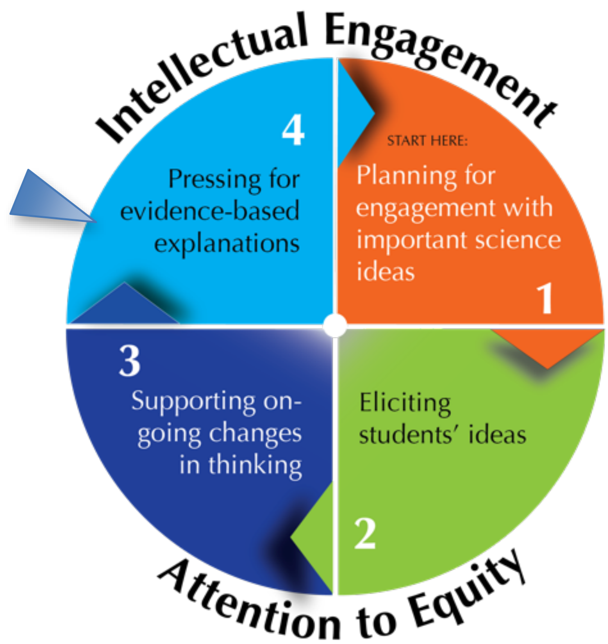
Teaching practice set: *Pressing for evidence-based explanations*

Overview



This is the last of four practice sets that make up the framework for ambitious science teaching. In the first practice you unpacked your curriculum to identify "big ideas," then created an anchoring event that students could develop an explanation for. In the second practice you elicited students' ideas, partial understandings, and background experiences that were relevant to the anchoring event and other target science ideas of the unit. Then, throughout the middle of the unit you used repeated rounds of the third practice, which was helping students change their thinking by making sense of activities, to piece together component ideas for the underlying explanatory model.

This final set of practices—*pressing for evidence-based explanations*—is designed to help students rally different kinds of evidence in support of their culminating explanations. The two practices involved are:

1) Constructing and evaluating claims
2) Drawing final ideas together in models and explanations

Goals

The goals of this practice are:

- Support students in using evidence to account for different aspects of their explanatory model.
- Hold students accountable for using multiple sources of information to construct final explanatory models for the anchoring event.
- Engage *all* students in authentic disciplinary discourse around constructing and defending explanations.

When do you use these practices?

This sequence of events happens with about two days left in a unit of instruction. Some parts of this discourse, especially the talk about evidence, should certainly be used at other times during the unit when you are trying to get students to support claims they are making. The reason to leave a couple of days open *after* these practices, is so that students can then apply their explanatory models to events or processes that have *not* been to target of study so far (to understand how explanations can be generalizable) or to use the model to design a further study of interest to them, or to use the model to design a solution to a problem.

How to enact these practices

On the following pages we provide a description of each practice and a possible sequence of talk and action to guide you. We emphasize that these are not scripts.

1. Constructing and evaluating final claims

In this practice the teacher asks students to be prepared to defend one key aspect of their explanatory model by using relevant evidence from a public record such as a summary table. This part of an explanation is called a **claim**.

What is a claim? A claim is a statement about some event, process, or relationship in the natural world that you believe to be true. A claim, however, is not simply a statement about trends in data.

You can think of a claim as a small part of a larger explanation. For students just beginning to use evidence, it is easier to focus on using evidence to support a specific claim rather than supporting an entire explanation (which can be composed of several integrated claims).

This part of the conversation starts with you saying something like: "I'd like you to select one part of your current explanation and describe evidence from one or more activities that supports that part of your explanation." You should provide examples of what counts as a claim, what counts as evidence, and how you can support a claim with that evidence.

