



## Supporting Students in Science Thinking and Writing

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## Agenda

- Introductions
  - Activity - Chemistry Investigation
- Break*
- Presentation - Rationale & Framework
  - Watch and Discuss video of 7th grade classroom
- Lunch*
- Activity - Analyze student writing
  - Presentation - Student challenges
  - Presentation - Designing learning tasks
  - Activity - Design learning tasks
  - Logistics and Wrap-up



## Introductions

- Kate and Mandy
- Introduce yourself to the group
  - Name
  - School or Institution
  - Position (e.g. grade level and topics)



## Activity - Chemistry Investigation

With your group:

- Conduct investigation 7.1: What happens to properties when I combine substances?
  - Record observations before combining
  - Combine the substances
  - Record observations after combining



## What do students know at this point?

- Matter is composed of atoms & molecules in constant motion.
- Substances can exist in solid, liquid, and gaseous states.
- Substances have characteristic properties that help identify substances and distinguish them from one another.
- Solubility, density, and melting point are properties of substances.
- Both baking soda and road salt are soluble in water (determined in a previous investigation).



## Activity - Chemistry Investigation

- Conduct investigation 7.1: What happens to properties when I combine substances?
  - Record observations before combining
  - Combine the substances
  - Record observations after combining
- On a large piece of post-it paper with your group, write an ideal student response to the conclusion question.
  - Write a **scientific explanation** that states whether or not you think new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.



## Activity - Chemistry Investigation

- Post ideal student responses on the wall.
- Discussion Questions:
  - What are the similarities and differences across what the different groups wrote?
  - What are some characteristics of strong scientific explanations?
  - What challenges do you think students have with this type of writing?

## Break!



## Scientific Explanations and Arguments

	Data				
	Color	Hardness	Solubility	Melting Point	Density
Fat	Off white or slightly yellow	Soft squishy	Water - no Oil - yes	-37° C	0.92 g/cm <sup>3</sup>
Soap	Milky white	Hard	Water - yes Oil - no	Higher than 100° C	0.84 g/cm

Write a scientific explanation stating whether fat and soap are the same substance or different substances.

## Brandon's First Explanation

↓ Fat and soap are both stuff but they are different substances. Fat is used for cooking and soap is used for washing. They are both things we use everyday. The data table is my evidence that they are different substances. Stuff can be different substances if you have the right data to show it.

## Brandon's Revised Explanation

Fat and soap are different substances. Fat is off white and soap is milky white. Fat is soft squishy and soap is hard. Fat is soluble in oil, but soap is not soluble in oil. Soap is soluble in water, but fat is not. Fat has a melting point of 37°C and soap has a melting point above 100°C. Fat has a density of 0.92 g/cm<sup>3</sup> and soap has a density of 0.84 g/cm<sup>3</sup>. These are all properties. Because fat and soap have different properties, I know they are different.

## What are Explanation and Argumentation?

- **Explanation**
  - make sense of how or why a phenomenon occurred
  - Examples:
    - Explain why the biodiversity decreased
    - Explain what has happened to the pitch of bird song in cities
- **Argumentation:**
  - Defend or support knowledge claims through evidence, warrants and backing
  - Examples:
    - Argue for your explanation for why the biodiversity decreased
    - Argue for your experimental design to study what is happening to the biodiversity

## Importance of Scientific Explanation and Argumentation

- Science is a social process in which scientists debate knowledge claims and continuously refine and revise knowledge based on evidence
- Students should generate and evaluate scientific evidence and explanations
- Aligns with reform documents focused on 21st century skills and k-8 science classrooms.
- Stressed in science education standards.



## National Science Standards

- Use data to construct a reasonable explanation (NRC, A1/D)
- Communicate investigations and explanations (NRC, A1/E)
- Seek reasons for believing something rather than just claiming "Everybody knows that..." or "I just know" and discount such claims when made by others. (AAAS, 12E/E3\*)
- *Inquiry and the National Science Education Standards* (NRC, 2000)
  1. Engaging in scientifically-oriented questions
  2. Giving priority to evidence
  3. Formulating explanations from evidence
  4. Connecting explanations to scientific knowledge
  5. Communicating and justifying explanations.



