Explanations across the curricula: Integrating *Common Core State Standards* in literacy with the *Next Generation Science Standards*

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In every discipline, including science, literacy is an essential 21st-century competency. If students are to become productive world citizens, they need to be proficient oral and written communicators. The *Common Core State Standards* state that students should be able to "write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence" (NGAC and CCSSO 2010, p. 18). Such standards make clear that the abilities to develop and support claims are key disciplinary literary competencies in English language arts (ELA) and history as students engage with literature and historical source material. These same literacy competencies are essential for science students to help them explain various phenomena in the natural world. Constructing evidence-based explanations is emphasized as an important scientific practice in every major science education document including, most recently, the *Next Generation Science Standards* (*NGSS*), which focus on three-dimensional learning as a new methodology of instruction (NGSS Lead States, 2013). Three-dimensional instruction integrates scientific practices, such as Developing Explanations, with disciplinary core ideas and crosscutting concepts. *Scientific explanations* are responses to questions about how or why phenomena occur; these statements are supported by evidence.

The use of a similar and explicit explanation framework in science classrooms and in other content areas can foster the development of literacy skills related to communication, move students toward a deeper understanding of big ideas, and provide support for creating a cohesive student experience when learning about analytical writing. The explanation framework consists of three components: *claim*, *evidence*, and *reasoning* (CER) (McNeill and Krajcik 2011). A *claim* is a statement that answers the question or problem students are investigating. It might also state the viewpoint the student will defend or explicate. *Evidence* can take a variety of forms and may vary depending on the content area and assignment. For example, it may include data from an experiment, take the form of literary quotations or primary or secondary sources, or be an expert testimony. *Reasoning* requires that students go more deeply into the material by applying content ideas to explain how their evidence supports their claim. In some cases, a *rebuttal* can be added to the framework, allowing students to address and refute a counterargument. The length of this framework can range from a few sentences to a full-length essay, depending on content area and assignment sophistication.

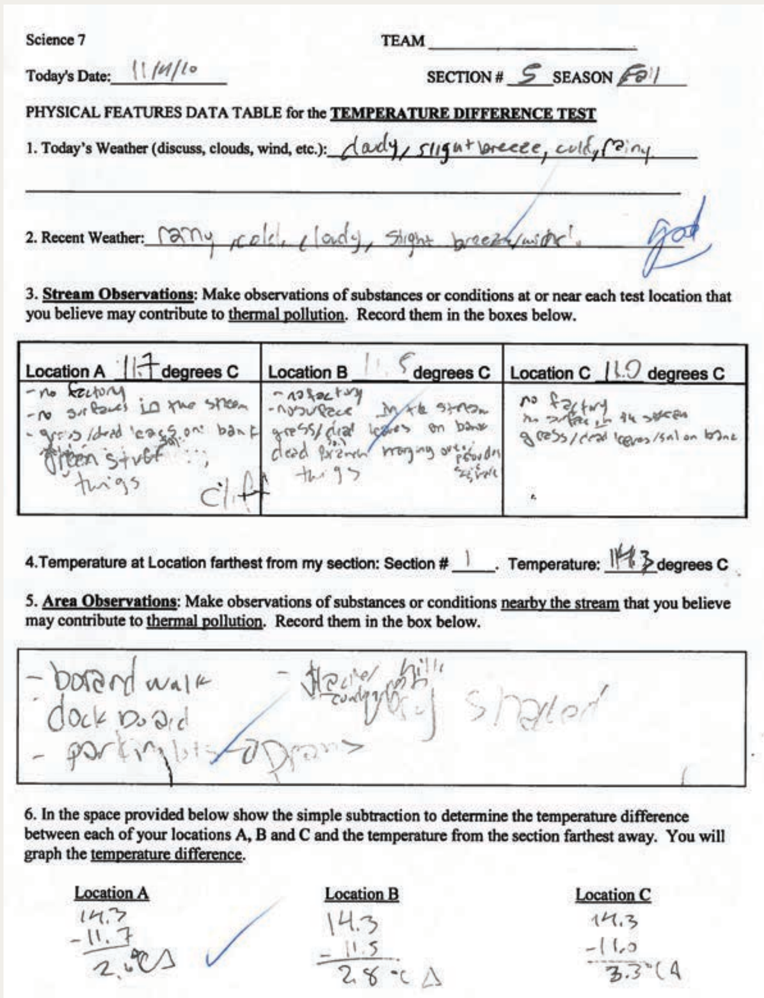
We use this explanation framework in our seventh-grade science, ELA, and social studies classes, along with public speaking units that are dispersed throughout these curricula. Using this common framework, students create explanations of science phenomena, literary ideas, historical events and perspectives, and personal convictions throughout their seventh-grade year. Moreover, they develop their abilities to communicate these explanations both orally and in writing. The process of constructing explanations also helps students make connections between ideas, resulting in deeper learning of disciplinary core ideas.

