the framework. We also use a video clip from a third-grade classroom to demonstrate how to introduce the framework to your students, and writing samples from students in a variety of content areas and grade levels to illustrate how to apply the framework. Furthermore, we describe variations of the framework that increase in complexity that you can use with your students, depending on their prior experiences with this important scientific inquiry practice, and we discuss benefits of the framework for all learners.

Framework for Explanation-Driven Science

Engaging in scientific inquiry can be challenging for students, in part because they are not familiar with the norms in science. Science is a way of knowing with particular ways of thinking, reasoning, talking, and writing (Michaels et al., 2008).

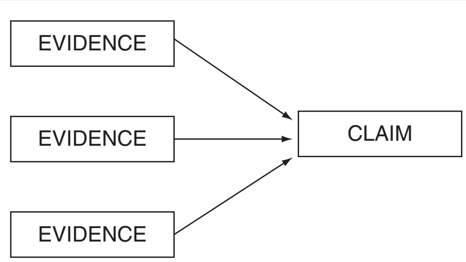
A key aspect of science is the role of building and debating explanations. To support students in this complex practice, we have adapted Toulmin's model of argumentation (1958) in order to develop a framework for scientific explanation (McNeill & Krajcik, 2012; McNeill et al., 2006; Zembal-Saul, 2009) that consists of four components: *claim*, *evidence*, *reasoning,* and *rebuttal*. With elementary students, we typically focus on either the first two components (claim and evidence) or first three components (claim, evidence, and reasoning) of the framework, particularly in terms of students' writing. Rebuttals are often not introduced until middle school or even high school. Yet, in this section, we describe all four components to provide an overview of the entire framework. We begin this important scientific inquiry practice by describing the first two components, claim and evidence, and how they can be used to support early elementary students as well as students with little prior experience in explanation. Figure 2.1 illustrates these first two components.

Claim

The first component of the framework is the *claim.* The claim is the statement or conclusion that answers the original question or problem. Creating a claim that specifically answers the question can be quite challenging for elementary students. Often, students will provide an answer that addresses the topic (e.g., states of matter), but does not directly answer the question (e.g., Is rice a solid, liquid, or gas?). Consequently, it can be important to support students in constructing claims that specifically address the question being asked. Furthermore, students' claims can address the question, but initially be either too specific or too general considering the data available to the students. Crafting an appropriate claim can take revision and practice as a whole class.

For example, in the opening vignette, Ms. Marcus asked her students to consider their observations across the various stations in order to develop a claim that responds

FIGURE 2.1
Claim and Evidence



to the question, *Can you make shadows with any kind of light source?* During the discussion, one student proposed a claim, but then another student refined the claim to make it more accurate. More specifically, the initial claim was: *Any kind of light makes a shadow.* However, because the class did not test all possible light sources the claim became: *Light from different sources makes shadows.* The final version of the claim still addressed the question and was more accurate given the available evidence. Furthermore, because the claim was negotiated publicly during the science talk, all members of the class had access to the thinking behind the revision process, which can be particularly beneficial for English language learners. This enabled all the students to develop a stronger understanding of what counts as an appropriate claim.

Evidence

An essential component of science is the use of *evidence.* When scientists construct or revise claims, they do so using evidence. Consequently, we want even young students to be using evidence to support the claims that they make in science. Evidence is scientific data that support the claim. Data are observations or measurements about the natural world. Data can be qualitative, such as the colors of plants, or they can be quantitative, such as the heights of plants. Both quantitative and qualitative data play important roles in science; however, students can have a more difficult time seeing qualitative data as evidence. Initially, it can be easier for students to recognize "numbers" as evidence. Thus, it is essential to help students develop an understanding of what does and does not count as evidence.

As students develop an initial understanding of evidence, we can also introduce the ideas of *appropriateness* and *sufficiency* of data (although not necessarily using those terms). Data are *appropriate* for a claim if they are relevant or important to answer the specific question or problem. For example, students may use inappropriate data, like their everyday experiences, as evidence for the claims they make in science. In fact, this is quite common among younger students. Although it is important to connect to students' everyday experiences and we want to help students see that science is all around them in the world, it is also important to help students develop an understanding of scientific evidence. More specifically, evidence in science comes from observations and investigations about the natural world. You have a *sufficient* amount of data if you have enough to support your claim. In science we often use multiple pieces of data as evidence to support our claim. For example, Figure 2.1 illustrates that there are three pieces of evidence supporting the claim. Initially, when you introduce the framework to your students, you might want to focus on only one piece of evidence, but as the children gain more experience and expertise you should encourage them to use multiple pieces of evidence to support their claim. The specific number of pieces of evidence will depend on the particular learning task or investigation that students complete. There is not an ideal number of pieces of evidence (i.e., three pieces); rather, students should be using all appropriate evidence that is available to make their claim.

In the vignette, we saw Ms. Marcus's students using multiple pieces of qualitative data to support their claim. After the class refined their claim and recorded it, Ms. Marcus specifically asked her students, *What is our evidence?* As with the claim, the students' first attempt to articulate evidence was vague: *We tested different kinds of lights and they all made shadows.* Suggestions from other students involved adding the specific light sources tested and information about shadows being made on a white paper surface. Consequently, as a class, the students refined their evidence to include qualitative data (i.e., they made shadows) from five different investigations: *Our evidence is that we tested a black light, a flashlight, a candle, a desk light, and a TV, and we saw that they all made shadows on the white paper.* In this case, the evidence that was included was relatively brief yet still included five different pieces of evidence.

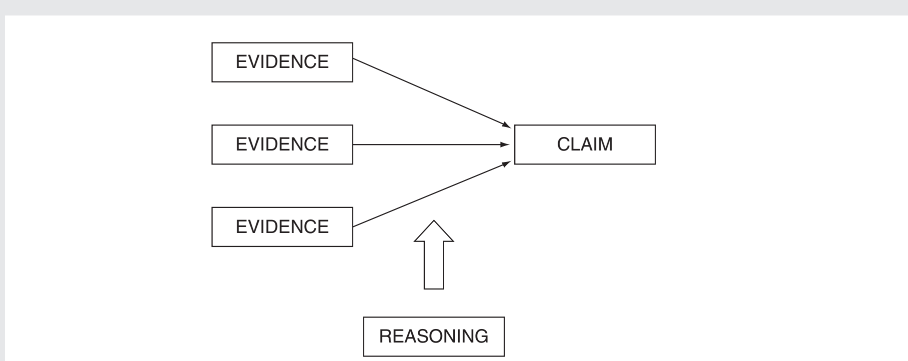
Reasoning

After students become comfortable using evidence to support their claims, you can then introduce the third component of the framework: *reasoning.* Reasoning is a justification that connects the evidence to the claim. The reasoning shows why the data count as evidence by using appropriate and sufficient scientific principles. Figure 2.2 expands the initial framework to add the reasoning component that is explaining that link between the claim and evidence.

