Implementing the Claim, Evidence, Reasoning Framework

An Intentional Approach Toward Teaching Students How to Construct High-Quality Scientific Explanations and Arguments

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Your Input is Valued

Throughout this presentation, I will be asking you to provide your own thoughts and answers.

• To do this, we will be using an interactive response system known as **Poll Everywhere**.
• To respond to a question/poll/survey, please go to the following website on *any* device that can access the internet.

Pollev.com/benmeacham026

Provide your name (or whatever you want)

Once joined, your screen will automatically update once a poll becomes available so you can respond.
MOM!! SHE CALLED ME A STINKY BOOGER-FACE!!
WELL, WAS THE CLAIM EVIDENCE-BASED?

JELLY BEANS CAUSE ACNE!
SCIENTISTS! INVESTIGATE!
BUT WE'RE PLAYING MINECRAFT!
...FINE.

WE FOUND NO LINK BETWEEN JELLY BEANS AND ACNE (P > 0.05).

THAT SETTLES THAT.
I HEAR IT'S ONLY A CERTAIN COLOR THAT CAUSES IT.

Scientist Parents
LIFE

Decisions I Make

How Others Influence Me

Claim
Evidence
Reasoning
Science literacy as an *intellectual vaccine*
Q: What can you conclude about the identity of object A, B, and C?

“Objects A and B are tin and object C is lead. The density of object A is 7.44 g/cm$^3$ and the density of object B is 7.34 g/cm$^3$. Based on the evidence, this proves that we are right.”

There has to be a better way to go about this...
Science is about *making sense* of phenomena

8 Practices of Science and Engineering that Guided the Development of the NGSS

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

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1 Appendix F—Science and Engineering Practices in the NGSS. [https://goo.gl/VNmHdq](https://goo.gl/VNmHdq)

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If *making sense* of phenomena is the driver, then the act of constructing scientific explanations is what helps our students make sense of the things we want them to understand.
The Underlying Problem

1) Our students are **not** scientists

2) Many students lack the reasoning skills needed for quality science explanations

In 35 secondary schools in 3 states (MN, WI, MT) resulting in 6,629 data points:

- More than 50% of students in grades 7-9 are only concrete thinkers
- More than 85% of students graduating high school are not considered formal thinkers

College—General Chemistry
- 50.4% concrete operational
- 25.2% formal operational
- 24.4% transitional

College—General Chemistry
- 22% concrete operational
- 29% formal operational
- 49% transitional
To support our students, we need to develop a more *intentional* and *effective* approach

<table>
<thead>
<tr>
<th>For Students...</th>
<th>For Educators...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STRUCTURE</strong>—Helps with developing routine and consistency</td>
<td><strong>MEANING</strong>—I know <em>why</em> I’m doing this</td>
</tr>
<tr>
<td><strong>CLARITY</strong>—Students know what’s expected of them</td>
<td><strong>APPLICABLE</strong>—Variety of settings (test, lab, homework, etc.) and can be used for any topic I teach</td>
</tr>
<tr>
<td><strong>INTERPRETABLE</strong>—Requirements are written in a manner that all students can understand</td>
<td><strong>SAVE TIME</strong>—Structure of framework allows me to grade more efficiently</td>
</tr>
<tr>
<td><strong>NONINTIMIDATING</strong>—With practice, students start to believe in their ability to write</td>
<td><strong>PREDICTABLE</strong>—Based on topic, I know what I’m looking for</td>
</tr>
<tr>
<td><strong>OPTIMISTIC</strong>—I should eventually start to see better explanations/understanding</td>
<td></td>
</tr>
</tbody>
</table>
Implementing a scaffolding framework for organizing legal analysis helps them think and write in ways consistent with the expectations of their profession.

Is an oral contract valid after 15 years?

Can someone sue for battery as a result of inhaling second-hand smoke?
Dr. Kate McNeill and Dr. Joe Krajcik

Using the Claim, Evidence and Reason Lab Out Loud — April 12, 2015
What exactly is claim, evidence, reasoning?

