**ABSTRACT:** This study examines the ways in which teachers provide students with written scaffolds in assessment tasks and the impact of these on students’ abilities to demonstrate a core disciplinary proficiency—constructing evidence-based explanations. Data include 76 assessment tasks designed by 33 science teachers and 707 samples of student work. We found five types of scaffolding embedded in assessments that allowed students to make their reasoning explicit: (a) using contextualized phenomena, (b) rubrics, (c) checklists, (d) sentence frames, and (e) encouraging students to draw explanatory models in combination with written explanation. Analyses showed that all five forms of scaffolding were significantly associated with the quality of student explanation even when controlling for teacher variance and student background. Providing contextualized phenomena had the greatest impact on the quality of student explanations, both by itself and in combination with other scaffolding. The results indicate that strategic combinations of scaffolds can prompt students across all achievement levels to more readily use what they know to produce evidence-based explanations, but that the scaffolding must be of high quality.


**Scaffolding by Prompting Drawing in Combination With Writing (p.10)**

Many assessment tasks allowed students to explain focal phenomena with drawing and writing. We found two different categories for prompts for drawing: One was generic drawing or posterizing (these were at the lower level of sophistication), and the other was modeling (see both examples in Figure 1). Generic drawing asked students to illustrate any aspect of the focal phenomena without clear guidance. Posterizing prompted students to reproduce models that could be found in the textbook and that illustrated some known set of discrete/unproblematic relationships, such as in the rock cycle or a “standard” volcano eruption. Both generic drawing and posterizing were categorized as lower level (Level 1) because this form of drawing, as scaffolding, simply provided alternative ways to express canonical ideas. In contrast, when students engaged in modeling, the work of drawing itself engaged them in higher levels of intellectual work.

Drawing as modeling usually provided designated spaces, structures, or templates for drawing, such as boxes, an outline of the sun, human body, or an enlarged blank inset. In contrast, the samples of student drawing that were coded as posterizing often fail to include any structure or prompt in the task design as shown in Figure 1. A few noticeable characteristics appeared in the prompts for modeling. First, students were prompted to illustrate unobservable underlying mechanisms that cause an observable event or phenomenon. For example, in one assessment of cell membrane mechanisms in ninth-grade biology (see Figure 2), students were prompted to “draw [a] scientific diagram” showing “what is happening that we can’t see!” In some assessments, students were prompted to illustrate something over changes in time (e.g., draw what happens before, during, and after), temperature, and concentration (e.g., low vs. high). Another characteristic was that students were prompted to illustrate how events happened at an appropriate scale (e.g., cellular level, molecular level). Occasionally, students were not prompted to draw at a particular scale; in these cases, students did not use their drawing to explain ideas effectively. For example, in an assessment about cancer, students were prompted to draw...
what would happen to someone who had cancer before, during, and after, the onset of the disease but without specification of the scale. In this case, students illustrated a person at the organism level (i.e., drawing of human body), instead of what would happen at the cellular level, which made the drawings less useful for revealing in-depth explanations of cancer growth.

Figure 1. Drawing in combination with writing.

**Drawing in Conjunction With Writing: Prompting to Attend to Relationships and Underlying Mechanisms (p. 26):**

The combination of drawing with other forms of scaffolding showed substantially different and positive impacts of two different forms of drawing—namely, generic drawing or posterizing (i.e., Level 1) in contrast with modeling (Level 2)—as predictors. When students engaged in posterizing, they illustrated known facts or information from authoritative sources, typically from textbooks. For example, in the rock cycle assessment task in an earth science unit (see Figure 1), most students produced almost the same drawings that simply illustrated the scientific model of the rock cycle. This kind of drawing may direct students to reproduce the canonical scientific models rather than actively engaging in sensemaking processes. In contrast, when students were prompted to construct models that were products of their own sense making through drawing, they produced diverse types of inscriptions that revealed a wider variety of developing ideas, partial understandings, and different ways of reasoning. For example, in the assessment about buoyancy (see Figure 1), students were prompted to first draw a person floating in salt water, then in fresh water, and to describe all the forces acting on the person, and then to write their explanation of how the density of a fluid affects the buoyant forces. Engaging in this assessment task, students used their drawings to explain the focal phenomenon (i.e., why people float higher in salt water than in fresh water) by highlighting the underlying mechanism (i.e., how the density of a fluid affects buoyant forces in relation to the force of gravity).
We theorize that “drawing as modeling” provides support for student reasoning in the process of making sense of relationships among events, structures, properties, and concepts. Modeling prompts students to identify unobservable events/processes and then connect them causally to patterns of observation (Windschitl, Thompson, & Braaten, 2008). The prompts to illustrate changes either over time or between conditions guide students to express the relationship between unobservable events and changes in the state of the systems across conditions. All of these reasoning tasks are challenging for learners new to reasoning with scientific practices.

Previous studies have suggested that scaffolding different modes of students’ expression of ideas, such as drawing, open up opportunities for students who may have difficulty in using scientific language. This is one of the major barriers in science learning (Moje et al., 2001; Rosebery et al., 2010). Our analyses suggest that drawing allows students to show more of what they know, but it needs to be prompted in particular ways to support students’ representations of evidence-based explanations.