In this article, we present examples of how the explanation framework is used to promote literacy across several content areas: science, integrated public speaking, ELA, and social studies.

The use of the CER structure within and across the various disciplines helps students develop an understanding of explanation and argumentation. Seeing the similarities that exist across content areas can also make these competencies less intimidating, less tacit, and more accessible for students to use in their own argumentation and writing. In all content areas, the claim begins the argument or explanation and is a clear statement. Various types of evidence are then used to support the claim, and reasoning is expected to answer how or why the evidence supports the claim. However, across content areas, the format and structure of a claim and evidence will differ. For example, in science, the claim is a clear statement that answers a question or addresses a problem students are investigating. In history, a claim could put two time periods into conversation with one another, sharing a common thread of human experience, whereas in ELA, a claim may offer insight into a moment of strangeness in a piece of literature. Although the evidence presented during a public speaking, ELA, or social studies task generally takes the form of primary and secondary source material, in science, evidence often takes the form of experimental data. In addition, the type of reasoning can vary based on discipline. For example, in ELA, emphasis may be placed on close analysis of language and text structure, but in science, emphasis is placed on the integration of particular scientific ideas and crosscutting concepts.

Especially in middle school, this common support allows teachers to more deeply collaborate and

FIGURE 1 Raw student data


Science 7 TEAM ______

Today's Date: 11/14/10 SECTION # 5 SEASON Fall

PHYSICAL FEATURES DATA TABLE for the TEMPERATURE DIFFERENCE TEST

1. Today's Weather (discuss, clouds, wind, etc.): cloudy, slight breeeze, cold, rainy

2. Recent Weather: rainy, cold, cloudy, slight breeze/wind.

3. Stream Observations: Make observations of substances or conditions at or near each test location that you believe may contribute to thermal pollution. Record them in the boxes below.

Location A 11.7 degrees C	Location B 11.5 degrees C	Location C 11.0 degrees C

4. Temperature at Location farthest from my section: Section # 1. Temperature: 14.3 degrees C

5. Area Observations: Make observations of substances or conditions nearby the stream that you believe may contribute to thermal pollution. Record them in the box below.

- boardwalk
- dock board
- parking lots

6. In the space provided below show the simple subtraction to determine the temperature difference between each of your locations A, B and C and the temperature from the section farthest away. You will graph the temperature difference.

Location A	Location B	Location C
14.3 − 11.7 = 2.6	14.3 − 11.5 = 2.8 °C	14.3 − 11.0 = 3.3 °C

discuss the ways that writing and reasoning happen across domains, and then support the experiences and development of a "toolkit" for students as they navigate across classrooms, tasks, and texts. In the next section, we elaborate more on the way CER was used in science and an accompanying public speaking unit, and then highlight two brief examples within ELA and history classes.