Claim

A conclusion, explanation, conjecture, model, principle, or other answer to a question
- An assertion that something is true
- A statement that describes how and why a phenomenon occurs

- Typically one sentence in length
- It answers the question guiding the investigation
- Does not start with a yes or no
- Should be unambiguous as to what the author is trying to convince you of accepting as truth
Evidence

What are some things you would classify as "evidence"?
Evidence

Data or findings from your investigation (or research) that have been collected, analyzed, and interpreted in a way to support the claim

Data + Analysis + Interpretation

- **Sufficient:** Use enough evidence to support the claim
- **Appropriate:** Not all raw data is necessary. Cite data that supports the claim.
- Qualitative, quantitative, or a combination of both
- Graphs, equations, pictures, particle diagrams, energy bar charts, tables, observations, etc.
- **Analysis:** This simply refers to taking the time to analyze your data so you will eventually be able to interpret what it means
- **Interpretation:** What does your data mean? This is where you provide an interpretation for the reader as to what your data is saying.
Reasoning

Explains the importance of the evidence by making the concepts or assumptions underlying the analysis and interpretation explicit

Ultimately, it functions as a justification for why the reader should accept your claim / explanation

- Cites sufficient and relevant evidence to support the claim
- Describes how the cited evidence defends the claim
- Includes one or more **scientific principles** that are important to the claim and evidence
- **Scientific Principles:** What known scientific principles are at play that support your evidence? These scientific principles connect your evidence to the bigger scientific picture.
A Scientific Argument

The Claim
Statement about the results of an investigation or the answer to the research question being asked

Must be consistent with...

The Evidence
Observations and numbers (data) that have been collected, analyzed, and interpreted in a way that supports the claim

Defended with...

The Justification of the Evidence
A statement that explains the importance of the evidence by making the scientific concepts or assumptions underlying the analysis and interpretation clear to the reader

 ...

The quality of an argument is evaluated using...

Empirical Criteria
- The amount of evidence is sufficient
- The methods used to collect and analyze the data were appropriate

Theoretical Criteria
- The claim contributes to our understanding of the natural world
- The claim is consistent with current theories and laws
- The interpretation of the data analysis is consistent with current theories and laws

Argument-Driven Inquiry in Chemistry. p. 6—Figure 3
CER (Claim, Evidence, Reasoning)
CERR (Claim, Evidence, Reasoning, Rebuttal)
ERC (Evidence, Reasoning, Claim)
CEJ (Claim, Evidence, Justification)
Claim/Explanation → Argument

Argument-Driven Inquiry (ADI)
Which argument do you think is better?

When poll is active, respond at PollEv.com/benmeacham026  📲 Text BENMEACHAM026 to 37607 once to join
Guiding Question: What type of metal is object A, B, and C?

Claim: Object A and B are tin. Object C is lead.

Evidence: The density of object A is 7.44g/cm³ and the density of object B is 7.34g/cm³. The density of C is 11.12g/cm³.

Justification: Therefore, object A and B have almost the same density as the known density of tin and object C has almost the same as the known density of lead.

Insufficient evidence

More of a conclusive statement rather than a justification of how this evidence supports the claim
Guiding Question: What type of metal is object A, B, and C?

Claim: Object A and B are tin. Object C is lead.

Evidence: The density of object A is 7.44 g/cm³ and the density of object B is 7.34 g/cm³. These objects have almost the same density as the known density of tin, which is 7.36 g/cm³. The density of C is 11.12 g/cm³. This object has almost the same as the known density of lead, which is 11.34 g/cm³.

Justification: Our evidence is based on the following assumptions:
• Density is a physical property of matter and remains constant regardless of the amount of the object present.
• Density can be used to identify a substance.
• The difference in the calculated densities and the known densities is likely due to measurement error.
Evidence includes data but the analysis of data is weak and no real interpretation of what the data is saying.

No scientific principle to support underlying analysis and interpretation.
Guiding Question: How is the strength of an electromagnet affected by the number of coils of wire?

Claim: As the number of coils increases, the strength of the electromagnet increases.

Evidence: There is a positive relationship between the number of coils and the number of paper clips held by the electromagnet – as the number of coils increases the number of paper clips held also increases.

