Conceptualizing the Quality of Student Explanations (p. 5)

Building on previous studies and grounded in the analysis of 707 samples of student work, we propose four dimensions of explanation that mark important differences in the quality of written accounts:

1. **The conjectural framing of explanations:** How observable natural phenomena and unobservable processes or ideas are treated in the explanation
2. **The role of evidence:** How explanations are supported with observation or data
3. **The depth of explanation:** The degree to which explanations provide comprehensive and gapless accounts for focal phenomena, including causal relationships and underlying mechanisms
4. **Causal coherence:** How explanations are logically consistent with data, observation, evidence (i.e., internal coherence) as well as generally accepted scientific principles and theories (i.e., external consistency)

**The Conjectural Framing of Explanation.** Explanations can be characterized as either narrated or constructed as reflecting the modes of thought involved in the processes (Bruner, 1985). *Narrated explanations* take a form of a “correct version” of a story about some natural phenomenon. Students (re)produce uniform textbook-like explanations without significant variation. The links between observable phenomena and unobservable scientific ideas are not clear, and the tentative, revisable, and testable features of the explanation are not evident.

In contrast, *constructed explanations* show causal links between observable phenomena and a proposed explanatory mechanisms. These explanations incorporate claims and reasoning. In some cases, students’ explanations are constructed by reasoning through data and at other times by principled reasoning with scientific ideas. Students usually reveal a wider spectrum of understandings when they construct explanations about natural phenomena as opposed to reproducing textbook explanations.
The Role of Evidence. The second dimension of explanation is the role that evidence plays. Evidentiary support is a key feature of explanation that indicates students’ conceptions of the epistemic nature of the discipline (McNeil & Krajcik, 2006; Sandoval, 2003). In science explanation studies, two characteristics of evidence—appropriateness and sufficiency—are frequently used (Kenyon & Reiser, 2006; McNeil & Krajcik, 2008; Sandoval, 2003). Appropriateness concerns whether the data cited are relevant to the problem, and sufficiency involves whether sufficient and credible data are provided to warrant the claim. Ruiz-Primo and her colleagues extended this framework to better capture the quality of evidence. They examined (a) type (i.e., what type of evidence did the student provide?),(b) nature (i.e., did the student focus on patterns of data or isolated examples?), and (c) sufficiency (i.e., did the student provide enough evidence to support the claim?). Building on these previous studies, we have characterized explanations with special attention to the roles of evidence: (a) explanations with no support (i.e., no use of evidence), (b) evidence-referring explanations, and (c) evidence-based explanations. Evidence-referring explanations have some forms of evidence, but the connection between evidence and claim is not sufficient or appropriate. For example, students simply refer to activities, information, or data as evidence without elaborating key patterns of the activity and how they support their claim. In contrast, evidence-based explanations are supported by data or observations that are directly related to the object of explanation.

The Depth of Explanations. The third dimension of student explanation is the degree to which explanations provide comprehensive and in-depth accounts of observable phenomena or events. The depth of explanations—providing a best explanatory model of how and why things happen—is the heart of scientific explanation. Drawing upon Braaten and Windschitl’s (2011) framework, we have characterized explanations as (a) “what” explanations, (b) simple causal explanations or “how” explanations, and (c) “why” explanations. “What” explanations focus on describing observations in terms of patterns, without suggesting cause. Simple causal explanations focus on a causal relationship of one observable event affecting another with little attention to underlying mechanisms or principles (i.e., what fundamentally influences observations). “Why” explanations provide causal stories for a phenomenon and use unobservable or theoretical ideas or processes to explain patterns of observations.

Causal Coherence. A good scientific explanation is internally consistent, thus providing well-connected accounts for focal phenomena. Such an explanation is also consistent with generally accepted scientific principles and theories. Using causal coherence as an analytic feature, student explanations can be characterized as (a) explanations with no causation expressed, (b) partially coherent explanations, or (c) coherent and consistent causal explanations. First, explanations with no causation have bits and pieces of information relevant to the problem, but the information is not organized so as to reveal the causal relationships. Such an explicating-type explanation (i.e., “what” explanation) is likely to provide no causation. Partially coherent explanations show a chain of reasoning that is not fully coherent internally or not consistent with other science ideas. For example, students may produce an interesting and plausible theory of how and why things happen, but such theory may be scientifically inaccurate (i.e., inconsistent with generally accepted scientific ideas). In other cases, some part of the explanation may be coherent and logical, but other parts conflict with the referenced data or evidence. Coherent and consistent causal explanations show a logical chain of reasoning; the link between evidence and an explanatory model is adequate and substantial (i.e., internally consistent), and the proposed explanatory model is consistent with generally accepted scientific ideas (i.e., externally consistent).