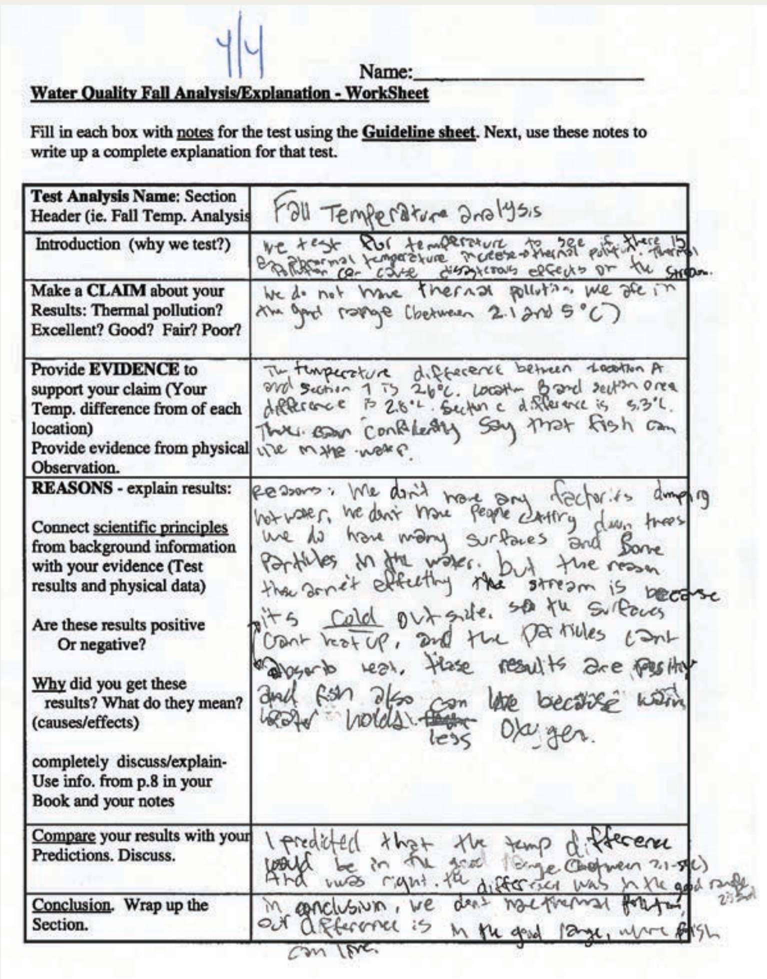
Explanations in science

Constructing evidence-based explanations is an important scientific practice, but students need support in writing explanations (McNeill and Krajcik 2011), particularly with respect to providing reasoning to support claims. Prior to using the CER framework in my classes, students simply reported science data without thinking about why they obtained the data they did, what that data meant, and if the data counted as evidence to support the claim.

In my seventh-grade, project-based water quality unit, I ask students to construct explanations about the health of a stream for freshwater organisms, based on data collected from various water quality tests and their understanding of the science ideas. Figure 1 presents the raw data a student obtained while investigating temperature differences at the stream. Large temperature differences between various locations can signal thermal pollution, resulting in disastrous consequences for fish and other organisms in the stream. Students collected both qualitative and quantitative information, then analyzed the data and communicated their findings by writing scientific explanations. Figure 2 shows the guide sheet students are provided, which they complete with partners. It serves as a scaffold after students have been introduced to the explanation framework and contains prompts to aid students in various aspects of constructing their explanation, such as what to think about and discuss with each other. Spaces are included for notes on an overall claim about the results of the water-quality test, data reporting, and prompts that use science concepts to justify why the data serve as evidence to support their claim. This last part, incorporating the science ideas to explain data, is reasoning. It is the most challenging component of scientific explanations; thus, it requires support, practice, and feedback. The guide sheet not only provides students support for thinking about the ideas, but it also presents the format for writing the explanation.

Students use their original data sheet and a graph of their evidence

FIGURE 2 Student guide sheet



4/4

Name:

Water Quality Fall Analysis/Explanation - WorkSheet

Fill in each box with notes for the test using the **Guideline sheet**. Next, use these notes to write up a complete explanation for that test.

