PUTTING IDEAS ON PAPER

Formulating scientific explanations using the Claim, Evidence, and Reasoning (CER) framework

By Jared Allen and Meredith Park Rogers

Many students find it easier to express their ideas about science through talking rather than writing. However, writing in science promotes new learning, helps students consolidate and review their scientific ideas, and aids in reformulating and extending their scientific knowledge (Abell 2006). These practices lead to formulating and defending scientific explanations (NGSS Lead States 2013). To support elementary students in the complex practice of science explanations, teachers first must provide experiences for students to observe phenomena before asking them to explain the phenomena.

To illustrate the role writing can have on creating explanations, we describe how we implemented a framework referred to as CER (Claim, Evidence, and Reasoning) to achieve the *NGSS* practice of Constructing Explanations. The CER framework supports the development of explanations and guides young children in communicating their understandings of science through writing (Zembal-Saul, McNeill, and Hershberger 2013). This framework supports students' learning and writing through forming statements (claims) based on their observations (evidence) and then discussing these results with respect to the underlying scientific principles (reasoning) to build a deeper understanding of the content.

Investigating Matter

This activity is designed for upper elementary and typically takes two days or lessons to complete. Originally, the activity was developed around state science standards for grade 3, though the *NGSS* standards align the content more with fourth grade (see Connecting to the *Next Generation Science Standards*, p. 37). The purpose of the activity is three-fold: for students to gain an understanding of how the properties of matter affect light and sound, how these effects are related to each other, and to practice

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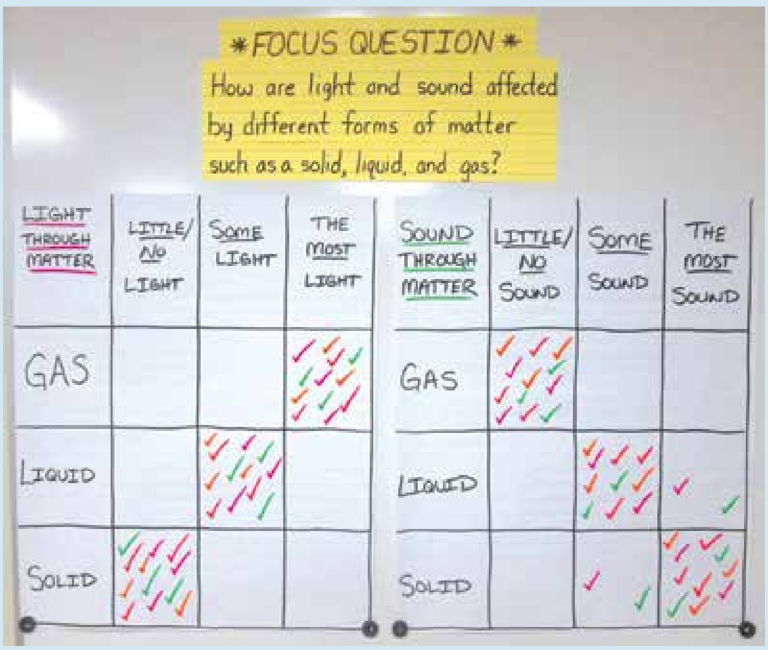
Students observe the effect a liquid has on sound.

formulating explanations. The CER Framework is incorporated to help guide students in making explanations that address many of the skills laid out in the *NGSS*. The lesson begins with a focus question that connects the two science investigations within the lesson: "How do different states of matter such as a solid, liquid, and gas affect light and sound?" The focus question's role is to provide the students with an objective for learning. After the students read through the posted focus question, the teacher engages the students by showing them a beaker with a solid (sand), a beaker with a liquid (water), and an empty beaker (i.e., one containing a gas, air). The teacher asks the following questions: *What can you tell me about what is inside these three beakers? What states of matter do they represent? What observations did you make that helped you answer the question?* This discussion serves as a review of the properties that are unique to each state of matter.

FIGURE 1.

Students created a data chart to locate patterns in the evidence to support the class claim.