<table>
<tr><th colspan="3">Teacher:
"Please use your [notebooks or the summary table] to identify your claim, then cite an activity or a science idea that supports that claim."
To do this, students will need a written guide that prompts them to 1) describe what aspect of the explanation they are supporting, 2) what evidence they are drawing upon, and 3) how the evidence "fits" with that part of the explanation (the reasoning linking the two).</th></tr>
<tr><td>If students can't seem to identify anything that would count as evidence—

Teacher: "Let's focus on an activity or idea we've talked about [refer to summary table] that helped you understand some part of the explanation. Can you think of one? If that activity made you think that [state science principle in students' words] why does that convince you that this [part of the explanation] is true?"</td><td>If students cite an activity as evidence, but don't provide any reasoning (very common)—

Teacher: "OK, so you've named the activity or idea, what about it convinces you that [this part of the explanatory model] is accurate? How does the activity or science idea fit with your theory?</td><td>If students are able to identify evidence and begin reasoning about how it supports part of the explanation or model—

Teacher: "Can you tell me more about your thinking here? Would you say your evidence is strong or convincing? Why or why not?"</td></tr>
</table>

Following the first part of this practice, perhaps the following day, teachers would re-assemble the class and have groups of students compare claims with one another. These groups could defend one particular part of the explanation (their claim) to the class, cite the evidence used, and the reasoning they used to link the evidence with the claim (this is another instance in which sentence frames or other language support is effective). The teacher could select groups who have contrasting explanations to present publicly and ask the entire class to comment on the use of evidence and explanatory coherence. Questions here might be "What evidence appears to be convincing and why?" "What gaps do we still have in our models/explanations?" "What is another way to interpret that evidence?"

In some classrooms, we have found it helpful to send one member of each group to another table as an "ambassador." The role of this person is to listen as the group presents their claim, evidence, and reasoning. The ambassador then offers feedback about the clarity of the claim, the strength of the evidence and the effectiveness of the reasoning. The ambassador then returns to her/his own group and shares what they heard at the table they visited. This strategy is challenging for middle school and high school students, but even if this activity is roughly enacted, it still helps groups hear more examples of claims, evidence and reasoning. The simpler alternative is to have student groups share out in a whole class setting and get feedback from teacher and peers. There are many ways to structure this so that all students participate and don't simply sit passively as the other groups present.

2. Drawing final ideas together in models and explanations

In this practice, you are pressing students for a *final explanatory model* (drawn) *and a gapless explanation* (written). The model depicts, in words and drawings, a chain of reasoning linking observations and information from a variety of sources (first-hand data, second-hand data, information resources, known facts, concepts, laws, etc.) with theoretical (unobservable) events, structures, or processes. We emphasize—*the model should show how the unobservable (the causes) and the observable (the effects) are linked*.

In the first step of this practice the teacher asks students in small groups to finalize their models, incorporating all relevant ideas and forms of evidence they have encountered during the unit. Even though the teacher and students have revised the explanatory models perhaps once during the unit, creating the final version would be difficult without special scaffolding and tools. Scaffolding moves might include:

- guides for what to include in an explanation (the use of specific science language, reminders to describe what is not observable)
- providing a model template for drawing into, and a designated space for students to write their explanations
- dividing a phenomenon and its explanation into "before, during and after"
- special tools should include student-created explanation checklists and a table that summarizes ideas and different type of evidence assembled across the unit (summary table).

The initiating talk by the teacher is something like this: "Let's work now in our small groups to update our models. Please use the explanation checklist to help you include all the important features and ideas in the model and in your explanation"

In the second step of this practice, the teacher circulates among groups of students and prompts them to consider gaps or contradictions in their final models and explanations—"You seem to have a beginning and an end in your explanation, but what is happening in the middle?" "This part of your model looks like it may not 'fit' with the others."

It is important to have students actually use the tools and scaffolds you provide. Ask them when you visit tables if they have included in their models and written accounts everything that is on the explanation checklist. If they are missing a key part of their model, point to the summary table and ask them to recall what they learned in a particular activity that could fill that gap. Students will not always do these things without prompting.