Test Analysis Name: Section Header (ie. Fall Temp. Analysis	Fall Temperature analysis
Introduction (why we test?)	we test for temperature to see if there is [illegible] thermal temperature increase→thermal pollution. thermal pollution can cause disastrous effects on the stream.
Make a **CLAIM** about your Results: Thermal pollution? Excellent? Good? Fair? Poor?	We do not have thermal pollution. we are in the good range (between 2.1 and 5 °C)
Provide **EVIDENCE** to support your claim (Your Temp. difference from of each location) Provide evidence from physical Observation.	The temperature difference between location A and Section 1 is 2.6°C. Location B and section one difference is 2.8°C. Section C difference is 5.3°C. [illegible] confidently say that fish can live in the water.
REASONS - explain results: Connect scientific principles from background information with your evidence (Test results and physical data) Are these results positive Or negative? Why did you get these results? What do they mean? (causes/effects) completely discuss/explain- Use info. from p.8 in your Book and your notes	Reasons: We don't have any factories dumping hot water, we don't have people cutting down trees we do have many surfaces and some particles in the water. but the reason they aren't effecting the stream is because its cold outside. so the surfaces can't heat up, and the particles can't absorb heat. These results are positive and fish also can live because warm water holds less oxygen.
Compare your results with your Predictions. Discuss.	I predicted that the temp difference would be in the good range (between 2.1-5°C) And I was right. the difference was in the good range [illegible]
Conclusion. Wrap up the Section.	In conclusion, we don't have thermal pollution, our difference is in the good range, where fish can live.

to complete notes for an explanation. They then use their notes from the guide sheet to create a formal scientific explanation that answers various questions. Figure 3 is this student's formal explanation, answering the question "Does the stream have thermal pollution?" The guide sheet that students use for notes also serves as the rubric for assessing the final explanation. McNeill and Krajcik (2011) present a base rubric for assessing explanations (available with this article's online supplements at *www.nsta.org/middleschool/connections.aspx*). As students gain more experience in writing explanations, a different, less detailed (less scaffolded) explanation guide sheet (Figure 4) is used until eventually students more automatically use the CER framework any time they are creating an evidence-based explanation or justification.

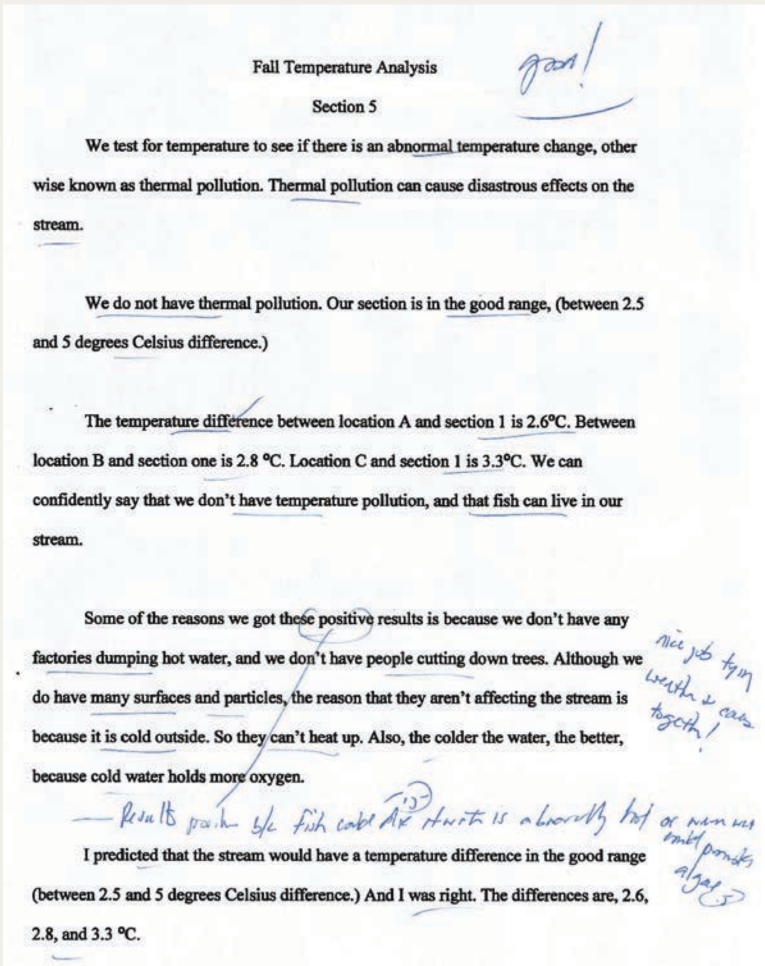
Figures 5 and 6 show examples of student explanations from a seventh-grade chemistry unit, which asked students, "How can I make new stuff from old stuff?" (Krajcik et al. 2012). The student explanation shown in Figure 5 is based on data obtained from a teacher demonstration of burning magnesium and answers the question, "Did a chemical reaction occur when your teachers burned magnesium?" Figure 6 shows a student explanation constructed following an experiment in which students created an acid rain environment using vinegar to see whether vinegar and copper react to make new substances. Both students constructed their explanations using the CER framework to help them explain the various phenomena. Each example explanation illustrates a response to a question about how or why the phenomenon occurred and is supported by evidence; each student has a clear claim followed by the use of evidence that supports that claim. Science ideas related to new substances being formed, reflected in differences in properties before and after the chemical reaction, are integrated into the explanation.