Articulating their reasoning is a more complex process for students. For elementary students, we have found that reasoning is more challenging than the claim and evidence components (McNeill, 2011). This also is the case for older students in middle school (McNeill & Krajcik, 2007; McNeill et al., 2006) and

FIGURE 2.2

Claim, Evidence, and Reasoning (McNeill & Krajcik, 2012)



in high school (McNeill & Pimentel, 2010). Students can have a difficult time explaining how they used scientific principles or scientific ideas to decide what counts as evidence. Instead of explaining how or why the evidence supports their claim, students' initial reasoning sometimes ends up being just a repetition of their claim and evidence. Instead, the reasoning should include the big science idea or science concept that is the focus of the lesson. Including the reasoning encourages students to consider and reflect on these science ideas, as well as provides them with the opportunity to become more comfortable using scientific terms and language.

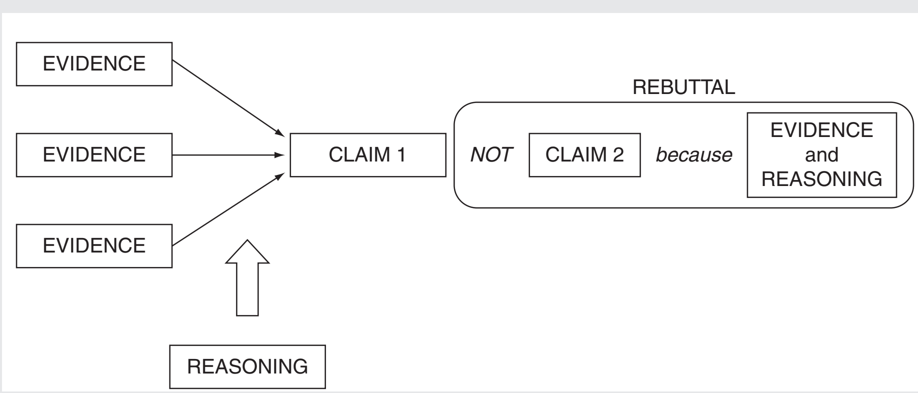
For example, in the opening vignette, the class ends up including the following statement as their reasoning: *We saw the shadows because the light was traveling in a straight line until our objects blocked it.* Prior to this investigation, the second-grade class had completed several investigations that allowed them to observe that light travels in straight lines until it is blocked by an object, which makes a shadow. This scientific principle allowed students to justify the connection between the claim and evidence, which we refer to as *reasoning.* Including the reasoning encourages students to use the big ideas in science to articulate how or why evidence supports their claim.

Rebuttal

Finally, the last component in the framework is the *rebuttal.* The rebuttal recognizes and describes alternative explanations and provides counterevidence and counter-reasoning for why the alternative explanation is not appropriate. Figure 2.3 adds the rebuttal to the scientific explanation framework.

FIGURE 2.3

Claim, Evidence, Reasoning, and Rebuttal (McNeill & Krajcik, 2012)



Often, scientists debate multiple alternative claims and try to determine which claim is more appropriate. As Figure 2.3 illustrates, the rebuttal explains why an alternative claim (Claim 2) is not a more appropriate claim for a specific question. Similar to the original claim (Claim 1), the rebuttal uses both evidence and reasoning. But in the case of the rebuttal, the evidence and reasoning articulate why Claim 2 is not appropriate.

Rebuttals are another challenging aspect of scientific explanations. In our work with elementary students, we have not explicitly named or discussed this component of the framework. Rather, as our examples will illustrate, the teachers we have worked with have chosen either to focus just on claim and evidence, or on claim, evidence, and reasoning. Particularly in terms of students' writing, this is not something we typically see until middle school or high school. Yet, in looking at students' science talk, we often see students debating multiple claims, which engages students in the process of a rebuttal even if we do not specifically name it as such. For example, in discussing what plants need to grow, one student may make the claim that plants do not need soil to grow (Claim 1), whereas another student may claim that plants do need soil to grow (Claim 2). The discussion and investigations that then occur in the classroom will allow the students to collect data and make sense of those data to determine which of the two claims is more appropriate. Engaging in this process includes the use of rebuttals, which is an important component of science, but explicitly naming that process as rebuttal may not be productive for elementary students. In contrast, we find that using the language of claim, evidence, and reasoning can help support students in understanding the practice of science and the expectations around how to support and justify a claim in science.

In Ms. Marcus's lesson, the class discussed how to refine the language of their claim and how to support that claim with evidence, but they did not debate alternative explanations. We feel that the level of talk in the vignette is quite sophisticated (but also quite achievable) for second-grade students, and it was not necessary to introduce the idea of the rebuttal. However, if students had disagreed with Alex's initial claim—*Any kind of light will make a shadow*—an alternative explanation and rebuttal may have naturally arisen during the classroom discussion. For example, one student may have responded with a common misconception by saying, "I don't think all light sources make shadows because the moon is a light source, but everything is dark at night so the moon does not make shadows." If this alternative claim had arisen that only some light sources make shadows, additional evidence and reasoning would have needed to be considered to determine which of the two claims was more appropriate. The teacher could then ask students to go outside at night when the moon is out to collect data about whether the moon creates shadows or she could go out at night and take photos that she would bring in as additional data to discuss as a class. In this case, multiple explanations would have been considered, and yet we still feel that it is not necessary to introduce the language of "rebuttal" to second-graders. Rather, focusing on the ideas of claim, evidence, and reasoning provides a more simplified and easier framework to engage students in constructing scientific explanations.

Video Example: Introducing the CER Framework

At this point we thought it might be helpful to use a video example to illustrate how you can introduce the framework to your students. Video 2.1 is from Ms. Hershberger's third-grade class from 2009–2010. Students have been investigating inclined planes as part of a unit on simple machines. Although the class has some prior experience using the language of claims and evidence, Ms. Hershberger reviews the components of scientific explanation with students and supports them in constructing working definitions for each component. She then creates a poster using students' language for explanation, which is displayed in the classroom for the rest of the year and used by the class as a reference when talking and writing scientific explanations.

