Why Teach Children to Construct 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. 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 at.,2006.)

Finally, in a recent synthesis of research from fields including science education and educational psychology, the National Research Council report, *Taking Science to School* (Dusch! 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.

- *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/or 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.

A Framework for Explanation-Driven Science

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.

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 to the question, *Can you make shadows with any kind of light source?* During the discussion, one student proposed a claim, hut 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. 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.

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 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.

Often, scientists debate multiple alternative claims and try to determine which claim is more appropriate. The rebuttal explains why an alternative claim is not a more appropriate claim for a specific question. Similar to the original claim, the rebuttal uses both evidence and reasoning. But in the case of the rebuttal, the evidence and reasoning articulate why the alternative claim 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 young 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 third or fourth 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.

Text taken from: *The Importance of Engaging Students in Scientific Explanation*
What's Your Evidence? (Facilitator's Guide)
By Carla Zembal-Saul, Katherine McNeill, Kimber Hershberger

Handout 12—Base Scientific Explanation Rubric

		Claim	Evidence	Reasoning	Rebuttal
		A statement or conclusion that answers the original question/problem.	*Scientific data that support the claim. The data need to be appropriate and sufficient to support the claim.*	*A justification that connects the evidence to the claim. It shows why the data count as evidence by using appropriate and sufficient scientific principles.*	*Recognizes and describes alternative explanations, and provides counterevidence and reasoning for why the alternative explanation is not appropriate.*
LEVEL	0	Does not make a claim, or makes an inaccurate claim.	Does not provide evidence, or provides only inappropriate evidence (evidence that does not support the claim).	Does not provide reasoning, or provides only inappropriate reasoning.	Does not recognize that alternative explanation exists and does not provide a rebuttal, or makes an inaccurate rebuttal.
	Varies from	Makes an accurate but incomplete claim.	Provides appropriate, but insufficient evidence to support the claim. May include some inappropriate evidence.	Provides reasoning that connects the evidence to the claim. May include some scientific principles or justification for why the evidence supports the claim, but not sufficient.	Recognizes alternative explanations and provides appropriate but insufficient counterevidence and reasoning in making a rebuttal.
	1 to 5	Makes an accurate and complete claim.	Provides appropriate and sufficient evidence to support the claim.	Provides reasoning that connects the evidence to the claim. Includes appropriate and sufficient scientific principles to explain why the evidence supports the claim.	Recognizes alternative explanations and provides appropriate and sufficient counterevidence and reasoning when making rebuttals.

Handout 13—Specific Scientific Explanation Rubric—
How Does the Position of the Light Source Change the Position of the Shadow?

	Claim	Evidence	Reasoning
	A statement or conclusion that answers the original question/problem.	*Scientific data that support the claim. The data need to be appropriate and sufficient to support the claim.*	*A justification that connects the evidence to the claim. It shows why the data count as evidence by using appropriate and sufficient scientific principles.*
0	Does not make a claim, or makes an inaccurate claim like—"Light does not create shadows."	Does not provide evidence, or provides only inappropriate evidence or vague evidence like "the data show me it is true" or "our investigation is the evidence"	Does not provide reasoning, or provides only inappropriate reasoning like "light is not important for shadows."
1	Makes an accurate but incomplete claim that includes 1 of the following 2 pieces: • The shadow falls in a straight line from the light source. • The shadow moves in the opposite direction of the light source.	Provides 1 of the following 3 pieces of evidence: • When I held the flashlight on the left, the shadow was to the right. • When I held the flashlight behind the person, the shadow moved straight in front. • When I held the flashlight on the right, the shadow was to the left. OR Makes a general statement about how the shadow is opposite the direction of the light without specifying all of the 3 specific observations from the investigation. May also include inappropriate evidence.	Provides 1 of the following 2 reasoning components: • Light travels in a straight line. • Objects (like the pipe cleaner person) block light to create a shadow.
2	Makes an accurate and complete claim that includes 2 of the following 2 pieces: • The shadow falls in a straight line from the light source. • The shadow moves in the opposite direction of the light source.	Provides 2 of the following 3 pieces of evidence: • When I held the flashlight on the left, the shadow was to the right. • When I held the flashlight behind the person, the shadow moved straight in front. • When I held the flashlight on the right, the shadow was to the left. May also include inappropriate evidence.	Provides 2 of the following 2 reasoning components: • Light travels in a straight line. • Objects (like the pipe cleaner person) block light to create a shadow.
3		Provides 3 of the following 3 pieces of evidence: • When I held the flashlight on the left, the shadow was to the right. • When I held the flashlight behind the person, the shadow moved straight in front. • When I held the flashlight on the right, the shadow was to the left.	

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

Increasing the Complexity of the Framework over Time

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.

Flaws in scientific reasoning

Without explicit instruction, students often make claims based on their opinions and previously held, naive conceptions. Students' lack of prior experiences and opportunities initiates many of their claims and explanations. Flaws in students' reasoning can also be overcome by teachers' questions and prompts. Verbal questions and prompts include the following:

- What is the basis for your claim (or inference)?
- What evidence did you collect that supports your claim, your idea, or your hypothesis?
- Why do you think this is so?
- What do you mean by ....?
- Does the evidence support or refute your claim?
- Are the data biased? Are the data reliable?
- How would you interpret the data and evidence?
- What is the relationship between the independent and dependent variables?
- What do the data say or imply?
- What conclusions can you draw from the evidence?
- How does the evidence support or refute your claim?
- What explanation can you propose from the evidence collected?
- How do the results support what you expected?
- How do the results support what you already knew about the phenomenon?
- Can you develop an explanation from the results?
- Can you construct a model to support your explanation?
- Were your original assumptions about the question correct?
- How will you defend your findings?

Taken from: *Fostering Argumentation Skills: Doing What Real Scientists Really Do*
by Douglas Llewellyn and Hema Rajesh
Science Scope, September 2011, pgs. 22-28