## Benefits of Scientific Explanation

Support students to:

1. Understand science concepts
2. Use evidence to support claims
3. Reason logically
4. Consider and critique alternative explanations
5. Understand the nature of science
6. Engage in academic writing

For teachers:

1. Makes student thinking visible
2. Can serve as an important formative and summative assessment tool

## Students' Understandings of Explanation and Argument

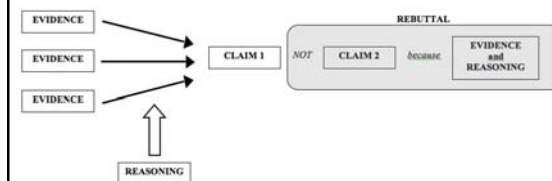
- Students' understandings of explanation and argument does not necessarily match expectations.
- What do you think it means for a scientist to create a scientific explanation?
  - Exchange between people (57%) - "if they tell somebody, like all the people, like in public that they learned something like new."
  - Observation (48%) - "they try to explain what they're doing, sort of like a observing, describing what they see and what they're doing."
- What do you think it means for a scientist to create a scientific argument?
  - Exchange between people (83%) - "Well like if he and another scientist are talking about something and then he thinks that the"

## CER Framework

Adapted from Toulmin (1958)

- **Claim**
  - a conclusion about a problem
- **Evidence**
  - scientific data that is *appropriate* and *sufficient* to support the claim
- **Reasoning**
  - a justification that shows why the data counts as evidence to support the claim and includes appropriate scientific principles
- **Rebuttal**
  - describes alternative explanations and provides counter evidence and reasoning for why the alternative is not *appropriate*.

## CER Framework Adapted from Toulmin (1958)



## Brandon's Revised Explanation

Fat and soap are different substances. Fat is of white and soap is milky white. Fat is soft squishy and soap is hard. Fat is soluble in oil, but soap is not soluble in oil. Soap is soluble in water, but fat is not. Fat has a melting point of  $47^{\circ}\text{C}$  and soap has a melting point above  $100^{\circ}\text{C}$ . Fat has a density of  $0.92\text{ g/cm}^3$  and soap has a density of  $0.84\text{ g/cm}^3$ . These are all properties. Because fat and soap have different properties, I know they are different.

## Brandon's Revised Explanation

Are fat and soap are the same substance or different substances?

Fat and soap are different substances. (Claim) Fat is of(f) white and soap is milky white. (#1) Fat is soft squishy and soap is hard. (#2) Fat is soluble in oil, but soap is not soluble. Soap is soluble in water, but fat is not. (#3) Fat has a melting point of  $47^{\circ}\text{C}$  and soap has a melting point above  $100^{\circ}\text{C}$ . (#4) Fat has a density of  $0.92\text{ g/cm}^3$  and soap has a density of  $0.84\text{ g/cm}^3$ . (#5) (Evidence) These are all properties. Because fat and soap have different properties, I know they are different. (Reasoning)

## Physics Example

What type of pulley system requires the least force to move the block?

A pulley system with two moveable pulleys and one fixed pulley required the least amount of force to move the block.

(Claim) This system took an average of 0.82 Newtons to move the block. We tried three other systems, but the closest one was still 0.23 Newtons more, because it required 1.05 Newtons. (Evidence) The fixed pulleys just change the direction of the force, while moveable pulleys reduce the amount of force. Using one fixed, let us have two moveable pulleys, which decreased the force more than just having one moveable pulley. (Reasoning)

## Biology Example

What will happen to the shark population if the phytoplankton populations die out?

The shark population will die out. (Claim) The shark eats other fish such as the ocean fish and the lantern fish. The ocean fish and the lantern fish eat other organisms such as shrimp and copepods. The shrimp and copepods eat the phytoplankton. (Evidence) All of the other organisms in the food web depend on the phytoplankton, even if they do not directly eat them. Organisms are affected by other organisms in a food web even if they are not directly linked to them. (Reasoning)

## Biology Example

What will happen to the shark population if the phytoplankton populations die out?