Justification: Our evidence is based on the following assumptions:
- In order for a substance to become magnetized the magnetic domains of substance must be aligned.
- Electric currents produce magnetic fields that can cause shifts in the magnetic domains of substances.
- Picking up more paperclips is a measure of magnetic strength because a stronger force is needed to pick up more mass.
Guiding Question: Which metal has the greatest specific heat?

Claim: Object B has the highest specific heat.

Evidence:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mass (g)</th>
<th>Initial Temp (°C)</th>
<th>Mass (g)</th>
<th>Initial Temp (°C)</th>
<th>Final Temp (°C)</th>
<th>Change in Temp (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.0</td>
<td>100</td>
<td>5.0</td>
<td>23.2</td>
<td>24.5</td>
<td>1.3</td>
</tr>
<tr>
<td>B</td>
<td>2.5</td>
<td>100</td>
<td>5.2</td>
<td>22.1</td>
<td>27.3</td>
<td>5.2</td>
</tr>
<tr>
<td>C</td>
<td>2.2</td>
<td>100</td>
<td>5.6</td>
<td>25.5</td>
<td>28.6</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Metal B transferred more energy to the water and caused the temperature of the water to increase by 5.2°C, which is more than any of the other metals.

Justification:

Our evidence is based on the following assumptions:

- Different substances require different amounts of energy to change temperature by 1°C.
- Each metal absorbs different amounts of energy to reach a temperature of 100°C.
- Thermal energy moves from warmer objects to cooler objects, when thermal energy transfers into an object the kinetic energy of the particles increases and the temperature of the substance increases.
- Greater temperature changes for the water means more energy was transferred from the metal to the water.
Guiding Question: Which metal has the greatest specific heat?

Claim: Object B has the highest specific heat.

Evidence:

<table>
<thead>
<tr>
<th>Metals</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>Mass (g)</td>
</tr>
<tr>
<td>A</td>
<td>25.0</td>
</tr>
<tr>
<td>B</td>
<td>23.5</td>
</tr>
<tr>
<td>C</td>
<td>26.2</td>
</tr>
</tbody>
</table>

Justification: Metal B has the greatest specific heat because it increased the water temperature by 5.2°C, which is more than any of the other metals.

Metal B caused the greatest temperature change in the water.
**Guiding Question:** Which substance has the strongest intermolecular forces?

**Claim:** Isopropyl alcohol has the strongest intermolecular forces.

**Evidence:**
Isopropyl alcohol had the smallest temperature change during evaporation and therefore lost the least amount of energy.

<table>
<thead>
<tr>
<th>Liquid</th>
<th>Initial Temp. (°C)</th>
<th>Minimum Temp. (°C)</th>
<th>Temp. Change (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>22.2</td>
<td>4.7</td>
<td>-17.5</td>
</tr>
<tr>
<td>Ethanol</td>
<td>21.3</td>
<td>10.3</td>
<td>-11.0</td>
</tr>
<tr>
<td>Isopropyl alcohol</td>
<td>21.9</td>
<td>13.6</td>
<td>-8.3</td>
</tr>
</tbody>
</table>

**Justification:**
Our evidence is important because:
- Kinetic molecular theory says that all particles are in constant motion.
- Particles in a substance with high kinetic energy are moving faster than particles with lower kinetic energy.
- During evaporation particles with high energy escape from a liquid because they can overcome the intermolecular forces between molecules.
- When high-energy particles evaporate from a liquid the temperature of the liquid drops.
- Strong intermolecular forces reduce evaporation.
Communicating what your data is saying is not the same thing as communicating what your data literally says.
Appropriate Evidence

**Claim:** Based on the data my group collected, we can conclude that unknown solution number 3 is sodium carbonate.

**Evidence:**

<table>
<thead>
<tr>
<th>FIRE TEST</th>
<th>HCl AND BaCl₂ TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>CATION</td>
<td>OBSERVATION</td>
</tr>
<tr>
<td>Na⁺</td>
<td>GREEN</td>
</tr>
<tr>
<td>UNKNOWN #3</td>
<td>ORANGE</td>
</tr>
</tbody>
</table>

Both sodium and unknown #3 were the only cations to turn the flame orange. Also, CO₃²⁻ and unknown #3 were the only two cations that reacted by creating bubbles when mixed with HCl and produce a white cloudy precipitate when mixed with BaCl₂.