VIDEO 2.1

Introducing the CER Framework

In the discussion prior to this video clip, students were identifying patterns in data for force and distance that they had collected during an investigation in which they were trying to answer the question, *How do inclined planes help us do work?* Ms. Hershberger wants the class to write a scientific explanation associated with their investigation, so before they begin the writing task, she prompts them to reconsider the parts of an explanation. She chooses to emphasize the first three components of the framework: claim, evidence, and reasoning. Watch the 6-minute video clip from this lesson. Ms. Hershberger uses a variety of strategies during the discussion of the framework to help students develop a better understanding of claim, evidence, and reasoning, and to link this framework to their prior experiences. These strategies and others will be described in more detail in Chapter 5.

The clip begins with Ms. Hershberger asking the class about the three parts of a scientific explanation. After the students identify claim, evidence, and scientific principles from their prior science learning experiences, Ms. Hershberger asks more specifically, "What is a claim?" Not surprising, given the earlier part of the discussion about inclined planes, students respond with claims specific to the current investigation. She prompts students to think more generally about how claims are made and what is useful in crafting a claim. When the class continues to focus on the specific investigation and data that students collected for inclined planes, she asks, "How do we begin an investigation?" This question helps shift students' thinking to focus on the question as the driving force behind an investigation. After students revisit their question for the inclined plane investigations, they are much better able to describe the claim as a statement that answers the question. Ms. Hershberger writes this definition on chart paper using students' words. Her approach of eliciting students' ideas and connecting the definition for *claim* to the current investigation stands in contrast to providing the class with a standard definition. Ms. Hershberger's approach is student-centered and encourages ownership of the framework among students.

In the next part of the science talk Ms. Hershberger asks, "You have the claim, but what else do you need?" The students immediately make the connection that claims are based on evidence from the inclined plane investigation. Nevertheless, the teacher pushes further by asking, "Where does evidence come from?" The class describes the evidence for a claim coming from their investigation data, and one student adds, "If you didn't have data, how would you even answer the question?" In this way, students are able to relate data and evidence back to the claim. One child elaborates on this to explain that if you have data that do not support the claim, then you may need to consider a different claim. Although rebuttal is not addressed specifically in the discussion of scientific explanation, this point suggests that at least some members of the class are considering the important need for "fit" between data and claim, and the need to consider alternative explanations when the fit is not complete. Once again, Ms. Hershberger records the definition for evidence on chart paper using students' language for reference in future investigations and explanation development.

When Ms. Hershberger asks the class about reasoning as a component of explanation in the next part of the discussion, they already know that it requires the use of scientific principles. For this unit, Ms. Hershberger kept a running record of "big ideas" in science intended to help students think about their investigations. More specifically, the list of scientific principles for simple machines included ideas such as work, force, and friction. Through the discussion, students come to describe the role of scientific principles as helping with the "why" for a claim–evidence connection. One student adds that scientific principles help to tell the "whole story" of the explanation. Because they had been referring to principles in prior instruction, Ms. Hershberger introduces *reasoning* as a component of explanation, but still uses students' words to create the definition.

The claim, evidence, reasoning framework is a lot for K–5 students to process at one time. Ms. Hershberger's approach of engaging students in science investigations in which they became familiar with drawing conclusions from data allowed her to introduce claim, evidence, and reasoning as components of scientific explanation much more easily and to attach these components to students' prior experiences. By recording the definitions for the components of explanation in students' own words and posting them in the classroom, Ms. Hershberger and her class have a meaningful tool that they will use again and again during the school year as they engage in science writing and discussion.

Examples of Scientific Explanations

The scientific explanation framework can be used across the different content areas in science—life science, earth and space science, and physical science. In this section, we provide a specific example from each content area to further illustrate the framework, as well as discuss other topics to which the framework can be applied.

Life Science Example

In life science, there are many topics where students can either collect or be given data to analyze. The scientific explanation framework can support students' meaning making, either in talk or in writing, as they try to make sense of the data and develop a stronger understanding of the science concepts. For example, the framework can be applied when investigating topics such as the needs of plants, the needs of animals, adaptations, behaviors, life cycles, inherited and acquired characteristics, similarities and variation among organisms, food webs, habitats, senses, the human body, nutrition, and germs. All of these topics provide opportunities in which students can either collect data or they can be asked to make sense of data that have been given to them.

For example, one third-grade teacher we worked with was teaching a unit on plant growth. He had his students plant seeds and place one pot with seeds in direct sunlight, while the other pot with seeds received no direct sunlight. Over two weeks, the students collected observational data of the leaves, stems, roots, and flowers, as well as quantitative data about the height of the plants, which they recorded in their science notebooks. After collecting all of their data, the teacher asked the class to construct a scientific explanation that answers the question, *Do bush bean plants grow better in direct sunlight?* The teacher was looking for his students to write scientific explanations similar to the claim, evidence, and reasoning shown in Table 2.1. He did not ask his students to include a rebuttal, but we included the rebuttal in the table to illustrate what it might look like. He wanted students to make a claim: *Bush bean plants grow better in direct sunlight*. Next, he wanted them to include at least three pieces of evidence such as the plant heights, the number of leaves, and the color. Finally, the reasoning provides a justification that links the claim and evidence. In this case, the reasoning is fairly simple: *Height, number of leaves, and color are all important for a plant's health. Since the plant in direct light was taller, had more leaves, and was dark green, that means it was able to grow better.* Figure 2.4 shares a sample of writing from one of the third-grade students in the teacher's classroom.

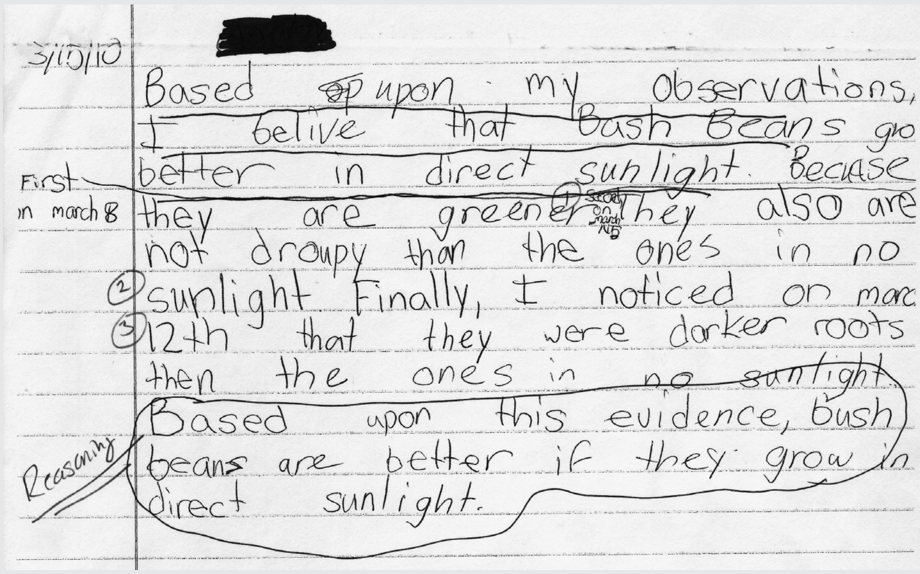
In order to provide the student with feedback, the teacher underlined the claim, numbered the evidence, and circled the reasoning in addition to his written comments. In this example, we see the student provided the appropriate claim: *Bush beans gro[w]*