Explanations in public speaking

After creating their formal scientific explanations for their water quality findings, all five classes of our students work with the interdisciplinary public speaking teacher, in collaboration with the science teacher, to develop formal presentations including individual and group components, to present to their classmates. Twenty to 25 students then travel to a neighborhood retirement home, which is in close proximity to the stream, to present the Stream Study findings.

Through CER, student groups orally and visually present the water quality data gathered in science

FIGURE 3 Student's formal explanation


Fall Temperature Analysis

good!

Section 5

We test for temperature to see if there is an abnormal temperature change, other wise known as thermal pollution. Thermal pollution can cause disastrous effects on the stream.

We do not have thermal pollution. Our section is in the good range, (between 2.5 and 5 degrees Celsius difference.)

The temperature difference between location A and section 1 is 2.6°C. Between location B and section one is 2.8 °C. Location C and section 1 is 3.3°C. We can confidently say that we don't have temperature pollution, and that fish can live in our stream.

Some of the reasons we got these positive results is because we don't have any factories dumping hot water, and we don't have people cutting down trees. Although we do have many surfaces and particles, the reason that they aren't affecting the stream is because it is cold outside. So they can't heat up. Also, the colder the water, the better, because cold water holds more oxygen.

I predicted that the stream would have a temperature difference in the good range (between 2.5 and 5 degrees Celsius difference.) And I was right. The differences are, 2.6, 2.8, and 3.3 °C.

class after conducting numerous tests (e.g., pH, thermal pollution, turbidity) on the stream. The goal is to inform the audience about the test and its results and to persuade the audience to act in such a way that through their everyday activities on land, the quality of the water in the stream is maintained or improved rather than negatively impacted. Groups of three or four students collaborate to develop one presentation. They see models of effective presentations (view examples with this article's online supplements), then take selected information from their water quality study and apply it to their assigned section of the presentation.

Students are assisted in tackling the challenge, which asks, "How do I adapt scientific research into an effective oral presentation?" Students learn the organization format for a persuasive speech, including elements of persuasion, as they investigate how authors make decisions about language or story. They are introduced to the speaking skills that are essential to communicate effectively, asking, "How does language create or obfuscate meaning?" In addition to organizing the speech and developing a short PowerPoint presentation, students are coached on vocal and physical delivery skills. The overall presentation reflects best practices of oral, written, and visual communication, especially as they relate to communicating scientific data and arguments.

FIGURE 4 Less scaffolded guide sheet

Water Quality Explanation Outline

Introduction { What is it? Why is it important?

Claim {Statement: Answers the question about the test with the standard.

Evidence { Your data from each location. Other qualitative data from physical data Sheet. Does it support you claim?

Reasoning { What do the results mean? Use science ideas
Are they positive or negative? Why?
What are the consequences?

Why do you think you got these results?

What is the cause or source of the pollutant?
Use the science to discuss your results – this will tie the science, your results and your physical data together.

Rebuttal { Is there an alternative explanation that you ruled out?

Prediction? {How did your predictions compare with your results?

Conclusion {Statement: Specific to the water quality test with standard.

Explanations in ELA and history

In the previous example, the CER framework was used within science, but a key part of our students' experience is the use of the CER framework in two other content area classes—ELA and history. This experience serves to reinforce the ways of communicating within domains. In this section, we offer two brief examples of the language and approach used with CER in seventh-grade ELA and history.