**Justification:** Each element on the periodic table produces its own unique spectra of light when put into fire. Thus, unknown #3's cation must be sodium since they both produced the same color flame. And no two cations react the same. Each element has different chemical properties, causing them to react in different ways to the same chemical. Thus, unknown #2's cation must be CO₃²⁻ since they both reacted in the same way to the same chemicals.
On a scale of 1 - 4 (4 being the best), what score would you give this CER for explaining the trend of atomic radius going across the periodic table?
- Which direction? L → R or R → L?
- “it goes down” is not entirely clear

“Going across the periodic table from left to right, atomic radius decreases”

- What do the “points” represent?
- No mention of data showing an increase in atomic radius after one period ends

- Misconception is evident
- No scientific principle to support or justify why reader should accept this explanation
What is the mathematical relationship between the moles of a solute, the volume of the solvent, and the molarity of an aqueous solution?

**OUR CLAIM:** In any unsaturated solution, the solute / the solvent = the concentration. But this won't work for saturated solutions.

### EVIDENCE

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.54 M</td>
<td>0.785 L</td>
</tr>
<tr>
<td>0.54 M</td>
<td>0.350 L</td>
</tr>
<tr>
<td>0.63 L</td>
<td>0.632 L</td>
</tr>
<tr>
<td>0.266 M</td>
<td>0.280 L</td>
</tr>
</tbody>
</table>

### SATURATED

<table>
<thead>
<tr>
<th>Solvent</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.777 M</td>
<td>0.230 L</td>
</tr>
<tr>
<td>0.777 M</td>
<td>0.412 L</td>
</tr>
<tr>
<td>0.56 M</td>
<td>0.547 L</td>
</tr>
<tr>
<td>0.56 M</td>
<td>0.708 L</td>
</tr>
</tbody>
</table>

### REASONING

With the same amount of solute, if you put it in less solvent, there is less room for the particles to dissolve so the concentration will go up and the more solvent the more room for particles to dissolve so the concentration will go down. No matter how much solvent you put in the solution, the concentration will stay the same because it can only dissolve to a certain point.

![Diagram showing high and low concentrations](image-url)
Providing opportunities for students to write in this explicit format makes it so much easier for me to identify misconceptions.

Providing only the raw data isn’t what we’re trying to get them to do here.
Justification: Unknown 1 must be copper(II) nitrate for two reasons.

1) A metal will maintain its properties even if chemically bonded.
2) A nonmetal will not alter its reactions if bonded with a cation.

Therefore, Unknown 1 must contain copper because the cation retains its original properties and the spectra of the two cations matched after the flame test. Unknown 1 must also contain nitrate because the anion will continue to react the same even if it is bonded and the two cations had the exact same reactions to B a c l 2 and H C l . In conclusion, the Unknown 1 is copper (II) nitrate.
Question: Why do temperature and reactant concentration affect reaction rate?

Claim: Increased temperature and reactant concentration increases reaction rate.

Evidence: 3M of HCl goes through the reaction much faster than 1M, which goes through the reaction much quicker than 0.5M. Also, when the reaction takes place in hot water, it goes much faster than cold water.

Reasoning: This occurs because increased temperature allows the molecules to collide with each other at a faster rate, causing the reaction to occur faster. Also, increased reactant concentration means that there is an increased amount of one of the reactants in the experiment, giving the two reactants a greater probability of colliding with one another, therefore speeding up the rate of reaction.

Personally, I prefer data to be visible in an organized manner:
- I don’t want to read a paragraph about your data.

Often, students forget to explicitly state the scientific principle that supports the statements they make throughout their reasoning:
- “Based on KMT, we know that increasing the temp. will cause particles to move faster....”
At first, many students will often construct their argument from a purely logical point of view rather than using logic and connecting it with known scientific ideas.