TABLE 2.1 Examples of the Different Components of Scientific Explanations

Question	Claim	Evidence	Reasoning	Rebuttal
Life Science Do bush bean plants grow better in direct sunlight?	Bush bean plants grow better in direct sunlight.	The plant in direct sunlight grew 16 cm, and the plant with less sunlight grew 11 cm. The plant in direct sunlight had 6 leaves, and the plant with less sunlight only had 3 leaves. Finally, the plant in direct sunlight was a dark green, and the plant with less sunlight was pale green.	Height, number of leaves, and color are all important indicators of a plant's health. Since the plant in direct light was taller, had more leaves, and was dark green, that means it was able to grow better.	On day 2, the plants looked the same, so you might think that light does not matter. But after 2 weeks, the height, leaves, and color were different.
Earth and Space Science How can sun shadows be used to tell time?	The length of the sun shadow can be used to tell time.	At 10:45 a.m., the shadow was 20 cm and the sun was low. At 12:25 p.m., the shadow was 17 cm and the sun was high. Finally, at 2:15 p.m., the shadow was 21 cm and the sun was low. Shadows are longer in the morning and afternoon, and they are shorter at noon.	The length of the shadow is determined by how high the sun is in the sky. The sun changes position in the sky because the earth rotates once each day. When the sun is higher in the sky, the shadows are shorter, which is why they can be used to tell time.	Someone may think that shadows cannot be used to tell time because they have nothing to do with the time of the day. Someone may just think shadows are determined by the object that makes the shadow. But the shadow for the same object actually changes over the course of the day.
Physical Science Does the number of turns of the rubber band affect the distance the vehicle travels?	The number of turns does affect the distance a vehicle travels.	When we turned the rubber band 4 times it traveled 45 cm, and when we turned it 8 times it traveled 63 cm.	Turning the rubber band transforms kinetic energy into stored or potential energy. The stored energy then transforms into kinetic energy when the rubber band is released. Kinetic energy is energy of movement. The more times the rubber band is turned, the more stored energy there will be upon transformation, which means the more kinetic energy there is. That is why the more you turn it, the farther the vehicle travels.	Some people may think that the number of times the rubber band is turned does not affect the distance because they do not realize that the rubber band stores energy and that is why the vehicle moves. They may think it moves just because it has wheels or because someone can push it. But the energy comes from the wound rubber band.

FIGURE 2.4

Third Grade Scientific Explanation about Bush Bean Plants


3/15/10
[redacted]
Based ~~op~~ upon my observations,
I belive that Bush Beans gro
First better in direct sunlight. Because
on march 8 they are greener. ① second on march 12 they also are
not droopy than the ones in no
② sunlight. Finally, I noticed on marc
③ 12th that they were darker roots
then the ones in no sunlight.
Based upon this evidence, bush
Reasoning beans are better if they grow in
direct sunlight.

better in direct sunlight. The student then included three pieces of evidence: *Because on March 8 they are greener. Second on March 12 They also are not droopy than the ones in no sunlight. Finally, I noticed on Marc[h] 12th that they were darker roots then [sic] the ones in no sunlight.* The student also provided some initial reasoning linking the evidence to the claim: *Based upon this evidence, bush beans are better if they grow in direct sunlight.* Neither the evidence nor reasoning is as detailed as the ideal example in Table 2.1. In particular, the reasoning just illustrates restating the evidence and claim, rather than describing how or why the evidence supports the claim. Yet, the student is successfully justifying her claim with some evidence and reasoning. Although she has room to improve, this student is having some success using the framework to help her both make sense of her data and to engage in science writing.

Earth Science Example

There are many opportunities in earth science to construct scientific explanations. Students can analyze data either from their own investigations or data that have been given to them for topics such as weather, properties of soil, rocks and minerals, fossils, erosion, weathering, earthquakes, volcanoes, the water cycle, seasons, phases of the moon, position of the sun, and shadows. All of these topics provide multiple opportunities to support students in constructing scientific explanations in talking and writing.

For example, one fifth-grade teacher asked her students to write a scientific explanation that addressed the question, *How can sun shadows be used to tell time?* In order to answer this question, the students collected data three times during the day (morning, noon, and afternoon) for the length of the shadows in their schoolyard. Table 2.1 illustrates an ideal student response for this question. Similar to the last example in life science, we included a rebuttal in the table to illustrate what it might look like, but the teacher asked her students to include only a claim, evidence, and reasoning. The student's claim would state: *The length of the shadow can be used to tell time.* The student's evidence would consist of the different shadow lengths at different times during the day. Finally, the reasoning would articulate why shadow length allows someone to tell time by discussing the idea that the earth rotates once per day, which is why the sun changes position in the sky. Specifically, the reasoning might state: *The length of the shadow is determined by how high the sun is in the sky. The sun changes position in the sky because the earth rotates once each day. When the sun is higher in the sky, the shadows are shorter, which is why they can be used to tell time.* The reasoning in this case is more sophisticated than the previous example because it requires a more in-depth discussion of the scientific principles in order to articulate why the evidence supports the claim.

