# SUPPORTING STUDENTS IN SCIENCE THINKING AND WRITING: JUSTIFYING CLAIMS WITH EVIDENCE AND REASONING

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# 7<sup>TH</sup> GRADE STUDENT EXAMPLES

*Examine the following data table:*

|          | *Density*        | *Color*  | *Mass* | *Melting Point* |
|----------|------------------|----------|--------|-----------------|
| *Liquid 1* | *0.93 g/cm³*   | *no color* | *38 g* | *-98 ℃* |
| *Liquid 2* | *0.79 g/cm³*   | *no color* | *38 g* | *26 ℃*  |
| *Liquid 3* | *13.6 g/cm³*   | *silver*   | *21 g* | *-39 ℃* |
| *Liquid 4* | *0.93 g/cm³*   | *no color* | *16 g* | *-98 ℃* |

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

## Student Example #1

No, none of the liquids are the same Substances. They have different Properties. Liquid 1 density 0.93g/cm3, 2.0.79g/cm3, 3 13.6gl/cm3, 4 0.93 g/cm3. Color. 1 no color 2 no color, 3 silver 4. no color. Mass-1 38g, 2 38g. 3 21g, 4.16g. Melting Point. 1 -98°C, 2 26°C 3.-39°C, 4. -98 °C. Therefore none of them is the same substances.

## Student Example #2

I believe that liquid 1 and liquid 4 are the Same substance. There densities and melting point are the same. The mass is different but that only means that the portion or part is Smaller than the other. Like butter, the mass doesn't have to be the same but the melting point and density are the same. Therefore, I believe that liquid 1 and 4 are the same Substance.

## NATIONAL STANDARDS RELATED TO SCIENTIFIC ARGUMENTATION

The standards below come from *Benchmarks for Science Literacy* by the American Association for the Advancement of Science (AAAS, 2008).

**Grades K through 2**

| |
|---|
| Ask "How do you know?" in appropriate situations and attempt reasonable answers when others ask the same question. 12E/P1* |
| Describe and compare real-world objects in terms of number, shape, texture, size, weight, color, and motion. 12D/P1* |
| Draw pictures that portray some features of the thing being described. 12D/P2* |

**Grades 3 through 5**

| |
|---|
| Seek reasons for believing something rather than just claiming "Everybody knows that…" or "I just know" and discount such claims when made by others. 12E/E3* |
| Use numerical data in describing and comparing objects and events. 12D/E3 |
| Buttress their statements with facts found in books, articles, and databases, and identify the sources used and expect others to do the same. 12E/E1 |

**Grades 6 through 8**

| |
|---|
| Present a brief scientific explanation orally or in writing that includes a claim and the evidence and reasoning that supports the claim. 12D/M6** |
| Question claims based on vague attributions (such as "Leading doctors say…") or on statements made by celebrities or others outside the area of their particular expertise. 12E/M1 |
| Be skeptical of claims based on very small samples or biased samples. 12E/M3* |
| Notice and criticize the reasoning in arguments in which fact and opinion are intermingled. 12E/M5a |
| Notice and criticize the reasoning in arguments in which the claims are not consistent with the evidence given. 12E/M5b* |

**Grades 9 through 12**

| |
|---|
| Notice and criticize arguments in which data, reasoning, or claims are represented as the only ones worth considering, with no mention of other possibilities. 12E/H6a* |
| Notice and criticize claims that people make when they select only the data that support the claim and ignore any that would contradict it. 12E/H5* |
| Notice and criticize claims based on the faulty, incomplete, or misleading use of numbers, such as in instances when (1) average results are reported but not the amount of variation around the average, (2) a percentage or fraction is given but not the total sample size, (3) absolute and proportional quantities are mixed, or (4) results are reported with overstated precision. 12E/H1* |
| Insist that the key assumptions and reasoning in any argument—whether one's own or that of others—be made explicit; analyze the arguments for flawed assumptions, flawed reasoning, or both; and be critical of the claims if any flaws in the argument are found. 12E/H4* |

## 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.

### Rebuttal

When explaining phenomena, there can be more than one possible claim. Students can use the same data with different reasoning or different data to support an alternative claim about a phenomenon. When constructing scientific arguments, students should recognize and consider alternative arguments. They should provide rebuttals that counter the alternative claims through the use of evidence and reasoning that provides a justification for why the alternative claim is not appropriate. The rebuttal articulates why the alternative claim does not make sense to explain the phenomenon. Recognizing and arguing against other possible claims can be challenging for students. They can focus on one claim instead of considering all of the different plausible arguments.