Teacher: IMPORTANT: 1) As you visit these small groups, avoid being the person who stitches together their partial understandings. Prompt them instead to pay attention to things they may have overlooked like ideas, relationships, outcomes of activities, etc. 2) Aim to involve all students in these conversations.		
If **students** in these small groups give only a single word or phrase as an explanation— **Teacher**: "Which means what for this situation?" or "Why is that important?" Then ask others to add to or comment on this idea.	If two **students** each give a part of an explanation— **Teacher**: Ask the students to put the ideas together in a sentence. OR think of yourself as the person who adds connecting words to the kids' sentences…if one student contributes an idea, then you could say "and?" or "which means?" or "and that is important because?" Caution here: Avoid having the student who best understands the explanation being the only one who gets to contribute.	If a **student** provides a full gapless explanation— **Teacher:** Ask another student in the group to do the same, only in his or her own words. OR ask if there are any alternative explanations that are possible, why or why not?

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FYI: What the research says about making sense of activity (note, this is in "researcher language")

If you are interested in the origins of these types of discourse practice, we present here the research background that supports it. We explore teaching practices described in the literature that support the practices of explanation and argument. Explanation and

argument are scientific practices that represent "benchmarks" of knowledge-building in a community. In the classroom, these rhetorical structures coordinate the conceptual, epistemic and social resources of the collective to explore the questions "What do we *now* know?" and "Why do we believe it?" We first unpack the idea of explanation by pointing out the often confusing overlaps between the colloquial and the scientific uses of the term. Without attention to these varied meanings, studies of how teachers support "explanations" can be observing and promoting very different types of practices.
There is considerable ambiguity in the research literature and in classroom practice around the various meanings of explanation. This may be due to the ways the word "explain" makes its way from everyday conversation into the classroom. In the science education literature, it is common to see "explanation" used as a clarification for the meaning of a term or laying out of one's reasoning about a problem. For example, in science classrooms students are frequently asked to "explain their reasoning" while solving a problem ("Can you explain how you calculated the amount of force needed to lift that load with the pulley system?"), to "explain the meaning" of a technical phrase, or to "explain the results" of an experiment. Providing such explanations—or more properly *explications—is* in many ways an authentic communicative practice in the daily work of scientists who clarify ideas and findings for each other and for various audiences (Knorr-Cetina, 1999; Latour & Woolgar, 1979), however these products of intellectual work are qualitatively different from a scientific explanation.

The practice of constructing scientific explanations that account for natural phenomena involves more than explications of meaning (Braaten & Windschitl, 2011). For these purposes, causal and statistical explanations are used frequently in formal science. *Causal* explanations reference observation and patterns in data, and explicitly seek underlying reasons for these (see Salmon, 1989). By "underlying" we refer to entities, processes and properties that are not directly observable. In school settings, causal accounts use underlying mechanistic properties, processes, etc., to explain observable phenomena (Driver et al., 1996; Hammer, Russ, Mikeska, & Scherr, 2008; Perkins & Grotzer, 2005). Assembling these explanations can make students more aware of scientific epistemology—specifically the conjectural relationship between observation and theory. The mechanistic view may not always be appropriate in elementary settings where "causes" for events may well be visible and concrete (sources of pollution in a local stream for example). Even without invoking unseen influences or using conceptual language, young learners can collect data, evaluate evidence, and argue for coherent explanations. These exceptions notwithstanding, for the purposes of school science, causal explanations can be conceptually rich and support challenging epistemic conversations about data (the observable) and theory (the unobservable).

Not all branches of science, however, seek mechanistic causal explanations. Fields such as computational biology and quantum physics utilize statistical and probabilistic reasoning to make sense of phenomena for which there may not be any definable cause or regular mechanism (Knorr-Cetina, 1999; Nersessian, 2005; Pickering, 1995). Other fields, such as classical physics, employ laws (statements of observed regularities, often codified in equations) rather than underlying causes to account for the operation of simple machines or to describe the motion of objects. Both statistical and causal explanations require that teachers press for reasoning that goes beyond description; but studies of science teaching rarely clarify what explanation means or contrast their use of the term with other possible meanings. This of course makes it difficult to look across studies to make judgments about effective scaffolding or supportive discourse.

