CLAIM, EVIDENCE AND REASONING: SUPPORTING MIDDLE SCHOOL STUDENTS IN EVIDENCE-BASED SCIENTIFIC EXPLANATIONS

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A more detailed handout can be found at:

- http://www.katherinelmcneill.com/workshops.html

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Please write your answer for question 2 on THIS SHEET.

2. Carlos wants to know if two liquids will react with each other. He uses an eyedropper to get a sample from the two liquids – butanic acid and butanol. He takes some measurements of each of the two samples. Then he stirs the two liquids together and heats them. After stirring and heating the liquids, they form two separate layers — layer A and layer B. Carlos uses an eyedropper to get a sample from each layer. He takes some measurements of each sample. Here are his results:

		Measurements			
		Melting Point	Volume	Solubility in water	Density
Before stirring & heating	Sample of butanic acid	-7.9 °C	2.00 cm^3	Yes	0.96 g/cm^3
	Sample of butanol	-89.5 °C	2.00 cm^3	Yes	0.81 g/cm^3
After stirring & heating	Sample of layer A	-91.5 °C	2.00 cm^3	No	0.87 g/cm^3
	Sample of layer B	0.0 °C	2.00 cm^3	Yes	1.00 g/cm^3

Write a **scientific explanation** that states whether a chemical reaction occurred when Carlos stirred and heated butanic acid and butanol.

only if he makes a new substance would it be a chemical reaction. I think he made a new substance because at first the two substances were not soluble in water and after one was. so basically yes a chemical reaction occured

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Write a **scientific explanation** that states whether a chemical reaction occurred when Carlos stirred and heated butanic acid and butanol. A Chemical reaction did occure after stirring and heating the sampleof butanic acid and the sample of butanol acid because in a chemical reaction something new is made bonds break and rearange a new properties are made therefore after stirring and heating it becomes a chemical reaction.

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.

NATIONAL MIDDLE SCHOOL SCIENCE STANDARDS RELATED TO SCIENTIFIC EXPLANATION

The standards below come from *Benchmarks for Science Literacy* by the American Association for the Advancement of Science (AAAS, 1993).

Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence. (AAAS, 1B: 1, 6-8)
Know that often different explanations can be given for the same evidence, and it is not always possible to tell which one is correct. (AAAS, 12A: 3, 6-8)
Notice and criticize the reasoning in arguments in which (1) fact and opinion are intermingled or the conclusions do not follow logically from the evidence given, (2) an analogy is not apt, (3) no mention is made of whether the control groups are very much like the experimental group, or (4) all members of a group (such as teenagers or chemists) are implied to have nearly identical characteristics that differ from those of other groups. (AAAS, 12E: 5, 6-8)

The standards below come from *National Science Education Standards* by the National Research Council (NRC, 1996).

Develop…explanations… using evidence. (NRC, 1996, A: 1/4, 5-8)
Think critically and logically to make the relationships between evidence and explanation. (NRC, 1996, A: 1/5, 5-8)
Recognize and analyze alternative explanations and predictions. (NRC, 1996, A: 1/6, 5-8)
Communicate scientific procedures and explanations. (NRC, 1996, A: 1/7, 5-8)
Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances. (NRC, A2/5:5-8)
Science advances through legitimate skepticism. Asking questions and querying other scientists' explanations is part of scientific inquiry. Scientists evaluate the explanations proposed by other scientists by examining evidence, comparing evidence, identify faulty reasoning pointing out statements that go beyond the evidence, and suggesting alternative explanations for the same observations. (NRC, A2/6:5-8)

"Essential features of classroom inquiry" as described by the National Research Council (2000).

Learners are engaged in scientifically oriented questions.
Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions.
Learners formulate explanations from evidence to address scientifically oriented questions.
Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
Learners communicate and justify their proposed explanations.

<u>ESSENTIAL FEATURES OF CLASSROOM INQUIRY AND THEIR VARIATIONS</u>

Essential Feature	Variation			
Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Leaner sharpens or clarifies question provided by teacher, materials, or other sources	Learner engages in question provided by teacher, materials, or other sources
Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it.	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze
Learner formulates explanation from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanation from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence
Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections	
Learner Communicates and justifies explanations	Learner forms reasonable and logical arguments to communicate explanation	Learner coached in development of communications	Learner provided broad guidelines to sharpen communications	Learner given steps and procedures for communications

More-------------------Amount of **Learner** Self Direction--Less

Less------------------------Amount of Direction from **Teacher or Material**--More

Adapted from *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning* (p. 29, NRC, 2000)

FRAMEWORK FOR SCIENTIFIC EXPLANATION

WHY SCIENTIFIC EXPLANATIONS AND 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 EXPLANATION?

A scientific explanation 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 explanation 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 and 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, 2012) is then adapted to a specific question and the number of levels depends on the question.

TEACHING STRATEGIES FOR SCIENTIFIC EXPLANATIONS

Many middle school children will find constructing scientific explanations difficult. It is not an inquiry practice that they can learn quickly. Students need support in terms of when, how, and why to use the claim, evidence, and reasoning framework. We suggest using a number of teaching 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 (2008a).

1. **Make the framework explicit**. You want to help students understand the three components of explanations. They should understand what these three components are as well as the definitions of claim, evidence and reasoning.
2. **Discuss the rationale behind explanation**. Students need to understand not only what an explanation is, but also why people construct an explanation. Understanding the logic behind scientific explanation 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.
3. **Model the construction of explanations.** After introducing explanations, you want to model how to construct explanations through your own talking and writing. When it is appropriate, provide students with examples of explanations. Furthermore, identify for students where the claim, evidence, and reasoning were in your own example.
4. **Discuss similarities and differences with everyday explanations.** 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 explanations can be very similar to everyday explanations, they can also be quite different. When people use the word "explain" in everyday talk, they are often not asking for someone to provide evidence and reasoning for a claim. For example, someone might ask you: Can you explain to me where the grocery store is? In this case, the meaning of explain corresponds more closely with describe than to the scientific explanation framework. Students can develop a more complete understanding of scientific explanation if they understand how it is similar and different from everyday explanations.
5. **Provide multiple opportunities to construct explanations.** Provide numerous opportunities for students to construct explanation through various investigations. These explanations promote student learning and make great formative/embedded feedback. During class discussions, if a student makes a claim ask them to provide an explanation for that claim. Encourage students to provide evidence and reasoning to support their claims
6. **Have students critique explanations.** When students write explanations in class, you may want to have them trade their explanations with a neighbor and critique each other's explanations. Focus students' attention on discussing both the strengths and weaknesses of their partners' explanations and offering concrete suggestions for improvement. You may want to show students an overhead of a generic student's response and as a class

critique the explanation. Or you may want to provide students with an example of a scientific explanation from a newspaper, magazine or website. Then you could have students critique the explanation in terms of the claim, evidence, and reasoning.

7. **Provide students with feedback.** When students construct explanations, provide explicit and thorough feedback. You should comment on their explanation as a whole as well as the quality of the individual components. You may want to coach them on how to improve their explanations by asking them leading questions or providing them with examples. For example, you may want to ask students what the reasoning was in their explanation and how they might improve their reasoning. Explicit and thorough feedback that provides suggestions for improvement promotes student understanding.

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

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