Exploring Sound Through Matter

In the first investigation, the students begin by predicting if sound will travel better through solids, liquids, or gases. The definition of *better* should be determined by the class, for example "louder" or "clearer." In our case, better was defined as "louder" as observed by students in comparing the sounds heard against one another. Following student predictions, the teacher leads a class discussion to bring in the students' real-world experiences by describing examples of times they have heard things through different types of mediums (e.g., air, the bathtub or swimming pool, or putting their ear to a wall or door).

At the conclusion of the discussion, the students are split into teams of two or three to explore how the states of matter affect how sound travels *(Classroom management note: This is best done with three stations, having each team rotate between each station (solid, liquid, and gas). Depending on the number of teams, you might need more than one station of each type)*. A stethoscope is used to measure the sound, and the students are provided with a handout to record their data (see NSTA Connection). *Make sure to include alcohol wipes in your supply list to disinfect ear pieces between uses. Also, emphasize to the students the importance of not yelling into the end of the stethoscopes.*

CAUTION

Station 1: To measure the effect gas has on sound, one student places the stethoscope ear pieces into his/her ears and the other student taps their pointer finger and thumb together near the diaphragm, allowing the student to hear the sound through the stethoscope. This technique has two variables rather than one. Rather than tapping on a hard surface, the strategy in this case asks for tapping two soft surfaces together (fingers). To provide a valid comparison, students need to tap their finger on a hard surface (i.e., a table) at a distance from the diaphragm that is equal to the distance separating the tapping from the diaphragm in the other two tests.

Station 2: To measure the effect a liquid has on sound, the student with the stethoscope sticks the diaphragm into one end of a container filled with water and the other student taps their pointer finger and thumb together at the opposite end of the tub for the student to hear the sound it makes.

Station 3: Finally, to measure the effect a solid has on sound, the end of the stethoscope is placed on one side of a desk and the other student taps the opposite side of the desk. (Teacher tip: After performing these three mini investigations as described, we realized that we were changing too many variables for an accurate comparison in sounds. Therefore, we recommend using two craft sticks rather than fingers to tap together and test for the loudness through each medium. In addition, all three tests should be performed equally distant from the diaphragm of the stethoscope to ensure the distance the sound travels is the same.) These three tasks are repeated as many times as needed to provide all students with the opportunity to listen through the stethoscope, make observations, and gather their evidence. The more evidence the teams collect, the more accurate their claims will be.

Once all evidence is collected, the teams come to the board to place a check mark on the class data chart under the state of matter that made little to no sound, some sound, and the loudest sound (see Figure 1, p. 33). Charting the class data this way affords students the opportunity to compare their data to others, as well as recognize patterns in the class data for each state of matter. These patterns will eventually be used to support the claim the students create.

Students observe the effect a solid has on sound.

Exploring Light

In the second investigation, students are provided the opportunity to predict if light travels better through solids, liquids, or gases. The teacher begins through leading a discussion describing real-world examples students have experienced, like when they shone a flashlight through different states of matter like a window to look outside or on their hands to make shadow puppets. After the discussion, the students are split into teams again. A flashlight is used as the light source, and the students shine the light through a clear empty cup (a gas), a clear cup with water in it (a liquid), and a piece of square cardboard (a solid). Through shining light through each state of matter, they observe the effect these three conditions have on the amount of light seen on the wall behind each cup. As the students observe each condition, they collect their data on the data sheet provided (see NSTA Connection) to gather their evidence. These three tasks can be repeated to provide all students with the opportunity to shine the flashlight through each of the states of matter. Following the investigation, each team comes to the class data chart and transfers their data by placing a check mark under the state of matter that allows for little to no light to shine on the wall, some light to shine on the wall, or the most light to shine on the wall (see Figure 1). The class data chart then affords the students opportunities to look for and interpret patterns in the data to use as evidence to support their claim.

Forming Scientific Explanations

The students have now gathered evidence to create their own scientific explanation to answer the focus question provided at the beginning of the lesson: *How do different states of matter such as a solid, liquid, and gas affect light and sound?* To structure an explanation to this question, we employed the CER framework. To illustrate how each portion of the framework has the potential to support students in their writing and communication of the science ideas investigated, each portion of the framework will be discussed.