The shark population will die out. (Claim) The shark eats other fish such as the ocean fish and the lantern fish. The ocean fish and the lantern fish eat other organisms such as shrimp and copepods. The shrimp and copepods eat the phytoplankton. (Evidence) All of the other organisms in the food web depend on the phytoplankton, even if they do not directly eat them. Organisms are affected by other organisms in a food web even if they are not directly linked to them. (Reasoning) You might think the shark population would not change, because they do not eat the phytoplankton. But they will actually die out because they eat organisms that eat organisms that eat the phytoplankton. (Rebuttal)

## Environmental Science Example

Mr. Garcia: Do you think the climate is changing? Make sure you support your idea with evidence and reasoning.

Olivia: I think the climate is changing (Claim) because this fall has been really warm (Evidence).

Mariela: Does being warm just one fall count as evidence for climate change?

Nate: No, climate is long term changes. It is just weather if it is one day or a month or a season (Reasoning). So I agree with Olivia that the climate is changing (Claim). But I think it is changing because the air temperature has slowly gotten warmer over a long time. The average temperature has increased like 2 degrees in the last 100 years (Evidence).



# Introducing Claim



# Connect to Everyday Examples



# Connect to Everyday Examples

## Lunch!



## Activity - Analyze Student Writing



With your group, analyze the 7th graders writing:

1. Analyze each student's writing in terms of claim, evidence and reasoning.
2. Rank the students examples from 1 (being the strongest) to 4 (being the weakest).
  - Why did you rank #1 the strongest?
  - What challenges did students have?
3. If you gave this learning task to your students, what challenges do you think they would have? Why?

## Activity - Analyze Student Writing: Student A



**Conclusion:**  
Write a scientific explanation that states whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.

**Claim:**  
(Write a statement that responds to the original problem about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.)  
Substances were formed since color of liquid slowly powdered sugar and road salt

**Three pieces of evidence:**  
(Provide scientific data to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.)  
The ingredients showed some gas or chemical reactions and the properties changed. There was also an hissing of the bag.

**Reasoning:**  
(Write a statement that tells why your data count as evidence to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution. Your statement should include appropriate scientific principles that defend your claim and evidence.)  
forming a new substance was formed

## Activity - Analyze Student Writing: Student B

**Conclusion:**  
Write a scientific explanation that states whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.

**Claim:**  
Write a statement that responds to the original problem about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.  
New substances were formed after we mixed everything up.

**Three pieces of evidence:**  
(Provide scientific data to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.)  
Evidence is the experiment we did. The conclusion and the observation is also also evidence.

**Reasoning:**  
Write a statement that tells why your data count as evidence to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution. Your statement should include appropriate scientific principles that defend your claim and evidence.

My data counts as evidence because if you look at the evidence and the experiment it all adds up.

## Activity - Analyze Student Writing: Student C

**Conclusion:**  
Write a scientific explanation that states whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.

**Claim:**  
Write a statement that responds to the original problem about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution. A new substance was formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.

**Three pieces of evidence:**  
(Provide scientific data to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.)  
I saw the color of phenol red in solution change from yellow to orange. The products were at room temperature. The new substance was formed. The bag that contained all of the substance inflated (which indicates a gas was formed).

**Reasoning:**  
Write a statement that tells why your data count as evidence to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution. Your statement should include appropriate scientific principles that defend your claim and evidence. Color is a property and it changes when the two substances are formed. It appears to be the same volume. The substance changed the temp. increased and a gas was formed. A gas is a new substance, and we know it formed when the substance inflated.

## Activity - Analyze Student Writing: Student D

**Conclusion:**  
Write a scientific explanation that states whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.

**Claim:**  
Write a statement that responds to the original problem about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.  
There was a new substance formed after all the 4 substances.

