SRENGTHENING SCIENCE WRITING AND INQUIRY: HELPING STUDENTS DEVELOP CLAIMS WITH EVIDENCE AND REASONING

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FRAMEWORK FOR SCIENTIFIC ARGUMENTS

WHY SCIENTIFIC ARGUMENTS?

Science education reform efforts call for students to develop scientific processes and skills through inquiry (American Association for the Advancement of Science, 1993; National Research Council, 1996). One prominent inquiry practice in both the standards documents and research literature is the construction, analysis, and communication of scientific arguments. We believe that argument construction should be an important part of science class for multiple reasons. First, research into scientists' practices portrays a picture where scientists construct arguments or explanations including weighing evidence, interpreting text, and evaluating claims (Driver, Newton & Osborne, 2000). Second, previous research in science education has found that having students engage in argumentation may change or refine their image of science as well as enhances their understanding of the nature of science (Bell & Linn, 2000). Third, constructing arguments can enhance student understanding of the science content (Driver, Newton & Osborne, 2000) as well as their ability to write in science (McNeill & Krajcik, 2006). Finally, assessing students' scientific arguments can help make their thinking visible both in terms of their understanding of the science content and their scientific reasoning (McNeill & Krajcik, 2007; McNeill & Krajcik, 2008a).

WHAT IS A SCIENTIFIC ARGUMENT?

A scientific argument is a written or oral response to a question that requires students to analyze data and interpret that data with regard to scientific knowledge. Our argument framework includes four components: claim, evidence, reasoning and rebuttal. While we break down arguments into these four components for students, our ultimate goal is to help students to create a cohesive argument in which all components are linked together. Yet we have found that first breaking arguments down into the components can ultimately help students create cohesive arguments. In the following section, we describe the four components of a scientific argument.

Claim

The claim is a testable statement or conclusion that answers the original question. The claim is the simplest part of an argument and often the part students find the easiest to include as well as to identify when they are critiquing other peoples' arguments. One of the purposes in focusing on scientific arguments is to help students include more than a claim in their writing.

Evidence

The evidence is scientific data that supports the student's claim. This data can come from an investigation that students complete or from another source, such as observations, reading material, archived data, or other sources of information.

The data needs to be both *appropriate* and *sufficient* to support the claim. When introducing evidence to students, we suggest discussing *appropriate* data in terms of whether the data supports the claim. A good argument only uses data that supports the claim in answer to the original question. Students should also consider whether or not they have *sufficient* data. When introducing this concept to students, we suggest discussing *sufficient* data in terms of whether they have enough data.

When students are selecting their data to use as evidence, they should consider both whether it is appropriate to support their claim and whether they have enough data to support their claim. We have found that this can be difficult for students. While they realize that they should include data as evidence, they are not necessarily sure which data to use or how much data to use.

Reasoning

Reasoning is a justification that shows why the data counts as evidence to support the claim <u>and</u> includes appropriate scientific principles. The reasoning ties in the scientific background knowledge or scientific theory that justifies making the claim and choosing the appropriate evidence.

We have found that students have a difficult time including the entire reasoning component. Often students simply make a general link between the claim and evidence. You want to help students learn to include the scientific background knowledge that allowed them to make that connection between claim and evidence.

Base or Generic Rubric

		Claim *A statement or conclusion that answers the original question/problem.*	Evidence *Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.*	Reasoning *A justification that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.*
LEVEL	**0**	Does not make a claim, or makes an inaccurate claim.	Does not provide evidence, or only provides inappropriate evidence (Evidence that does not support claim).	Does not provide reasoning, or only provides inappropriate reasoning.
	VARIES FROM 1 to 5	Makes an accurate but incomplete claim.	Provides appropriate, but insufficient evidence to support claim. May include some inappropriate evidence.	Provides reasoning that connects the evidence to the claim. May include some scientific principles or justification for why the evidence supports the claim, but not sufficient.
		Makes an accurate and complete claim.	Provides appropriate and sufficient evidence to support claim.	Provides reasoning that connects the evidence to the claim. Includes appropriate and sufficient scientific principles to explain why the evidence supports the claim.

This base or generic rubric (McNeill & Krajcik, in press) is then adapted to a specific question and the number of levels depends on the question.