Claim: “X happened because Y”

Evidence: “Here’s evidence supporting that X happened because Y”

Reasoning: “Because the evidence that supports X happened because Y, we can conclude that X happened because Y”

Too much like a mathematical proof (transitive property)

If $a = b$ and $b = c$ then $a = c$
Which balanced chemical equation represents the thermal decomposition of sodium bicarbonate?

Option 1: $\text{NaHCO}_3 (s) \rightarrow \text{NaOH} (s) + \text{CO}_2 (g)$

Option 2: $2\text{NaHCO}_3 (s) \rightarrow \text{Na}_2\text{CO}_3 (s) + \text{CO}_2 (g) + \text{H}_2\text{O} (g)$

Option 3: $2\text{NaHCO}_3 (s) \rightarrow \text{Na}_2\text{O} (s) + 2\text{CO}_2 (g) + \text{H}_2\text{O} (g)$

Option 4: $\text{NaHCO}_3 (s) \rightarrow \text{NaH} (s) + \text{CO} (g) + \text{O}_2 (g)$

Guided Question: What is the correct balanced equation for the thermal decomposition of sodium bicarbonate?

Our Claim: The correct balanced equation for sodium bicarbonate is $2\text{NaHCO}_3 (s) \rightarrow \text{Na}_2\text{CO}_3 (s) + \text{CO}_2 (g) + \text{H}_2\text{O} (g)$

Justification:
The mass of the remaining solid was 7.04g which was closest to the predicted molar mass of $\text{Na}_2\text{CO}_3$ (7.207).

Evidence:
After completing the procedure with the bunson burner & flame test, we could narrow down our answers to 2 equations. Because the flame went out, we knew CO was being released. We also saw condensation form on the test tube which we concluded was water.

Insufficient Evidence
- Confusing molar mass with theoretical yield
- What about the other theoretical yields?
- % yields?

Appear to have evidence and justification mixed up
- Flame being extinguished when testing for CO$_2$ is evidence
- Appearance of condensation is evidence
Which balanced chemical equation represents the thermal decomposition of sodium bicarbonate?

Evidence:
- mass of NaHCO₃ = 41.08 g - 31.17 g = 9.91 g
- final mass of product = 41.24 g - (31.17 g + 8.75 g) = 6.32 g
- lit wood splint went out when exposed to gas in test tube
- wood splint did not reignite when exposed to gas in test tube
- condensation caused product to stick to stir rod
- theoretical yield of Na₂CO₃ = 6.3 g
- theoretical yield of Na₂O = 3.7 g

Reasoning:
- each element has its own unique chemical properties that can be used to identify its presence. Since the lit wood splint went out when exposed to the gas in the test tube, a reaction unique to the presence of CO₂, it can be inferred that CO₂ was being released from sodium bicarbonate. In addition, the presence of condensation on the stir rod indicates the release of H₂O. This eliminates two of the possible equations because they don’t produce CO₂ or H₂O. In the actual equation, the theoretical yield of the solid product should be close if not identical to the actual yield in the experiment based on stoichiometric proportions. Since the theoretical yield of Na₂CO₃ is much closer to the actual yield than the theoretical yield of Na₂O, the equation yielding Na₂CO₃, CO₂, and H₂O must be the correct chemical equation for the decomp of sodium bicarbonate.

I like this because they just provided the evidence. Many students followed this up by reasoning what that meant.

Wonderful use of providing underlying scientific principles to support statements being made.
Using CER for error analysis

**Appropriate**

**Error Analysis:**
Claim: The filter used to separate the solid and liquid product did not separate them completely.
Evidence: The aqueous product that goes through the filter is clear, while the solid product consists of a milky textured gel-like appearance. During the process of filtering the two products should be completely separate, yet they were not.
Reasoning: Since the liquid at the bottom of the flask had reminisce of a milky substance, and the solid was a milky substance, the filter did not completely separate the solid and aqueous product. Creating an error by adding more mass to the aqueous product, and taking away mass of the solid product which makes the weighted mass of the solid inaccurate.