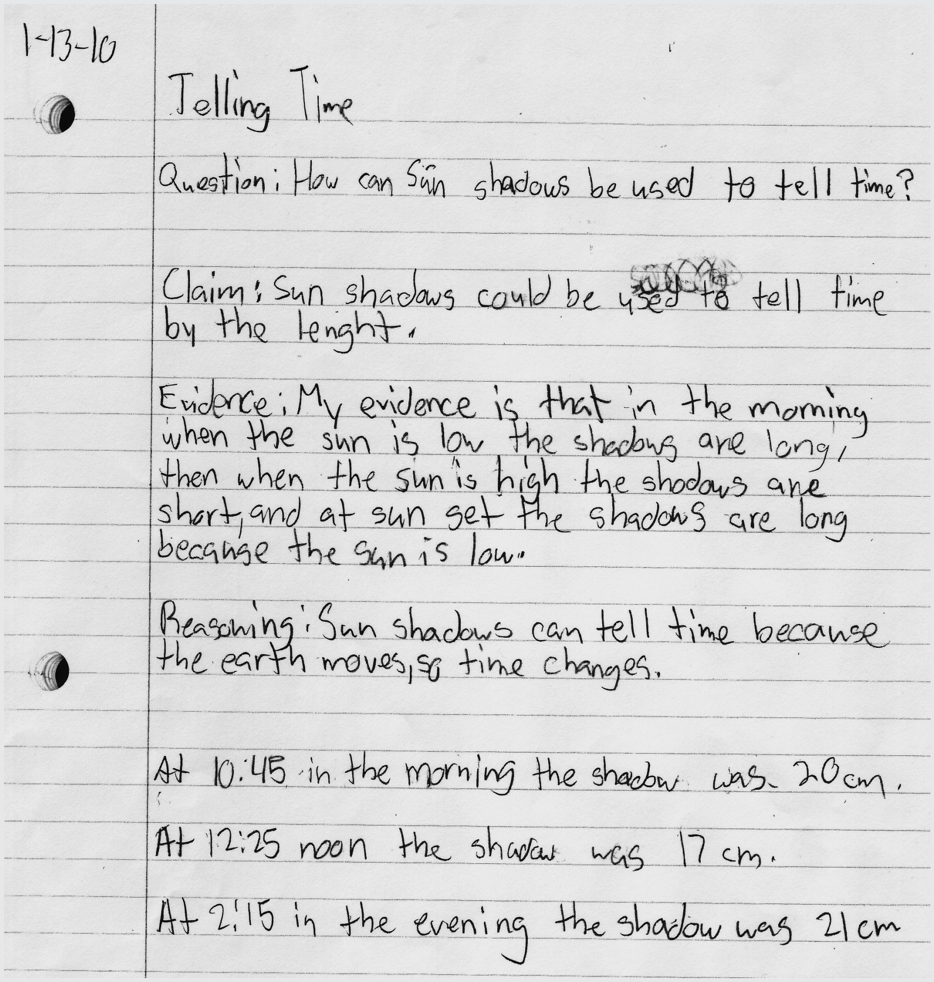
Figure 2.5 includes the scientific explanation from one of the fifth-grade students. He provided a correct and accurate claim: *Sun shadows could be used to tell time by the length [sic].* Interestingly, the next section that the student labeled as evidence included some of his evidence in terms of describing the general trends, such as *in the morning when the sun is low the shadows are long*. The rest of his evidence is actually at the bottom of the page where the student provided the specific times and specific lengths of the shadows. Across the two sections, the student's evidence is accurate and complete, although the different locations bring into question whether the student understood that the specific numbers should be included as part of his evidence. Finally, the reasoning started to explain why the evidence supports the claim in that it states: *Sun shadows can tell time because the earth moves, so time changes*. The student made a link between the movement of the earth and the length of the shadows, but this movement of the earth was not described in depth nor did the student discuss how this affects the position of the sun. This example illustrates how the framework is helping to support the student in writing his scientific explanation, yet his reasoning could be more in depth.

Physical Science Example

The physical sciences provide students with multiple opportunities to analyze data. There are numerous investigations students can conduct in class to collect their

FIGURE 2.5

Fifth Grade Scientific Explanation about Sun Shadows and Time


1-13-10

Telling Time

Question: How can Sun shadows be used to tell time?

Claim: Sun shadows could be used to tell time by the lenght.

Evidence: My evidence is that in the morning when the sun is low the shadows are long, then when the sun is high the shadows are short, and at sun set the shadows are long because the sun is low.

Reasoning: Sun shadows can tell time because the earth moves, so time changes.

At 10:45 in the morning the shadow was 20 cm.

At 12:25 noon the shadow was 17 cm.

At 2:15 in the evening the shadow was 21 cm

own data, or they can analyze data that are provided to them. For example, data can be analyzed around topics such as properties of objects, properties of substances, substances interacting with each other, states of matter, changes in states of matter, force, motion, energy, light, heat, electricity, magnetism, and sound. Students can then construct explanations in which they justify their claim with appropriate evidence and reasoning.

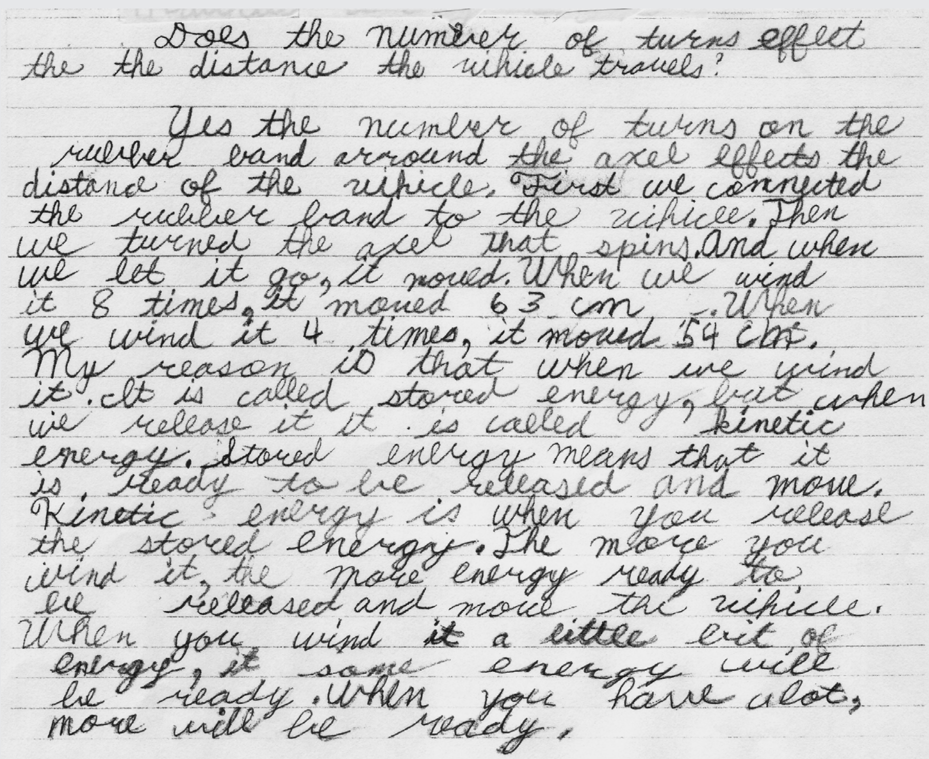
For example, a fourth-grade teacher was completing a unit with her students on the topic of force, motion, and energy. The students were testing rubber band cars in which the rubber band was wound around the axle. When the rubber band unwound it caused the axle to spin and move the car. Specifically, she had her students collect data and write a scientific explanation to address the question, *Does the number of turns of the rubber band affect the distance the vehicle travels?* Table 2.1 illustrates an ideal student response for this question. Again, this example includes the rebuttal in the table, even though the teacher did not ask her students to include a rebuttal in their writing. The student would analyze the data to come up with this claim: *The number of turns does affect the distance a vehicle travels.* Then the student would provide specific evidence from the investigation that illustrates that the more turns of the rubber band, the further the vehicle traveled. Finally, the reasoning would articulate why turning the rubber band results in the vehicle traveling a farther distance. Specifically, in the reasoning, the teacher is looking for the students to discuss potential and kinetic energy, which they had previously discussed in class: *Turning the rubber band transforms kinetic energy of the winding into stored or potential energy. The stored energy is then transformed into kinetic energy when the rubber band is released. Kinetic energy is energy of movement. The more times the rubber band is turned, the more stored energy there is, which means the more kinetic energy there is. That is why the more you turn it, the farther the vehicle travels.* This example requires the application of fairly complex scientific ideas in the reasoning. If the students were younger or had less experience with scientific explanations, we would expect a simpler reasoning statement, such as the light example in the vignette with the second-graders or the bush bean plant example with the third-graders. In this example, the teacher had been using the claim, evidence, and reasoning framework with her students for some time and she expected them to include fairly complex reasoning in their writing.