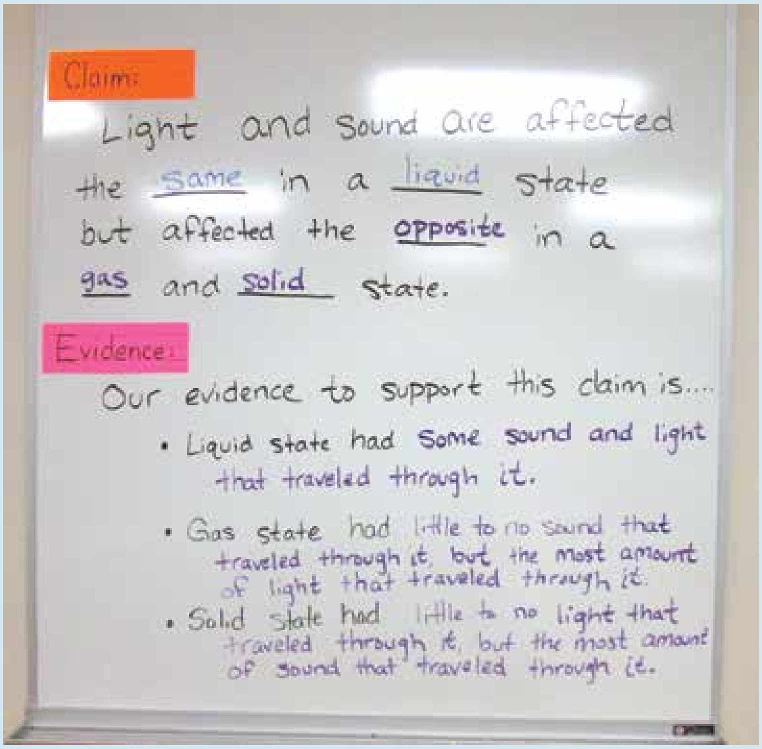
Claim

The claim is the statement or conclusion that answers the focus question. The teacher revisits the focus question and directs the students' attention toward the data chart by asking them to describe what they observe in the data posted. Productive questions for this type of discussion might include: *What do you notice about the effect liquid had on both sound and light? What do you observe about the effect of a gas, and a solid?* To begin writing the claim, elementary students may need support, so we suggest using sentence prompts that guide and organize their thinking. For example,

Light and sound are affected ________ in a ________ but ________ in a ________ and a __________(see Figure 2).

FIGURE 2.

The scaffolds and prompts used in the claim and evidence portion of the CER framework.



Evidence

An essential component of science is the use of evidence. When scientists construct a claim, evidence is used to support it. Making sense of data can sometimes be a difficult task, so again scaffolds aid students in analyzing data. This will lead them to select pertinent evidence to support the claim. For this task, we started out having the students look at the data for any patterns or similarities between the sound data chart and the light data chart (see Figure 1). The patterns they noticed were written on the board in a bulleted list. The list was organized further into brief statements that combined similar patterns. Once all the similar patterns were combined, the following prompt was provided: "Our evidence to support this claim is…" This prompt was followed up with the students creating three evidence statements, one for each state of matter, to help the students in organizing the data to support the claim (see Figure 2). In small teams, the three evidence statements are discussed and as a class are finalized.

Reasoning

The class discussion associated with this component of the CER framework is facilitated by the classroom teacher, often through introducing a nonfiction book (Zembal-Saul, McNeill, and Hershberger 2013). However, over time and with practice, older students can begin to access online resources or texts independently. We recommend continuing to support students by pre-selecting resources that accurately reflect the scientific principles associated with the concept. Through including this component in either written form or discussion form or both, you encourage your students to consider, reflect, express, or explain science ideas, and provide them the opportunity to become more comfortable using scientific terms and language.