**Inappropriate**

**Error Analysis:**
Claim: One error that occurred during our procedure was being a little off on our measuring of Sodium Hydroxide. Because of the small lacking of this reactant, our percent yield was affected.
Evidence: The amount of Sodium Hydroxide we had was off by 0.01 grams during measuring. We were supposed to get 0.48 grams but instead got 0.47 grams.
Reasoning: Because the percent yield was 77.4%, we can see that we lost mass during the process. Therefore, we can understand that since we had less of the Sodium Hydroxide we would lose mass in our percent yield.
Claim: The NaHCO₃ was not heated long enough.
Evidence: The actual mass weighed more than the mass we predicted for Na₂CO₃.
Reasoning: Since the NaHCO₃ was not heated long enough, not all of the CO₂ and H₂O was released making the Na₂CO₃ have more mass.
Implementation

Strategy
Introducing CER to Students

https://goo.gl/kJhX0k
I have evidence that my dad is an alien
   He speaks a weird language (dad gargling mouthwash)
   He drinks green stuff (dad’s green smoothie)
I mean...just look at him (dad walks by in full bicyclist gear)
And one more thing...he has a spaceship (pans to Audi car)
I have evidence that my dad is an alien

He speaks a weird language (dad gargling mouthwash)
He drinks green stuff (dad’s green smoothie)
I mean... just look at him (dad walks by in full bicyclist gear)
And one more thing... he has a spaceship (pans to Audi car)

1) Examine each piece of evidence mentioned and determine if it supports the claim or not.

2) Critically think about why each piece of evidence supports her claim. In other words, why would “speaking a weird language” or “drinks green stuff” justify the claim that her dad is an alien?

3) It gives them an opportunity to hear an argument that claims to be evidence-based but is fully of faulty reasoning
Spontaneous Generation Example

Do maggots come from rotting meat or do they come from other flies?

Claim: Flies only come from other flies
Evidence: Maggots, which develop into flies, only formed on the meat in the first flask—which was the only flask where flies had direct contact with the meat.
Reasoning: If rotting meat alone could produce maggots, then there would be maggots in flask 2, which was sealed and free from air. If rotting meat in combination with air could produce maggots, then there would be maggots in flask 3, which allowed air, but not flies, through the gauze. However, neither of these flasks had maggots. Therefore, flies are necessary to produce more flies.
Choose a murder mystery with all sorts of potential explanations that can be supported by evidence
Strong vs. Weak Argument Cards

Available online at Argument-Driven Inquiry store
Finding ways to incorporate CER throughout your curriculum

Due to the nature of our content, we have endless opportunities to incorporate this framework that fall outside of the lab

- Quizzes, Homework, Demos, Tests, Warm-Ups, etc.

Question from a recent quiz

3) Use the following data to construct an explanation using Claim, Evidence, Reasoning

Question: How does temperature affect the rate of a chemical reaction?

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Time taken for reaction to complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6 min. 30 sec.</td>
</tr>
<tr>
<td>20</td>
<td>3 min. 25 sec.</td>
</tr>
<tr>
<td>35</td>
<td>1 min. 47 sec.</td>
</tr>
<tr>
<td>60</td>
<td>34 sec.</td>
</tr>
</tbody>
</table>

Claim:

Evidence:

Reasoning:
Finding ways to incorporate CER throughout your curriculum

Explaining a Demo

\[ \text{Ba(OH)}_2 \cdot 8\text{H}_2\text{O} (s) + 2\text{NH}_4\text{Cl} (s) \rightarrow \text{BaCl}_2 (s) + 2\text{NH}_3 (g) + 10\text{H}_2\text{O} (l) \]

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \Delta H_f ) (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{Ba(OH)}_2 \cdot 8\text{H}_2\text{O}</td>
<td>-3,342</td>
</tr>
<tr>
<td>\text{NH}_4\text{Cl}</td>
<td>-315</td>
</tr>
<tr>
<td>\text{BaCl}_2</td>
<td>-860</td>
</tr>
<tr>
<td>\text{NH}_3</td>
<td>-46</td>
</tr>
<tr>
<td>\text{H}_2\text{O}</td>
<td>-286</td>
</tr>
</tbody>
</table>

**Your Task**

Come up with an argument (CER format) that provides an explanation for how this demonstration worked.

