



Supporting Students in Science Thinking and Writing: Justifying Claims with Evidence and Reasoning

Katherine L. McNeill
Boston College

Dean Martin
Gardner Pilot Academy



Overview of Talk



- Examine Student Writing
- Introduce Scientific Argumentation
- Dean's 5th Grade Classroom
- Video clips of Teaching Strategies
- Learning Progression across k-12

Example 7th Grade Students' Writing



Examine the following data table:

	Density	Color	Mass	Melting Point
Liquid 1	0.93 g/cm ³	no color	38 g	-98 °C
Liquid 2	0.79 g/cm ³	no color	38 g	26 °C
Liquid 3	13.6 g/cm ³	silver	21 g	-39 °C
Liquid 4	0.93 g/cm ³	no color	16 g	-98 °C

Write a scientific explanation that states whether any of the liquids are the same substance.

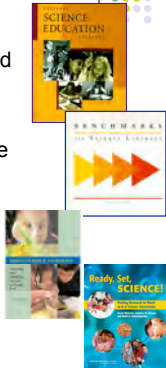
Examine 7th Grade Students' Writing



- Examine the two 7th grade students' science writing
- Questions:
 - How would you assess these responses?
 - What are the strengths?
 - What are the weaknesses?
 - What would you want to see in an "ideal" student response?

Importance of Scientific 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 arguments
- Change students' image of science
- Enhance students' scientific reasoning abilities
- Foster deeper understanding of important science concepts



Student Difficulties

- Students have difficulty articulating and justifying their claims (Sadler, 2004).
- Difficulties with evidence
 - Difficulty using appropriate evidence (Sandoval, 2003)
 - Use their own intuitive beliefs, experiences or opinions, as evidence instead of scientific data (Hogan & Maglienti, 2001).
 - Difficulty providing sufficient evidence (Sandoval & Millwood, 2005).

Student Difficulties

- Difficulties with reasoning
 - Difficulty providing backing or reasoning for why evidence supports the claim (Bell & Linn, 2000).
 - Difficulty using scientific principles to explain why their evidence supports their claim (McNeill & Krajcik, 2006).
- Difficulties considering alternative claims
 - The ability to use rebuttals is the most complex skill (Kuhn, 1991).
 - Difficulty considering alternative arguments and providing rebuttals (Osborne et al. 2004).

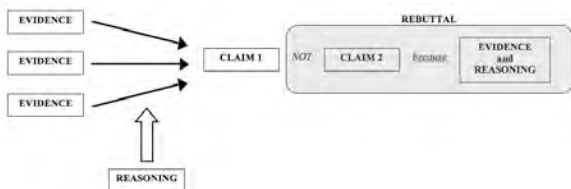
Framework for Scientific Argument

Adapted from Toulmin (1958)

- **Claim**
 - a conclusion about a problem
- **Evidence**
 - scientific data that supports 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.

Framework for Scientific Argument

Adapted from Toulmin (1958)



7th Grade Student Example

Write a scientific explanation that states whether any of the liquids are the same substance. Liquid 1 and 4 are the same substance. They both have a density of 0.93 g/cm^3 , have no color, and start to melt at -98°C . For substances to be the same, they must have the same properties. Since Liquids 1 and 4 have the same properties, they are the same substance. The other 2 liquids are different substances because they have different properties.

7th Grade Chemistry Example

Are any of the liquids the same substance?

Liquids 1 and 4 are the same substance. (Claim) They both have a density of 0.93 g/cm^3 , have no color, and start to melt at -98°C . (Evidence) For substances to be the same, they must have the same properties. Since Liquids 1 and 4 have the same properties, they are the same substance. The other 2 liquids are different substances because they have different properties. (Reasoning)

Physics Example

Does mass affect how quickly an object falls?

No, mass does not affect how quickly an object falls. (Claim) In the investigation, the blocks had different masses – 20 g., 30 g., 44 g., 123 g and 142 g. But the average time for all five blocks was about the same – between 1.5 and 1.8 seconds. (Evidence) Since the blocks had different masses but took about the same time to fall, I know that mass does not affect how quickly something falls. (Reasoning)

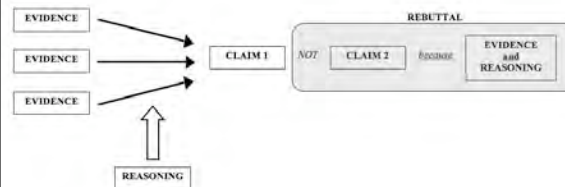
Earth Science Example

How was the Grand Canyon formed?