Figure 2.6 includes a specific example from another student in the fourth-grade classroom. This student provided a complete and accurate claim—*Yes the number of turns on the rubber band around the axel effects [sic] the distance of the vehicle.* The student then went on to provide two pieces of evidence from her experiment: *When we wind it 8 times, it moved 63 cm. When we wind it 4 times, it moved 54 cm.*

Finally, the student provided sophisticated reasoning in which she discussed both stored energy and kinetic energy: *My reason is that when we wind it it is called stored energy, but when we release it it is called kinetic energy. Stored energy means that it is ready to be released and move. Kinetic energy is when you release the stored energy. The more you wind it, the more energy ready to be released and move the vehicle.* Although there are some grammatical errors in the writing, the student clearly explained her ideas about why winding the rubber band impacts the distance traveled by the vehicle and incorporated the scientific ideas of stored energy and kinetic energy into her writing.

FIGURE 2.6

Fourth Grade Scientific Explanation about Energy



Does the number of turns effect
the the distance the vihicle travels?

Yes the number of turns on the rubber band arround the axel effects the distance of the vihicle. First we connected the rubber band to the vihicle. Then we turned the axel that spins. And when we let it go, it moved. When we wind it 8 times, it moved 63 cm. When we wind it 4 times, it moved 54 cm. My reason is that when we wind it. It is called stored energy, but when we release it it is called kinetic energy. Stored energy means that it is ready to be released and move. Kinetic energy is when you release the stored energy. The more you wind it, the more energy ready to be released and move the vihicle. When you wind it a little bit of energy, it some energy will be ready. When you have alot, more will be ready.

The complexity of the claim, evidence, and reasoning will depend on how you design the learning task as well as the age and experience of your students. In this section, we purposefully selected writing samples from third-, fourth-, and fifth-grade students because all of the examples include some reasoning. We wanted to illustrate what the different components could look like across different science content areas. In discussions (such as the second-grade vignette), we also see younger students articulating their reasoning at times. Yet, typically in K–2 classrooms, students' writing focuses on just the claim and evidence components of the framework. Throughout the book, we will include other examples from these earlier grade levels. Here we included more sophisticated examples to illustrate what the components can look like when students gain more experience using the framework in both science talks and science writing.

Increasing the Complexity of the Framework over Time

There are multiple variations of the scientific explanation framework that you can use with your students, depending on their level of experience and comfort level with this type of science talk and science writing. Table 2.2 provides a summary of these different variations of the framework. Variations 1–3 are typically used in elementary classrooms, whereas Variation 4 is more likely to be used in middle school or high school classrooms. This final variation (Variation 4) can also be broken down into greater complexity for more experienced students, which we describe in other work (see McNeill & Krajcik, 2012).

In this section, we describe and provide an example to illustrate Variations 1–4. The example throughout focuses on the same overarching science concept that objects can be described by both the materials of which they are made and their properties. Two objects made of different materials (or different substances) have different physical properties. For instance, a metal spoon and a plastic spoon both have the same use (e.g., eating), but they have different properties (e.g., color, hardness, flexibility, solubility) because they are made of different materials. Although all four examples focus on this key science concept, the complexity of the science content and the complexity of the scientific explanation increases across the four variations.

Variation 1: Claim and Evidence

Variation 1 of the framework focuses on simple patterns in data that allow for a claim to be generated and supported with one piece of evidence. We have found that this variation of the framework works well with kindergartners and first-graders, and that it is an appropriate starting place for even older students if they have minimal experience with this scientific inquiry practice. This initial framework focuses on constructing a claim that specifically answers the question asked, rather than a statement about the general topic that does not address the question. Furthermore, Variation 1 targets providing one piece of evidence that supports the claim. This includes the idea of *appropriate* evidence, although we would not recommend using that term with inexperienced students. Rather, students should focus on whether the evidence answers the question being asked and supports the claim.

For example, kindergarten students can investigate the science concept that objects can be described in terms of both the materials of which they are made and their physical properties. Their teacher provides them with a variety of objects (e.g., spoons, balls, and blocks) and asks them to sort the objects based on the material of the object (i.e., what the object is made of). Specifically, they are asked to answer this question: *Which objects are made of different materials?* After sorting the objects, the class comes together for a science talk in which they

TABLE 2.2 Variations of the Instructional Framework for Scientific Explanation

Level of Complexity	Framework Sequence	Description of Framework for Students
Simple	*Variation 1* 1. Claim 2. Evidence	*Claim* • A statement that answers the question *Evidence* • Scientific data that support the claim
	Variation 2 1. Claim 2. Evidence • Multiple pieces	*Claim* • A statement that answers the question *Evidence* • Scientific data that support the claim • Includes multiple pieces of data
↓	*Variation 3* 1. Claim 2. Evidence • Multiple pieces 3. Reasoning	*Claim* • A statement that answers the question *Evidence* • Scientific data that support the claim • Includes multiple pieces of data *Reasoning* • A justification for why the evidence supports the claim using scientific principles
Complex	*Variation 4* 1. Claim 2. Evidence • Multiple pieces 3. Reasoning 4. Rebuttal	*Claim* • A statement that answers the question *Evidence* • Scientific data that support the claim • Includes multiple pieces of data *Reasoning* • A justification for why the evidence supports the claim using scientific principles *Rebuttal* • Describes alternative explanations, and provides counterevidence and counterreasoning for why the alternative explanation is not appropriate

discuss their results. A student could potentially offer the following scientific explanation:

> *The two spoons are different materials (Claim), because one is white and the other is silver (Evidence).*

In this example, the student provides a claim that specifically answers the question being asked and she uses one piece of evidence from her investigation (i.e., the color of the two spoons). Using the evidence in this case is really important because it provides a rationale for why she decided the two spoons are different materials. Initially, students may just provide their claim and you will need to encourage them to use evidence (i.e., their observations and measurements) to explain why they came up with that claim. Most claims in science are better supported by multiple pieces of evidence. But if your students are new to thinking about the idea of using evidence to support a claim, it can help students initially to focus on one piece of evidence.