**Claim:** Most likely explanation for how this demonstration worked

\- Claim should be no more than 1 sentence in length

**Evidence:** What sort of qualitative and quantitative data do you have to support your claim?

**Reasoning:**

How does the evidence provided help support your claim?

What scientific principles can be used to justify your argument?
Claim: The beaker stuck to the wood by the water freezing between them. Evidence: The beaker felt cold and using the equation, we can tell that it's endothermic.

$$\text{Ba(OH)}_2 \cdot 8\text{H}_2\text{O} \rightarrow \text{Ba}^{2+} + 2\text{OH}^- + 8\text{H}_2\text{O}$$

Reasoning: Since the $\Delta H_{\text{rxn}} = 160 \text{kJ}$, we know the reaction is endothermic, and it would need to pull in energy. In this case, the energy is evidently pulled from the beaker and environment due to the beaker's loss of heat. This energy then was released in the reaction, and the resulting thermodynamic equilibrium caused the beaker to freeze to the water on the block.

Both need modification
Use it in exams

4.3—I can use stoichiometric analysis to represent chemical change

5) Based on the 2 options available and the data collected, determine the correct balanced chemical equation for solid copper reacting with nitric acid.

Option 1: \[ \text{Cu (s)} + 4\text{HNO}_3 (aq) \rightarrow \text{Cu(NO}_3)_2 (aq) + 2\text{NO}_2 (g) + 2\text{H}_2\text{O (g)} \]

Option 2: \[ \text{Cu (s)} + 2\text{HNO}_3 (aq) \rightarrow \text{Cu(NO}_3)_2 (aq) + \text{H}_2 (g) \]

Data

| Initial Mass of Nitric Acid = 15.4 g |
| Mass of Cu(NO₃)₂ produced = 11.5 g |

Show work here

Guiding Question: What is the correct balanced chemical equation for the reaction between copper and nitric acid?

Claim: Complete answer to the guiding question—Don’t simply say “Option 1” or “Option 2”

Evidence: Results of calculations made and data collected that support your claim.

Reasoning: A statement that explains why the evidence supports the claim and why the evidence should count as support.
The point is to provide consistent opportunities for exposure and feedback.
Feedback

As students continue to progress, feedback doesn’t always have to come from only you.
Students often struggle giving feedback to their peers

Conversation Starters

- What other things did you try?
- Why did you decide to do...?
- Tell me more about...
- I don’t know if I agree with...
- I disagree with this because...
- Would it be better if...?
- One way to modify this is...
- I have a question about...
- This could be improved by...
- How do you know...?
- I noticed...
- How can we help you?

Peer Review Feedback

IF YOU THINK THE AUTHOR...          WEAK FEEDBACK   STRONG FEEDBACK
...wrote something that was inaccurate.       ✗ That isn’t right.      ✓ We disagree with D31. We think you should change it to (Y).
...needs to make a change to a table, graph, or figure.   ✓ Fix this.      ✓ We think you need to reorganize your D31. Here is how we would change it.
...forgot to include something important.       ✗ Write more.      ✓ We think you forgot to include some important information that you really need to have, we suggest adding:
...included an important piece of information, but did not provide enough details about it.     ✗ Add more detail.      ✓ We think you need to be more specific about D31. We suggest adding the following changes:
...wrote something that was difficult to follow or confusing.     ✗ Unclear.      ✓ We did not understand what you meant by D31. You can make your writing more clear by (Y).

Available online at Argument-Driven Inquiry store
The 4 Ground Rules of Critique in Science

These are the four basic rules we will follow when we critique arguments and reports.

1. Be Respectful

Critique is how we identify errors or flaws in our ideas. In science, we always critique ideas, not people. When we are critiquing ideas, we never say hurtful things.

2. Be specific

Even if you are being respectful, you are not doing anybody any favors if you are vague. In science, we always make specific and detailed comments about what needs to be improved.

3. Be Helpful

Critique is more than identifying a flaw or error in an idea; it is also about offering suggestions for ways to improve it. In science, we always offer specific and detailed suggestions for how to make things better.