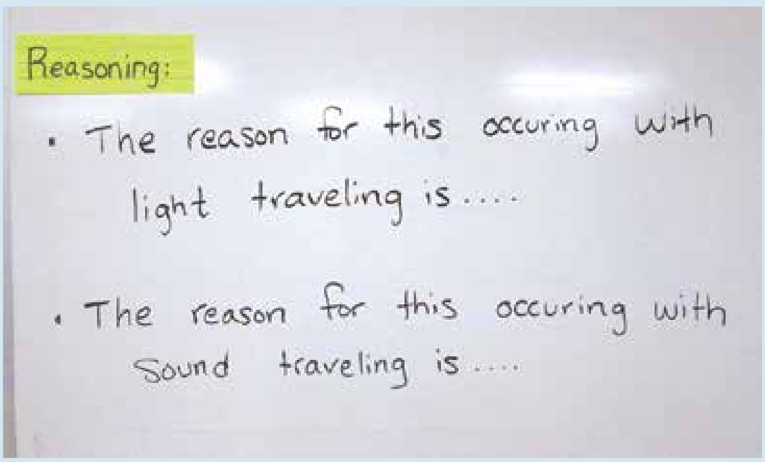
To support the reasoning component of this particular activity, we showed a quick video on how sound travels (Koch 2003) and provided the following prompt: "The reason for this occurring with sound traveling is…" (see Figure 3). To support students in reasoning through their evidence about the effects of matter on light, we provided the class a few brief snippets from an article on how light travels (Kindersley 2007). Again, a new prompt was used to facilitate a class discussion to explain how light interacts with the three states of matter.

Students observe the effect a liquid has on light.

We concluded the lesson through an enrichment activity that allowed the students to apply their understanding of their explanations. They mimicked how molecules are arranged in a solid, liquid, and a gas, and used their explanations to answer how sound and light might be affected by these arrangements given how each form of energy travels. Since the motion of molecules is beyond the third grade, this enrichment activity could be incorporated into a lesson with the higher grade levels. This demonstration provides the students the opportunity to make sense of what they learned through their application of the CER framework. In this lesson, we incorporated sentence prompts to structure the development of the science discussion. Once your students understand and become more confident in using the CER framework, you can gradually remove the prompts. We suggest beginning with the claim followed by the evidence prompt. Due to the complexity of the reasoning component, this component of the explanation may take students more time to construct on their own. The removal of any of these scaffolds should be made according to individual student's comfort level with the CER framework.

FIGURE 3.

The prompts used to support the reasoning portion of the CER framework.



Conclusion

Using the CER framework as a tool to support writing in science can help students nurture their conceptual understanding of science through allowing them the opportunity to justify their scientific claims (Zembal-Saul, McNeill, and Hershberger 2013). Thus, scientific explanations can support students in the following ways: to develop academic writing skills, in providing an understanding of science concepts, in using logical reasoning, to consider and critique alterna-

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013):

4-PS3 Energy

www.nextgenscience.org/4ps3-energy

The materials/lessons/activities outlined in this article are just one step toward reaching the Performance Expectations listed below. Additional supporting materials/lessons/activities will be required.

Performance Expectation	Connections to Classroom Activity *Students*:
4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.	• predict and observe how light and sound react in the three states of matter, and record data to support conceptual understanding concerning movement of light and sound energy through three states of matter.
Science and Engineering Practices	
Analyzing and Interpreting Data Constructing Explanations Communicating Information	• construct an explanation using the CER framework. • communicate their explanation through both verbal and written form. • analyze the class set of data to form a claim and provide a sufficient amount of evidence to support the claim.
Disciplinary Core Idea	
PS3.A: Definitions of Energy: Energy can be moved from place to place by moving objects or through sound, light, or electric currents	• observe how light and sound reacts in the three states of matter to determine how light energy and sound energy move from place to place.
Crosscutting Concept	
Patterns	• analyze the class set of data looking for patterns in the evidence to create a claim and formulating the appropriate evidence to support the claim.

tive explanations, and most importantly in using evidence to support claims (Zembal-Saul, McNeill, and Hershberger 2013). The lesson we have shared in this article demonstrates how to successfully integrate writing for the purpose of formulating scientific explanations for the purpose of developing students' understanding of core disciplinary ideas about energy and the scientific practices of doing science. ■

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Zembal-Saul, C., K.L. McNeill, and K. Hershberger. 2013. *What's Your Evidence: Engaging K–5 Students in Constructing Explanations in Science.* Pearson Education.

NSTA Connection

The student handout, a rubric to assess the handout, and a teacher preparation handout are available for download at *www.nsta.org/SC1511*.