### *Example 5<sup>th</sup> Grade Student Sheet*:
### Can you create the strongest argument?

## Directions
The 4<sup>th</sup> 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.

## 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.

# LEARNING PROGRESSION

Although engaging in scientific argumentation is an essential component of science, it takes time and practice for students to develop expertise.  Students need support and practice across multiple grade levels.  One way to think about this is in terms of a learning progression. A learning progression is defined as a sequence of successively more complex ways of thinking about a practice or content that develop over time (Smith, Wiser, Anderson, & Krajcik, 2006). Figure 1 illustrates one potential learning progression for scientific argumentation that builds in complexity from Variation 1-5, which could be used in K-12 classrooms (McNeill & Krajcik, in preparation).  By starting in early elementary school with variation #1 that focuses on claim and evidence, by the time students reach high school they will be better prepared to construct more complex arguments such as variation #5 in which they justify their claims with appropriate and sufficient evidence and reasoning as well as provide a rebuttal for counter claims.

Figure 1: Scientific Explanation Learning Progression

| Level of Complexity | Framework Sequence |
|---|---|
| Simple ↓ (arrow pointing down) | Variation #1<br>1. Claim<br>2. Evidence |
| | Variation #2<br>1. Claim<br>2. Evidence<br>3. Reasoning |
| | Variation #3<br>1. Claim<br>2. Evidence<br>  • Appropriate<br>  • Sufficient<br>3. Reasoning |
| | Variation #4<br>1. Claim<br>2. Evidence<br>  • Appropriate<br>  • Sufficient<br>3. Reasoning<br>  • Multiple components |
| Complex | Variation #5<br>1. Claim<br>2. Evidence<br>  • Appropriate<br>  • Sufficient<br>3. Reasoning<br>  • Multiple components<br>4. Rebuttal |

### REFERENCES

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

American Association for the Advancement of Science. (2008). *Benchmarks Online*. Retrieved on April 30, 2009 - http://www.project2061.org/publications/bsl/online/index.php

Bell, P., & Linn, M. (2000).  Scientific arguments as learning artifacts: Designing for learning from the web with KIE.  *International Journal of Science Education. 22*(8), 797-817.

DeBoer, G.E. (2005) Standard-izing test items. *Science Scope*, 28(4), 10-11.

Driver, R., Newton, P. & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education. 84*(3), 287-312.

McNeill, K. L. & Krajcik, J. (in preparation). *Claim, evidence and reasoning: Supporting grade 5-8 students in constructing scientific explanations*. New York, NY: Pearson Allyn & Bacon.

McNeill, K. L. & Krajcik, J. (2008a). Assessing middle school students' content knowledge and reasoning through written scientific explanations. In Coffey, J., Douglas, R., & Stearns, C. (Eds.), *Assessing Science Learning: Perspectives from Research and Practice*. (pp. 101-116). Arlington, VA: National Science Teachers Association Press.

McNeill, K. L. & Krajcik, J. (2008b). Inquiry and scientific explanations: Helping students use evidence and reasoning. In Luft, J., Bell, R. & Gess-Newsome, J. (Eds.). *Science as inquiry in the secondary setting*. (p. 121-134). Arlington, VA: National Science Teachers Association Press.

McNeill, K. L. & Krajcik, J. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In Lovett, M & Shah, P (Eds.), *Thinking with data*. (p. 233-265). New York, NY: Taylor & Francis Group, LLC.

McNeill, K. L., Lizotte, D. J, Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences, 15*(2), 153-191.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, D.C.: National Academy Press.

Smith, C. L., Wiser, M., Anderson, C. W., & Krajcik, J. (2006). Implications of research on children's learning for standards and assessment: A proposed learning progression for matter and the atomic molecular theory. *Measurement: Interdisciplinary Research and Perspectives, 4*(1&2), 1-98.