Causal or statistical explanations of authentic (rather than generic) events require time and tools and opportunities to think with others. In nearly all studies where researchers have had a hand in designing explanation-oriented activities, the phenomenon being explained required a succession of observations or experiments, the coordination of multiple science concepts, and *repeated opportunities* by students to reason with these resources in order to refine their explanations or models. This *drawing together* of learning experiences that have occurred over time is not common in schools; students are most often asked to "explain" the results of a single experiment (which typically is a restatement of data trends) and then move on, rather than using experimental results together with other observations and ideas to revise thinking about a phenomenon of some richness and complexity (Banilower, Boyd, Pasley & Weiss, 2006; Bowes & Banilower, 2004; Roth & Garnier, 2007).

Scientific argument incorporates explanation with evidence and reasoning. Here the goals are to articulate one's understandings and work to persuade others, in order to collectively make sense of the phenomenon under study (the literatures on supporting explanations and arguments have in some cases overlapped, but not without some controversy about whether they should be treated in classroom practice as distinct forms of rhetoric; see Osborne & Patterson, 2012 and Berland & McNeill, 2012). Engaging students in argumentative discourse is difficult for a number of reasons. When confronted with data sets, students struggle to select appropriate observations to use as evidence (McNeill & Krajcik, 2008) or provide sufficient evidence in written explanations (Sandoval & Millwood, 2005). Even when students can use evidence to make sense of phenomena and articulate those understandings, they do not consistently attend to the goal of persuading others of their understandings (Berland & Reiser, 2009). Moreover, students find it difficult to provide reasoning for why they chose particular forms of evidence (Bell & Linn, 2000; McNeill, Lizotte, Krajcik, & Marx, 2006).

Combining explanation and scientific argumentation is complex and requires a learning environment designed to elicit student participation in this practice with specific norms in place for criticizing ideas, ways of talking, and relevant tools for the difficult aspects of this work. However, when traditional school routines encourage students to articulate explanations there is rarely the expectation that these will be challenged or judged against other explanations (Driver et al., 2000; Lemke, 1990). Persuasion requires social interactions that are often inhibited by traditional classroom interactions (the emphasis on "correct" answers, the norm of one or two-word utterances by students). Because argument, or simply talk about evidence, is not common, teachers themselves have had few opportunities to use these specialized forms of rhetoric as learners (Zembal-Saul, 2009). Sampson & Blanchard (2012) found for example that secondary science teachers were not adept at using data to support reasoning about explanations of natural events.

Some of the teachers (most of whom have undergraduate degrees in science) reported never having participated as learners in classes where explanations had to be evaluated. McNeill (2009) recommend that students be provided with both general support for the Toulmanian argumentation framework of “claim, evidence, and reasoning” as well as context-specific support focused on “what counts” as each of those components for a particular scientific domain. These complementary supports reduce the complexity of the instructional context by defining an otherwise ambiguous and unfamiliar problem space, which can then enable students to have greater success with the practice of argumentation. Zembal-Saul (2009) has reported that providing such frameworks to elementary teachers helps them not only stimulate talk about evidence with young learners, but also to attend to student thinking. More generally these researchers recommend that teachers consider how to develop simpler instructional contexts with supports that make the expectations for participation explicit. Within these situations, teachers can help students understand what counts as appropriate and sufficient evidence for a particular scientific claim. Thus, *framing* the activity once again becomes important. Ford and Wargo (2012) draw upon the interactionist literature to suggest the importance of teachers laying out for students “what is being done with knowledge” in a particular classroom routine. Over the past 20 years, this idea of teachers making clear, in talk and in practice, what everyone’s role is in the production of knowledge, and whose knowledge will be valued, shows up consistently in classrooms where widespread student participation and learning are evident (see Brown & Campione, 1994; Engle, 2006; Magnussen & Palincsar, 2005; Rosebery et al., 2010).