4. Use Scientific Criteria

Scientists use empirical and theoretical criteria to determine if an idea is valid or acceptable. In science, we always use scientific criteria to critique arguments and reports.
Take the time to sit down with your colleagues and develop a CER grading rubric together

<table>
<thead>
<tr>
<th>Claim</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>

**0.2—I can construct an evidence-based argument**

- able to provide a clear claim that answers the question or concludes an investigation
- able to cite evidence that supports the claim
- able to apply known scientific principles and general reasoning to justify why evidence supports the claim
- able to construct an argument that is organized, coherent, and concise

<table>
<thead>
<tr>
<th>Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

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**Assessing it as a scientific practice**
When first implementing, do some collaborative grading to check for consistency between teachers.
It doesn’t have to be *one size fits all*

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**Figure 1: Components of Scientific Reasoning**

- **Statement**: Claim 
  - An assertion that something is true
  - OR
  - Explanation: How and why something occurs
- **Argument**: Provides reasons that others should believe your statement
- **Core Ideas as Evidence**
- **Crosscutting Concepts as Evidence**
- **Observations Developed into Evidence**
- **Ideas from Established Models as Evidence**

**Figure 2: Science Reasoning Rubric**

<table>
<thead>
<tr>
<th>Science Reasoning Rubric</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Claim</strong></td>
</tr>
<tr>
<td>Makes a claim that is sufficient to answer the question and is coherent.</td>
</tr>
<tr>
<td>Makes a claim that is sufficient to answer the question or is incoherent.</td>
</tr>
<tr>
<td>Does not make a claim or makes an incoherent claim.</td>
</tr>
<tr>
<td><strong>Explanations</strong></td>
</tr>
<tr>
<td>Provides an explanation that addresses how and why a phenomenon occurs.</td>
</tr>
<tr>
<td>Provides an explanation that addresses how or why a phenomenon occurs.</td>
</tr>
<tr>
<td>Does not provide an explanation.</td>
</tr>
<tr>
<td><strong>Reasoning</strong></td>
</tr>
<tr>
<td>Includes all of the following:</td>
</tr>
<tr>
<td>- Cites sufficient and relevant evidence to support the claim/explanation.</td>
</tr>
<tr>
<td>- Describes how the evidence defends the claim/explanation.</td>
</tr>
<tr>
<td>- Reader feels compelled to accept your argument.</td>
</tr>
<tr>
<td>Includes two of the following:</td>
</tr>
<tr>
<td>- Cites sufficient and relevant evidence to support the claim/explanation.</td>
</tr>
<tr>
<td>- Describes how the evidence defends the claim/explanation.</td>
</tr>
<tr>
<td>- Reader feels compelled to accept your argument.</td>
</tr>
<tr>
<td>Includes one or none of the following:</td>
</tr>
<tr>
<td>- Cites sufficient and relevant evidence to support the claim/explanation.</td>
</tr>
<tr>
<td>- Describes how the evidence defends the claim/explanation.</td>
</tr>
<tr>
<td>- Reader feels compelled to accept your argument.</td>
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Taking CER Beyond Your Classroom
It’s not some sort of massive paradigm shift

Talk to other teachers within the school and district
- “Do you want your students to become better at constructing evidence-based explanations and arguments?”
- Though expectations will change at different levels, CER is something that can be done as early as elementary school
- With more people involved, it’s important that everyone is on the same page about the definitions of claim, evidence, reasoning
Displays in Your Classroom

Available online at Argument-Driven Inquiry store
Evidence-Based Arguments Aren’t Just a Science Thing

**Claim:** Mesopotamia was a highly civilized society.

**Evidence:** Hammurabi’s code shows evidence of laws. Clay tablets show evidence of a writing system. According to Nardo, Mesopotamia had religion, a stable food supply and a social structure.

**Reasoning:** Mesopotamia shows many of the characteristics of an advanced civilization. Much like our current civilization, Mesopotamia also exhibits laws, religion, a stable food supply and a social structure.
Resources and Thanks


Link to Audi commercial, My dad is an alien—https://goo.gl/kJhX0k
Survey, Certificate, and Downloads

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To Download Resources:


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AACTconnect@acs.org