Variation 2: Using Multiple Pieces of Evidence

Variation 2 includes a focus on multiple pieces of evidence. As students gain more experience with this complex practice, students can construct explanations with a claim supported by more than one piece of evidence. More experienced or older children can debate about the strength of the evidence that they use to support their claim. The idea of using multiple pieces of evidence aligns with the concept of including *sufficient* evidence, although, once again, we do not necessarily recommend using that term with elementary students. Rather, we would talk about including *multiple* pieces of evidence or considering whether or not we have *enough* evidence to support our claim. Including multiple pieces of evidence also provides the opportunity to use and discuss different types of evidence, such as both quantitative and qualitative data. This can encourage students to think about what does and does not count as evidence in science.

Returning to the previous example in which the students were sorting the different objects, this investigation can also be used for Variation 2 of the framework. The students are still addressing the question, *Which objects are made of different materials?*, but now they need to include multiple pieces of evidence to support their claim. For example, one potential student explanation could be:

> *The two spoons are different materials (Claim). My evidence is that one spoon is white and the other spoon is silver (Evidence 1). The white spoon is also softer, because I can scratch it with my fingernail while the silver spoon is harder because I cannot scratch it (Evidence 2). Also, the two spoons are the same size, but they weigh different amounts. The white spoon was 3.0 grams and the silver spoon was 16.4 grams (Evidence 3).*

In this example, the student is making the same claim as in Variation 1, but in this case there are three pieces of evidence to support the claim. One student may come up with all three pieces of evidence. Yet another possibility is that during a science talk focused on the class results, various students generate the different pieces of evidence and the teacher records the multiple pieces of evidence on the board or on another visual so that the students can observe all the evidence that they came up with as a class. The example also includes both qualitative evidence (e.g., color and hardness) as well as quantitative data (e.g., the mass of two objects that are the same size).[2] This can provide an interesting opportunity to discuss what observations and measurements the students can use as evidence to address their overarching question of which objects are made of different materials.

Variation 3: Providing Reasoning

As students become more comfortable supporting claims with evidence, reasoning can also be introduced to students as a more complex variation of this practice. In the reasoning component, students need to explain why their evidence supports their claim. The reasoning includes the scientific principles or big ideas in science and articulates how the students are using these ideas to make sense of their data. Articulating this link between the claim and evidence can be challenging for students, because they need to describe how or why their evidence supports their claim. Initially, when using the framework it may be more appropriate to focus only on the claim and the evidence. As students gain more experience and comfort, the reasoning component can be added to the framework. In some of the classrooms in which we have worked, students as young as second and third grade have successfully begun to include the reasoning in both their science talk and writing. We have also worked with teachers who have decided to wait until fourth or fifth grade to introduce reasoning, mainly because they felt their students first needed more experience with using evidence to support their claims.

For the example about the properties of materials, the reasoning can be added onto the previous scientific explanation in order to articulate how or why the evidence supports the claim. For example, a student could create the following scientific explanation:

> *The two spoons are different materials (Claim). My evidence is that one spoon is white and the other spoon is silver (Evidence 1). The white spoon is also softer, because I can scratch it with my fingernail while the silver spoon is harder because I cannot scratch it (Evidence 2). Also, the two spoons are the same size, but they weigh different amounts. The white spoon was 3.0 grams and the silver spoon was 16.4 grams (Evidence 3). Color, hardness, and mass for the same size of objects are properties of materials. If two objects have different properties, they are different materials. Since the two spoons have different properties, I know they are different materials (Reasoning).*

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[2]The mass of two objects of the same size is focusing on the idea of *density* even though it does not use this term. Density can be a challenging concept for students, so you may or may not want to discuss this idea with your students. *Mass* by itself is not a property that allows you to determine if two objects are made of the same material (or substance). For example, you can have 8 ounces of water or 32 ounces of water. In both cases, they are water, but the mass will be different. On the other hand, if you have 8 ounces of water and 8 ounces of oil, the mass will be different because they are different substances that have different densities.

This example is identical to the previous one in terms of the claim and evidence. The one addition is that in the reasoning, the student describes why the evidence supports the claim. Specifically, the explanation includes the main science concept that different materials have different properties, which is why the two spoons can be separated or grouped as different materials. Including the reasoning encourages students to really think about the key science concept and how to articulate that science concept in either talk or writing.

Variation 4: Including a Rebuttal

The last variation includes the addition of the rebuttal. A rebuttal describes alternative explanations and provides counterevidence and counterreasoning for why the alternative is not appropriate. As we mentioned previously, the rebuttal is the most complex component of the framework, and it may not be appropriate to refer to this component by name with elementary students. As students continue on to middle school and high school, it becomes more important to encourage students to incorporate this alternative perspective in their writing. Yet the idea of a rebuttal may very well emerge during science talks, particularly if there is disagreement around a particular claim. If multiple potential claims emerge, the class will want to discuss the strength of those claims and what evidence and reasoning the class has to support the claims.