Specific Rubric: Substance and Properties

	Claim *A statement or conclusion that answers the original question/problem.*	**Evidence** *Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.*	**Reasoning** *A justification that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.*
0	Does not make a claim, or makes an inaccurate claim like – "None of the liquids are the same."	Does not provide evidence, or only provides inappropriate evidence or vague evidence, like "the data shows me it is true" or "the mass is the same."	Does not provide reasoning, or only provides inappropriate reasoning like "they are like the fat and soap we used in class."
1	Makes an accurate but vague or incomplete claim like – "Some of the liquids are the same."	Provides 1 of the following 3 pieces of evidence: • The density of liquids 1 and 4 are the same. • The melting point of liquids 1 and 4 are the same. • The color of liquids 1 and 4 are the same. May include inappropriate evidence (e.g. mass).	Repeats the density, melting point, and color are the same and states that this shows they are the same substance.
2	Makes an accurate and complete claim like – "Liquids 1 and 4 are the same."	Provides 2 of the following 3 pieces of evidence: • The density of liquids 1 and 4 are the same. • The melting point of liquids 1 and 4 are the same. • The color of liquids 1 and 4 are the same. May include inappropriate evidence (e.g. mass).	Provides 1 of the following 2 reasoning components: • Density, melting point, and color are all properties. • Same substances have the same properties.
3		Provides all 3 of the following pieces of evidence: • The density of liquids 1 and 4 are the same. • The melting point of liquids 1 and 4 are the same. • The color of liquids 1 and 4 are the same. Does not include inappropriate evidence (e.g. mass).	Provides 2 of the following reasoning components: • Density, melting point, and color are all properties. • Same substances have the same properties.

INSTRUCTIONAL STRATEGIES

Many students find constructing scientific arguments to be difficult. It is not an inquiry practice that they can learn quickly, but rather it takes support, time and practice. Students need support in terms of when, how, and why to use the claim, evidence, and reasoning framework. We suggest using a number of instructional strategies to help students with this complex practice. These strategies are described in more detail with examples from middle school teachers' classrooms in McNeill and Krajcik (2008b).

1. **Make the framework explicit**. Explicitly discussing the different components and using the language of claim, evidence and reasoning frequently in your classroom can help students develop a stronger understanding of how to justify a claim in science. Furthermore, you may want to have students develop definitions of the components as a class so the acquire an understanding of the different terms. Also, having a visual reminder in the classroom, such as a poster on the wall, can serve as a reminder of the expectations in science around talking, thinking and writing.
2. **Connect to everyday arguments.** Just like in science, in everyday life people try to convince each other of claims. You may want to provide students with an everyday example, like discussing the best musician or athlete, and discuss how the claim, evidence and reasoning framework can be used. Although scientific arguments can be very similar to everyday arguments, they can also differ. For example, what counts as evidence to convince someone about the best athlete is different than what counts as evidence for whether a chemical reaction occurred. Students can develop a more complete understanding of scientific argumentation if they understand how it is similar and different from everyday argumentation.
3. **Discuss the rationale**. Students need to understand not only what an argument is, but also why people construct an argument. Understanding the logic behind scientific argumentation can help students when they are engaging in this practice. For example, you may want to talk to students about how just providing a claim is not very convincing or persuasive. Providing evidence and reasoning creates a stronger case for why a claim is correct.
4. **Model the construction of arguments.** After introducing arguments, you want to model how to construct arguments through your own talking and writing across different science content. You may want to show students an overhead of a generic student's response and as a class critique the argument. Or you may want to provide students with an example of a scientific argument from a newspaper, magazine or website. Then you could have students critique the argument in terms of the strengths and weaknesses of each component.
5. **Provide multiple opportunities.** Provide numerous opportunities for students to construct arguments through various investigations. These arguments promote student learning and provide excellent opportunities for formative feedback. During class discussions, if a student makes a claim ask them to provide an argument. Encourage students to provide evidence and reasoning to support their claims
6. **Provide students with feedback.** When students construct arguments, provide explicit and thorough feedback. You should comment on their argument as a whole as well as the

quality of the individual components. You may want to coach them on how to improve their arguments by asking them leading questions or providing them with examples. For example, you may want to ask students what the reasoning was in their argument and how they might improve their reasoning. Explicit and thorough feedback that provides suggestions for improvement promotes student understanding.

7. **Have students critique arguments.** When students write arguments in class, you may want to have them trade their arguments with a neighbor and critique each other's arguments. Focus students' attention on discussing both the strengths and weaknesses of their partners' arguments and offering concrete suggestions for improvement. You may want to provide students with a specific format, such as using a rubric, to help them in providing constructive feedback to their peers.

While supporting students' construction of scientific arguments can be a time-consuming process, there are numerous benefits. Helping students understand and be able to construct arguments can result in a greater understanding of science content and science as an inquiry process as well as improve students' science writing.

***Example 5th Grade Student Sheet*: Can you create the strongest argument?**

Directions
The 4th graders have just finished a number of experiments testing how different variables affect the speed of a car. Mr. Martin asks them to write an argument that answers the following question: How can you design a car to go the fastest? Circle the choices below that you think would 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.

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