**Three pieces of evidence:**  
(Provide scientific data to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution.)  
One piece of evidence was that the color was different than it was before. Another piece of evidence was that it was powdery then it turned bubbly. One last piece of evidence was that it was about room temp. then it was very hot.

**Reasoning:**  
Write a statement that tells why your data count as evidence to support your claim about whether new substances were formed after combining the baking soda, powdered sugar, road salt, and phenol red solution. Your statement should include appropriate scientific principles that defend your claim and evidence.

There was a new substance because if it was not a new substance the color, temperature, and texture would not have changed.

## Student Challenges

1. Using appropriate and sufficient evidence
2. Providing reasoning
3. Considering alternative explanations or rebuttals

## Student Challenges: Using appropriate and sufficient evidence

Students can:

- Just repeat that the experiment or the data table is their evidence
- Rely on their own opinions or personal experiences instead of appropriate data
- Have difficulty using enough or sufficient data
  - May focus on one piece of data
- Struggle with using different types of data
  - May focus on quantitative and not consider qualitative data

## Student Challenges: Providing reasoning

Students can:

- Omit describing why they chose or did not use certain data
- Have difficulty describing the link between the claim and evidence
- Struggle with including a general scientific principle

## Student Challenges: Considering alternative explanations or rebuttals

Students can

- Focus on one explanation
- Have difficulty seeing that there are potentially multiple different ways to explain a phenomenon
- Struggle with evaluating and articulating why an alternative explanation is not appropriate

## Designing Learning Tasks

### Step 1: Identify Opportunities in the Curriculum

- 1a. Learning Goal
- 1b. Scientific Data
- 1c. Scientific Principle

### Step 2: Design Complexity of the Learning Task

- 2a. Openness of Question
- 2b. Type of Data
- 2c. Amount of Data
- 2d. Inclusion of Rebuttal

### Step 3: Create Classroom Supports

- 3a. Visual Representations
- 3b. Curricular Scaffolds

## Step 1: Identify Opportunities in the Curriculum 1A - Specify the Learning Goal

- Develop Learning Performance
  - Combines both the science content and the CER framework

Content Standard	Scientific Inquiry Standard	Learning Performance Standard
The position and motion of objects can be changed by pushing or pulling. The size of the change is related to the strength of the push or pull. (NRC, 1996, B: 2/3, K-4)	Use data to construct a reasonable explanation (NRC, A1/D).  Communicate investigations and explanations (NRC, A1/E)	Students construct a scientific explanation that includes a claim about how the size of a push impacts the position of an object, evidence in the form of different push and the related distance that an object traveled, and reasoning that the larger the push the greater the distance an object will travel.

## Step 1: Identify Opportunities in the Curriculum 1B - Scientific Data

- Engaging in scientific explanation requires identifying places in the curriculum or designing activities when students use and make sense of data.
- Students do not need to collect the data themselves, but there does need to be data they can use as evidence to support their claim.

## Step 1: Identify Opportunities in the Curriculum 1C - Scientific Principle

- The tasks needs to align with the scientific principles you want students to learn.
- Students need to be able to apply one or more scientific principles that show why the data counts as evidence to support the claim.

## Step 2: Design Complexity of the Learning Task

- 2a. Openness of Question
- 2b. Type of Data (What specific data?)
  - Student collect or provided to students
  - Quantitative versus Qualitative
- 2c. Amount of Data (How much data?)
- 2d. Variation of the Framework



### Step 2: Design Complexity of the Learning Task

Characteristic	Simple Task	Complex Task
Openness of Question	Does providing a plant with light 12 hours a day or 24 hours a day impact the growth of a plant?	What factors impact the growth of a plant?
Type of Data	Height in cm of plants	Height in cm of plants Number of leaves, buds and flowers Description of leaves, buds and flowers to indicate health
Amount of Data	3 plants in 2 conditions (6 total plants) Measured once a week for 4 weeks (24 total height measurements)	3 plants each in 8 different conditions to investigate three different variables (24 total plants) Measured once a week for 8 weeks (192 measurements or observations for each type of data)