The CER framework is used in a variety of ways in ELA, such as during *passage explanation*, in which students develop and support claims about the significance of a quotation. In the development of claims, students are pushed to move beyond a literal understanding of a text. At the middle school level, such understanding can be reached by considering what a quote shows about a character or larger theme. While reading S.E. Hinton's *The Outsiders* (1967), I ask students to make a claim about the meaning and significance of a quotation from the text. One student constructed the claim that suggests that a quiet character in actuality is brave (see this article's online supplements for the student's writing sample). The student then pointed to the fact that the character stood up to another character, Darry, as evidence of bravery. The student explained the reasoning for this argument by writing that, because Darry is the scariest member of the gang, standing up to him shows bravery.

In history, one example of the use of the CER framework during a unit on civil rights and the Civil War was a writing task in response to the question "Do you agree with the historian Barbara Fields that it 'would take a century for former slaves and people of color to achieve the freedom they longed for'? Do you think the Civil War in some ways is still happening?" To engage with this prompt, students investigated the arguments for the Civil War from different historical figures using primary sources. We analyzed a documentary film and investigated the pieces of evidence used to make an argument in the film about civil rights and discussed the ways remnants of the Civil War can still be seen today. The example of the prompt and the scaffolds provided for this writing task are provided with this article's online supplements.

Similar to the use of the framework in science and public speaking, when first learning the CER framework, students can benefit from the use of prompts to scaffold their explanations. Examples of such prompts and scaffolds for both history and ELA can be found with this article's online supplements. Over time, the prompts and scaffolding can be removed to encourage students to internalize and make use of the framework in more flexible ways.

Synthesis

Be it a scientific explanation, persuasive speech, analytical essay, or passage explanation, variations on the

FIGURE 5 A student explanation for the question "Did a chemical reaction occur when your teachers burned magnesium?"

	Properties of Magnesium		
Solid	Color	Hardness	Solubility in Water
Before Burning	silvery-grey	hard	not soluble
After Burning	white	soft, powdery	not soluble

A chemical reaction occured when magnesium was burned. Before burning the magnesium, it was a silvery-gray color. It was also very hard and wasn't soluble in water. After burning the magnesium, it was white. It was also soft, powderdy, and not soluble in water. When we burned the magnesium, it gave out light. All of these descriptors are properties. The magnesium before and after being burnt had different color and hardness. We know a new substance was created because there are different properties so a chemical reaction occured. Also the magnesium emmited light. If light is produced it is a clue that a chemical reaction took place.

FIGURE 6 A student explanation for the question "Does acid rain make new substances?"

Substance		Properties					
		Color	Hardness	Solubility in Water	Density	Melting Point
Before Experiment	penny	copper brown	Hard	Not soluble	8.96 g/cm³	1084°C
	Vinegar	No color	Liquid	Soluble	1.04g/cm³	17°C
After Experiment	New solid	Green	gritty soft powdery	Soluble	1.88 g/cm³	115°C

A chemical reaction occured between copper and acedic acid. After the experiment, the penny was a different color. The penny started brown, but then was green. Their hardness was different too. The copper was hard, but ended with a soft gritty powder outside of it. The copper was not soluble in water, but the green powder was. The copper penny had a density of 8.96 g/cm³, and the powder had a density of 1.88 g/cm³. They also had different melting points. Before the expeirement, the penny had a melting point of 1084°C, and the green substance coating it had a melting point of 115°C. Because these two substances had different properties, they are differen substances, meaning a chemical reaction occured

CER framework can assist students in making deeper connections between ideas and becoming more effective oral and written communicators. A common explanation framework helps students navigate across disciplines and creates a cohesive, coherent, and meaningful experience for learners as they develop these complex explanation and argumentation skills within and across domains. We have found that over a year of using CER, students develop increasingly sophisticated explanations offering more elaborated claims and effective and aligned evidence (at times offering and explaining multiple pieces of evidence and rebuttals), and they connect the claim and evidence to relevant and developed reasoning. The use of the framework across domains can facilitate the transition to full-length essays or more complex scientific explanations, as students have learned key components of explanation and argumentation within and between body paragraphs.

A common framework helps students navigate across disciplines and still write in meaningful ways, all of which assist students toward developing key literary competencies. ■

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