The Grand Canyon was mainly formed by water cutting into and eroding the soil. **(Claim)** The soil in the Grand Canyon is hard, cannot absorb water and has few plants to hold it in place. When it rains in the Grand Canyon it can rain very hard and cause flash floods. The flash floods come down the side of the Grand Canyon and into the Colorado River. **(Evidence)** Water moving can cause erosion. Erosion is the movement of materials on the earth surface. In terms of the Grand Canyon, the water moved the soil and rock from the sides of the Grand Canyon into the Colorado River where it was then washed away. **(Reasoning)**

Framework for Scientific Argument

Adapted from Toulmin (1958)



Providing Students with Support

- Making the implicit rules of science discourse explicit can help all students (Michaels et al., 2008).
- Using a variety of instructional strategies (e.g. modeling, connecting to everyday) can help students achieve greater success (McNeill & Krajcik, 2008b).
- Incorporating curricular scaffolds, graphic organizers and other supports into science instruction can help students justify their claims (McNeill et al., 2006).

BPS 5th Grade Science

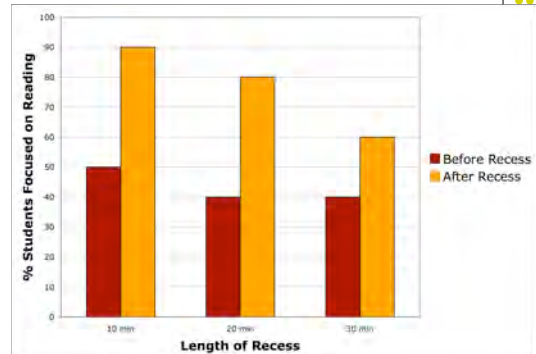
- Challenges
 - Students struggled with their science writing
 - Students struggled with making sense of science investigations - supporting claims with evidence
- 2008-2009 School Year
 - Integrate claim, evidence and reasoning into the curriculum.
 - Research changes in student understanding over the school year.
 - Support students in becoming better scientific writers and develop better scientific arguments.

5th Grade ELL - September

Response	Evidence of the Claim
3kg	
Reez	
ant	

Conclusion
Write an argument that answers the question: How many different habitats are in the outdoor classroom?

Everyday Example: How long should recess be?



Scientific Argument

- Claim
 - A statement that answers the question or problem
- Evidence
 - Scientific data that supports the claim
 - Data needs to be appropriate
 - You need to have enough data
- Reasoning
 - Applies your science knowledge to solve the problem
 - Explains why the evidence supports the claim

Discuss the Framework

5th Grade ELL - Winter

Write an argument that answers the question: Is my ecosystem a stable ecosystem?

Claim
(Write a sentence stating whether your ecosystem is or is not stable.)

I think that is not stable.

Evidence
(Provide scientific data to support your claim. Use evidence from your table above about the health and changes for the different characteristics of your ecosystem.)

*because they don't move and
because the water is not clean
and because the plant are
not growing.*

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 ecosystem was stable.)

*that I know that a stable
eco-column has living plants
and animals. my evidence show
but there are no living plants or
animals, that is why eco-column
is unstable.*

Can you create the strongest argument?

CLAIM
Circle ONE of the following.

- A. My car will go the fastest, because I will make it really strong.
- B. The car with the lightest load being pulled by the largest force will go the fastest.
- C. How fast a car goes is determined by how far it travels in a certain time.

EVIDENCE
Circle TWO of the following.

- A. The car with only one block on the car took 1 second to travel across the table while the car with three blocks took 3 seconds.
- B. We always built our cars carefully and they traveled really fast.
- C. Car companies, like Ford, try to build light cars because they will travel faster.
- D. The car that was pulled by 5 washers took 2 seconds to travel across the table while the car with 1 washer took 7 seconds.
- E. Our group had a lot of fun building and testing our cars, except for the one day that our car kept breaking.
- F. Our experiments showed that light cars travel faster.

REASONING
Circle ONE of the following.

- A. The data from our experiments shows us how to build our car. Since the data shows that fast cars have a light load and fast cars are pulled by a large force then this is how we should build our car.
- B. Since car companies and race cars have cars that are really light and have large engines this means we should design our car in the same way. It should have a light load and be pulled by a large force.
- C. The speed was determined by how many seconds it took for the car to travel across the table. The car with less blocks had a lighter load and it traveled faster. The car that was pulled by more washers was pulled by a greater force and it traveled faster.