This last example is from an older and more experienced classroom (e.g., fifth grade). Consequently, in addition to adding the rebuttal, this example also uses more scientific or academic language. In the *National Science Educations Standards* (NRC, 1996), there is a shift in the language of the standards from K–4 to 5–8 in which discussion focuses on properties of *substances* instead of properties of *materials.* A substance is something that is made of the same type of material (atom or molecule) throughout. And so, in this example the students are answering the question, *Which objects are made of different substances?* In discussing whether the two spoons are made of the same substance, a potential student misconception is that "use" is an important property to identify whether two objects are made of the same substance. Some students in the class may provide this claim: *The white and silver spoon are the same substance (Claim) because they are both used for eating (Evidence).* As the two different claims are discussed (the two spoons are the same versus different substances), rebuttals will emerge as part of the classroom discussion. Consequently, the following scientific explanation could be constructed as a class:

> *The two spoons are different substances (Claim). My evidence is that one spoon is white and the other spoon is silver (Evidence 1). The white spoon is also softer, because I can scratch it with my fingernail while the silver spoon is harder because I cannot scratch it (Evidence 2). Also, the two spoons are the same size, but they weigh different amounts. The white spoon was 3.0 grams and the silver spoon was 16.4 grams (Evidence 3). Color, hardness, and mass for the same size of objects are properties of*

substances. If two objects have different properties, they are different substances. Since the two spoons have different properties, I know they are different substances (Reasoning). Some people may think the two spoons are made of the same substance, because they are both used for eating. But use is not a property that tells us what an object is made of. Use cannot tell you if two objects are made of the same substance (Rebuttal).

This scientific explanation includes similar claim, evidence, and reasoning as Variation 3 with the use of the term *substance* instead of *material.* The one major addition is the rebuttal, which makes the scientific explanation itself more complex in terms of the structure; furthermore, the science content is more complex because it specifically addresses the idea of whether or not use is a property. Although you may not want to have students include the rebuttal in their writing, multiple potential claims may arise in your classroom. An important aspect of science is that scientists debate the appropriateness of different claims as well as the strength of the evidence and reasoning to support those claims.

We present the four different variations to illustrate there are multiple ways to engage your students in scientific explanations. You should select the variation that is most appropriate for your students, considering their previous experiences and age. You also may decide that over the course of the school year you might want to shift from one variation to the next as your students gain more experience with this scientific inquiry practice. For example, you could introduce the framework in terms of Variation 1 at the beginning of the year and add on the idea of multiple pieces of evidence as your students become more comfortable. Alternatively, with more experienced students you may want to begin with Variation 2 and then add the reasoning component as your students become better able to express their evidence to support their claims. The framework should be adapted to meet the specific needs of your students.

Benefits of the Framework for All Learners

Elementary classrooms consist of an academically diverse group of students, including students with special needs and English language learners. Meeting the needs of all learners is a challenging task. Yet, the strategies discussed throughout this book will help all students achieve greater science proficiency. Using an integrated approach to teaching science and literacy can support ELLs in learning both science and language. It also can support native speakers of English in developing a deeper understanding of the complex language of science (Pray & Monhardt, 2009). Teachers need strategies to help build both the language and content knowledge of all of their students in order for students to succeed in science (Olson et al., 2009). Using the claim, evidence, and reasoning framework can be an essential tool to support teachers in this task.

Science includes specialized ways of communicating, which can differ from students' everyday ways of talking and writing. Students from culturally and linguistically diverse backgrounds can prioritize forms of communication, such as storytelling (Bransford, Brown, & Cocking, 2000), different from the forms prioritized in science. In order to help all students learn science, it is important to develop an understanding of students' everyday ways of knowing and to make the implicit rules of science discourse explicit (Michaels et al., 2008). Elementary students can understand terms such as *evidence* and *explanation* from their everyday lives, which can be resources for science instruction. For example, we conducted a study in a diverse urban elementary school where we asked fifth-grade students at the beginning of the year what they thought it meant to "use evidence" and to "create an explanation" in their everyday lives as well as in their science class (McNeill, in press). When speaking about using evidence in their everyday lives, the majority of students talked about an exchange between people, such as when a person wants to convince someone, but they were less likely to talk about evidence as data or that one uses evidence to support an idea or claim. For explanation in their everyday lives, they also talked about an exchange between people, such as when someone explains why a person was out in a baseball game. When asked about creating an explanation in science class, the majority of the students said they did not know what it meant. Over the course of the school year, their teacher, Mr. Cardone, made connections to their everyday understandings and used the claim, evidence, and reasoning framework to support the students in developing stronger understandings of these ideas in science class as well as stronger science writing.

Consequently, it can be important to understand your students' everyday meanings and ways of knowing as well as discuss how these are similar and different from scientific ways of knowing. The students' understandings can vary, depending on their cultural and linguistic backgrounds. The scientific explanation framework can also serve as a tool to help students understand your expectations for what it means to justify a claim in either talk or writing in science class. The framework simplifies this complex scientific inquiry practice into components, which may be more accessible to students. Explicitly discussing the framework for science talk and writing may encourage more students to participate and successfully engage in the discourse in your classroom.

The different variations of the framework also serve as a resource to better support all students. The backgrounds, experiences, and understandings of your students will influence which variation of the framework is appropriate for your classroom. Furthermore, you can use the different variations in order to differentiate instruction to meet the needs of particular students. Differentiating instruction includes individualizing lessons to meet the needs of each student in an academically diverse classroom (Adams & Pierce, 2003). For example, one teacher we worked with focused her instruction on Variation 3 in that she required all of her students to justify their claims with appropriate evidence and reasoning. However, as a class, they also talked about the concept of a rebuttal, as when you disagree with another individual's claim. When some of her more advanced students completed their writing early, she challenged them to add a rebuttal to their writing. Consequently, the different variations of the framework can be used to individualize instruction to meet the specific needs of your students.

Check Point

At this point, we have discussed why scientific explanation is important to integrate into your classroom practice. We have also described a framework (i.e., claim, evidence, reasoning, and rebuttal) that you can use to support all students in scientific explanations. Furthermore, we have illustrated what introducing the framework can look like in a third-grade classroom, provided examples of scientific explanations across various content areas, and described different variations of the framework that can be adapted to meet the needs of your students. In the upcoming chapters, we will focus on how to get the evidence you need for scientific explanations. In order to create scientific explanations successfully, students need to have data to analyze, so this is a key aspect of the practice. Furthermore, we will discuss different teaching strategies you can incorporate into your instruction as well as how to plan for integrating explanations in your classroom. Finally, we will focus on assessment, providing strategies for designing assessments and rubrics as well as examples of how the assessments can be used to evaluate the strengths and weaknesses of your students to better meet their needs in your instruction.

Study Group Questions

1. Select a science concept that you currently teach your students. What is a question you could ask your students to create a scientific explanation? Write out a sample potential student explanation labeling the claim, evidence, and reasoning (and rebuttal if you would like) for that question.
2. Examine Table 2.2. What variation of the framework will you introduce to your students? Why do you feel that variation is appropriate?
3. How will you introduce the framework to your students? How will you define the different components?
4. Introduce the scientific explanation framework to your students. What worked well? What challenges arose? How would you introduce it differently in the future?