

Students' Abilities to Critique Scientific Arguments Based on the Form of Justification

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Argumentation and Assessment

- The significance of evidence-based arguments has been established as a central practice of scientists (Duggan & Gott, 2002) and learning science (Duschl, Schweingruber, & Shouse, 2007), and now appears in the national standards (Achieve, Inc., 2013).
- Large-scale assessments can impact teachers' pedagogical approaches to instruction through efforts to align with the types of items included on the test (Britton & Schneider, 2007). Furthermore, classroom assessments can provide important information about student learning, which can then be used by the teacher to modify instruction (Bell, 2007).
- We currently lack valid and reliable assessments to measure students' argumentation abilities (Osborne, 2010).

Arguments Across Multiple Modalities

- Argumentation, the process of constructing and critiquing an argument, is an authentic disciplinary literacy practice that can and should traverse the modes of reading, writing, and talking.
- One unique aspect of this work is its focus on assessing specific characteristics (constructs) of argumentation across multiple modalities (reading, writing, & talking)

Construct (characteristics of arguments)	Reading	Writing	Talking
Forms of Justification	✓	✓	
Relevant-Supporting Evidence	✓	✓	
Sufficiency of Evidence		✓	
Multiple Views		✓	
Reasoning		✓	
Text Features	✓		
Argument Process			✓
Argument Product			✓

Quality of Justifications

- A scientific argument uses evidence to defend how or why a natural phenomenon occurs (Berland & McNeill, 2012).
- A claim can be supported with different forms of justifications, including empirical evidence (McNeill & Krajcik, 2012), science ideas (Osborne et al., 2004), appeals to authority, plausible mechanisms, and prior experiences (Sandoval & Cam, 2012).
- A claim can be supported by one or more forms of justification, however some forms have a higher epistemic status in science, such as the preference for data as a form of justification (Sandoval & Cam, 2011).

Assessment Development

- We use the construct modeling framework from the BEAR Assessment System (BAS), which is comprised of four iterative steps: 1) construct, 2) item responses, 3) outcome space, and 4) measurement model (Wilson, 2005; Wilson, 2009).

Writing Construct Map

Level	Description	Items
High	<ul style="list-style-type: none"> Student limits all of the justifications to the most important forms (e.g., empirical measurements and observations) OR Student provides more important forms as well as less important forms of justification, and the less important forms are used as additional support of the more important forms. 	1
Mixture of Justifications	<ul style="list-style-type: none"> Student provides more important forms as well as less important forms of justification, but the less important forms do not provide further support for or do detract from the more important forms. 	
Less Important Justifications	<ul style="list-style-type: none"> Student only provides less important forms of justifications (e.g., appeals to authority, personal story, plausible mechanism). 	
Low	No Justifications	<ul style="list-style-type: none"> Student does not provide any justifications.

Sample Writing Item

Aisha wonders what is related to the power of a volcano's eruption.

On a field trip to a science museum, Dr. Martin tells Aisha that he studies large volcanoes from around the world. Aisha learns that the largest volcano on Earth is Mauna Loa, and that it is the newest of the volcanoes in the Hawaiian Islands.



Figure 1. The Mauna Loa Volcano in Hawaii.

Aisha learns that the magma from some volcanoes has more gas bubbles and is thicker than the magma in other volcanoes. She also learns that the power of an eruption is related to the amount of pressure built up by the magma inside the volcano. The thickness of the magma and the number of gas bubbles in the magma affect how explosive the volcanic eruption is.

Aisha found the table below:

Name of Volcano	Earth's Average Surface Temperature at the eruption site	Power of Eruption (Scale 0 to 8)	Thickness of Magma	Number of Gas Bubbles in Magma
A	6 °C	6	Sticky	Many
B	24 °C	5	Sticky	Many
C	18 °C	3	Sticky	Many
D	31 °C	2	Runny	Few
E	12 °C	1	Runny	Few

Aisha and her classmates need your help. Students in her class have different ideas about what is related to the power of a volcano's eruption. Using the information Aisha learned about volcanoes, write an argument to Aisha's class that answers the question: **What is related to the power of a volcano's eruption?**

When you are writing your argument keep in mind:

- Justifying your claim with evidence and reasoning, and
- Convincing Aisha and her classmates that your claim is stronger than other claims

Reading Construct Map

Level	Description	Items	
High	Compares & Critiques	<ul style="list-style-type: none"> Student critiques the quality of two arguments based on the forms of justification. 	3
Interprets	<ul style="list-style-type: none"> Student distinguishes between what is the claim versus the justification. 	1	
Identifies	<ul style="list-style-type: none"> Student identifies the form of justification used in an argument 	2	
Low	Does not Identify	<ul style="list-style-type: none"> Student does not identify the form of justification used in an argument. 	2

Sample Set of Reading Items

Cara wonders: **What is related to the height of ash clouds that are released from volcanic eruptions?** Cara did a little research and wrote the following argument. Read Cara's argument closely.

Cara's Argument:

(S1) = Sentence 1, (S2) = Sentence 2, (S3) = Sentence 3

(S1) *Volcanoes that have more explosive power usually produce ash clouds that reach higher into the sky. (S2) For instance, the Mount St. Helens Volcano had an explosive power of 5 and the ash cloud was about 22,000 meters high, and the Kilauea Volcano had an explosive power of 0 and its ash cloud is only about 100 meters high. (S3) The Mount St. Helens eruption was more powerful, which made the volcanic ash go much higher into the sky.*

- In which sentence does Cara support her claim?
 - Sentence 1 (S1) only
 - Sentence 2 (S2) only
 - Sentence 1 (S1) and Sentence 2 (S2)
 - There is no justification in the argument
- Cara supports her claim with...
 - an expert's opinion.
 - data from science investigations.
 - comparisons to a personal experience.
 - science ideas she already learned.
- To help the class write better arguments, Mrs. Warren put Cara and Jose's arguments on the board. She asked the class to compare them:

Cara's Argument:

Volcanoes that have more explosive power usually produce ash clouds that reach higher into the sky. For instance, the Mount St. Helens Volcano had an explosive power of 5 and the ash cloud was about 22,000 meters high, and the Kilauea Volcano had an explosive power of 0 and its ash cloud is only about 100 meters high. The Mount St. Helens eruption was more powerful, which made the volcanic ash go much higher into the sky.

Jose's Argument:

Volcanoes that have more explosive power usually produce ash clouds that reach higher into the sky. On our field trip to Mount St. Helens, a scientist said that when the Mount St. Helens Volcano erupted in 1980, the eruption was so large that the ash cloud blocked the sun for several days! This only happened because the eruption was so powerful that it was able to push the volcanic gases and dust really high into the sky.

Which student, Cara or Jose, better supports her or his argument? Why?