Instructional Strategies

1. Make the framework explicit ➡
2. Connect to everyday arguments ➡
3. Discuss the rationale behind argumentation ➡
4. Model the construction of arguments ➡
5. Provide multiple opportunities
6. Provide students with feedback ➡
7. Have students critique arguments ➡

Learning Progression

Level of Complexity	Framework Sequence
Simple ↓ Complex	Variation #1 1. Claim 2. Evidence
	Variation #2 1. Claim 2. Evidence 3. Reasoning
	Variation #3 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning
	Variation #4 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning • Multiple components
	Variation #5 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning • Multiple components 4. Rebuttal

Variation #1 (potential starting place)

- Claim
 - A statement that answers the question
- Evidence
 - scientific data that supports the claim

Variation #1 - Plant Example

The plant that received more light grew taller.
 (claim) The plant with 24 hours of light grew 20 cm. The plant with 12 hours of light only grew 8 cm. (evidence)

Variation #2 (potential starting place)

- Claim
 - A statement that answers the question
- Evidence
 - scientific data that supports the claim
- Reasoning
 - a justification for why the evidence supports the claim using scientific principles

Variation #2 - Add Reasoning



The plant that received more light grew taller. (claim) The plant with 24 hours of light grew 20 cm. The plant with 12 hours of light only grew 8 cm (evidence) Plants require light to grow and develop. This is why the plant that received 24 hours of light grew taller. (reasoning)

Variation #3 (more complex)



- Claim
 - A statement that answers the question
- Evidence
 - scientific data that supports the claim
 - Data needs to be appropriate
 - Data needs to be sufficient
- Reasoning
 - a justification for why the evidence supports the claim using scientific principles

Variation #3 - More Complex Evidence



The plant that received more light grew more. (claim) On average for the six plants that received 24 hours of light, they grew 20 cm, had six yellow flowers, had fifteen leaves and they were all vibrant green. On average for the six plants that received 12 hours of light, they grew 8 cm, had two yellow flowers, and had four leaves. Also, two of the plants had zero flowers. These plants were still vibrant green, but they were smaller with fewer flowers and leaves. (evidence) Plants require light to grow and develop. This is why the plant that received 24 hours of light grew more (reasoning).

Variation #4 (more complex)



- Claim
 - A statement that answers the question
- Evidence
 - scientific data that supports the claim
 - Data needs to be appropriate
 - Data needs to be sufficient
- Reasoning
 - a justification for why the evidence supports the claim using scientific principles
 - each piece of evidence may have a different justification for why it supports the claim

Variation #4 - More Complex Reasoning

Plants need water, carbon dioxide and light to grow. (claim)
 On average for the six plants that received constant light, carbon dioxide and water, they grew 20 cm, had six yellow flowers, had fifteen leaves and they were all vibrant green. On average for the six plants that received 12 hours of light, limited carbon dioxide and limited water, they grew 8 cm, had two yellow flowers, and had four leaves. Also, two of the plants had zero flowers. These plants were still vibrant green, but they were smaller with fewer flowers and leaves. (evidence) Photosynthesis is the process where green plants produce sugar from water, carbon dioxide and light energy. Producing sugar is essential for plant growth and development. That is why the plants that received a constant source of water, carbon dioxide and light grew the most. (reasoning)

Variation #5 (greatest complexity)

- Claim
 - A statement that answers the question
- Evidence
 - scientific data that supports the claim
 - Data needs to be appropriate
 - Data needs to be sufficient
- Reasoning
 - a justification for why the evidence supports the claim using scientific principles
 - each piece of evidence may have a different justification for why it supports the claim
- Rebuttal
 - describes alternative explanations and provides counter evidence and reasoning for why the alternative is not appropriate.

Variation #5 - Add Rebuttal

Plants need water, carbon dioxide and light to grow. (claim) On average for the six plants that received constant light, carbon dioxide and water, they grew 20 cm, had six yellow flowers, had fifteen leaves and they were all vibrant green. On average for the six plants that received 12 hours of light, limited carbon dioxide and limited water, they grew 8 cm, had two yellow flowers, and had four leaves. Also, two of the plants had zero flowers. These plants were still vibrant green, but they were smaller with fewer flowers and leaves. (evidence) Photosynthesis is the process where green plants produce sugar from water, carbon dioxide and light energy. Producing sugar is essential for plant growth and development. That is why the plants that received a constant source of water, carbon dioxide and light grew the most. (reasoning) Our experimental design just limited the amount of air the plants received not specifically the amount of carbon dioxide. So you could argue that plants need water, air and light. But we know that the process of photosynthesis requires carbon dioxide and not another gas (like oxygen), which is why we concluded specifically that the carbon dioxide was required for growth. If we could limit just the carbon dioxide in our design, we would have better evidence for this claim (rebuttal).

Learning Progression

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	Variation #4 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning • Multiple components
	Variation #5 1. Claim 2. Evidence • Appropriate • Sufficient 3. Reasoning • Multiple components 4. Rebuttal

Conclusion

- Scientific argumentation is an essential part of science that is challenging for students
- Make the scientific argumentation framework explicit (claim, evidence, reasoning and rebuttal)
- Different variations of the framework can be introduced to students over time as their abilities increase.
- Provide prompts or scaffolds for student writing
- Use instructional strategies in your teaching



More Information

- Kate's Contact information
 - kmcneill@bc.edu
 - www.katherinelmccneill.com
- Dean's Contact information
 - anderson.martin@netzero.net
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