In classrooms where explanation and argument are well supported over time, one can see how this intellectual work is intimately related to other scientific practices, and how conceptual, social, epistemic, and material dimensions of the practices can be skillfully coordinated to support the advancement of understanding. A case in point for incorporating these ideas into the design of instruction comes from Radinsky, Oliva and Alamar (2010) who describe a middle school classroom in which students were developing models for the movement of the earth, sun, and moon. The teacher and students began co-constructing an initial explanation by reviewing the community’s shared assumptions about the relevant science ideas. Students then engaged in successive inquiries; they referenced peers’ ideas and experimental results as warrants for changing their explanations, building from isolated ideas—attributed to specific individuals—toward a coherent whole class model, which in turn was attributed to the community. The study identified the means by which proposed explanations were taken up and developed by the class, including using multiple shared representations, leveraging peers’ language to clarify ideas, and negotiating the language and representations for new, shared explanations.

Summary

As with so much of science education research, the vast majority of empirical research focuses on what students are able to do. The parallel literature about the knowledge, resources, and judgment teachers deploy in supporting explanation and argument is remarkably thin. Forms of support for students’ explanation and argument is largely inferred from studies of students and how they respond to special interventions that researchers introduce in the classroom. From a practice-based perspective, such gaps in the literature compromise efforts to improve teaching.

Also unresolved in this literature is how teachers can walk the fine line between having students synthesize well-supported explanations, without having them simply reproduce textbook accounts. The reproduction of a canonical explanation requires little more than memorization, aided in some cases by modest levels of comprehension. This illustrates yet another reason why units of instruction might be best grounded in complex but accessible phenomena rather than well-structured problems lifted from the pages of the textbook. In studying force and motion for example, the fully elaborated explanation for why karate champions can break boards in some cases but not in others has a number of interconnected conceptual threads (acceleration of one's hand, equal and opposite reactions, the "give" of the board, force per unit area, the conservation of energy, and more...) that must be interwoven to create a coherent account of martial arts success or failure. The potential richness of such explanations is precisely because they come from familiar everyday contexts with the attendant details that require more inter-articulation of ideas than back-of-the-chapter problems. For the teacher then, there is a delicate balance between supporting the construction of explanations that may take a variety of legitimate forms, while ensuring that scientifically rigorous ideas and language are integrated into students' explanations. There are case studies of teachers successfully navigating this territory (Grotzer & Basca, 2003; Magnussen & Palincsar, 2005; Rosebery et al., 2010; Stewart, Cartier, & Passmore, 2005) but there have been few systematic syntheses of what professional reasoning and practices are involved. This form of expertise remains elusive to define, to represent, and consequently to support in other professionals.

There are several reasons why supporting students' evidence-based explanation should be considered a core teaching practice. From a disciplinary perspective, explanation of natural phenomena is the ultimate aim of science. From a learning perspective, both explanation and argumentation extend learners' conceptual understandings and engage them in the reasoning and discourses of the discipline. Students mobilize a range of conceptual resources, consider how to link the unobservable with the observable, and to argue from evidence.

Research-based Principles that should guide all variations of this practice

- Causal explanations in science draw upon multiple forms of evidence and multiple ideas.
- This coordination requires specialized tools for organizing ideas.
- Students benefit when the teacher is explicit about what counts as evidence, how it is used to support explanations, and in general what the rules of epistemic talk are in the classroom.
- Explanations for *contextualized* events or processes can take many legitimate forms and can be expressed in different ways. This heterogeneity in student expression stimulates comparative reasoning about the understanding of scientific concepts and explanatory coherence.
- Reproducing canonical explanations can result in fragile and short-lived understandings.

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