### Variations of the Instructional Framework

Level of Complexity	Framework Sequence
Simple ↓ Complex	Variation #1 1. Claim 2. Evidence 3. Reasoning
	Variation #2 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning
	Variation #3 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning • Multiple components
	Variation #4 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning • Multiple components 4. Rebuttal

### Step 3: Create Classroom Supports

Scaffold Type	Example
Visual Representation	Poster on the wall of the classroom titled Scientific Explanation with claim, evidence and reasoning listed underneath and the definition of each component.
Curricular Scaffolds	Sentence starters, prompts or questions included on an investigation sheet to remind and provide students with support around including claim, evidence and reasoning in their written response.



### Visual Representation

### Curricular Scaffolds

Content-Specific Scaffold	Generic Explanation Scaffold
(State whether a chemical reaction occurred in the plastic bag experiment, that is whether it created new substances. Provide a change in properties, such as melting point, solubility, and density, to support whether or not the experiment was a chemical reaction. Tell why properties staying the same or changing tells you whether a chemical reaction occurred.)	<b>Claim</b> (Write a statement that responds to the original problem.) <b>Evidence</b> (Provide scientific data to support your claim. You should only use appropriate data and include enough data.) <b>Reasoning</b> (In your reasoning statement, connect your claim and evidence to show how your data links to your claim using scientific principles.)

### Curricular Scaffolds: Combine Content and Generic

**Claim:** Write a sentence stating whether your ecocolumn is or is not stable.

**Evidence:** Provide scientific data to support your claim. Use evidence from your table above about the helath and changes for the different characristics of your ecocolumn.

**Reasoning:** Explain why your evidence supports your claim. Describe what it means for an ecosystem to be stable and why your evidence allowed you to determine if your ecocolumn was stable.



## Fading Support of the General Scaffold

Amount of Support	Generic Explanation Scaffold
Detailed Support	<p><b>Claim</b> (Write a statement that responds to the original problem.)</p> <p><b>Evidence</b> (Provide scientific data to support your claim. You should only use appropriate data and include enough data.)</p> <p><b>Reasoning</b> (In your reasoning statement, connect your claim and evidence to show how your data links to your claim using scientific principles.)</p>
Intermediate Support	<p><b>Claim</b> (Respond to the problem.)</p> <p><b>Evidence</b> (Provide scientific data to support your claim.)</p> <p><b>Reasoning</b> (Connect your claim and evidence.)</p>
Minimal Support	Remember to include claim, evidence, and reasoning.

## Activity - Design learning tasks

- Work in Grade Level Groups with your Curriculum

### Step 1: Identify Opportunities in the Curriculum (20 min)

- 1a. Learning Goal
- 1b. Scientific Data
- 1c. Scientific Principle

### Step 2: Design Complexity of the Learning Task (20 min)

- 2a. Openness of Question
- 2b. Type of Data
- 2c. Amount of Data
- 2d. Inclusion of Rebuttal

### Step 3: Create Classroom Supports (20 min)

- 3a. Visual Representations
- 3b. Curricular Scaffolds

## Share Learning Task

- On a Large Post-it, record the following:
  - Question you will ask students
  - Example student CER - illustrate the "ideal" response for the different components

## Discussion

- How will you introduce the framework and what supports will you provide students for their writing?
- What challenges arose in designing learning tasks?
- What questions do you have about using CER with your students?

## Logistics and Wrap-up

- Before March 2 Workshop
  - Read Chapters 1-2
  - Try CER Learning Task with your students. Collect samples of student writing
- March 2 Workshop
  - Same room - Higgins, Rm. 270. at BC
  - Bring 6 samples of student writing (2 stronger, 2 middle, 2 weaker)
  - Bring your science curriculum

## Contact information

- Workshop Webpage
  - <http://bpssciencecer.weebly.com>
- Kate McNeill's contact information
  - [Kmcneill@bc.edu](mailto:Kmcneill@bc.edu)
- Mandy Knight's contact information
  - [amanda.knight.1@bc.edu](mailto:amanda.knight.1@bc.edu)