Teaching practice: Eliciting students’ ideas and adapting instruction

Teachers have regular routines that are referred to as practices. We have studied how expert teachers work with their students, and paid attention to moves master teachers make that stimulate student engagement and learning. These educators have been particularly successful in getting quiet and/or marginalized students to regularly participate in reasoning and sharing ideas. All the practices we describe to you are grounded in research and in the work of experts. You will see that they are unlike traditional forms of instruction.

The practice we begin with here is eliciting students’ ideas and adapting instruction. Teaching practices all have common features. They have goals for student thinking or participation, they have a recognizable sequence of interactions between the teacher and learners, and they have characteristic tasks, talk, and tools that are used. Before we go on, we note here that you have already read (or should read) about the practice called planning for engagement with big science ideas. We assume that you have already organized your unit around a core set of science ideas and selected a compelling phenomenon that your students will develop evidence-based explanations for.

Overview
This practice—eliciting students’ ideas and adapting instruction—is used at the beginning of a unit of instruction. The goals of this practice are to 1) reveal a range of resources (ideas, experiences, language) that students use to talk about a set of science ideas, 2) to activate their prior knowledge about the topic, and 3) to use this information to adapt further instruction.

There are four dimensions of students’ experiences that could shape the direction of instruction. You should try to elicit these:

• students’ partial understandings of the target ideas
• students’ alternative conceptions about the target ideas
• students’ everyday language that can be leveraged to help them understand scientific ideas
• students’ everyday experiences related to the core science idea that can be leveraged in later instruction.
**Why this practice?**

If your main objective as a science teacher is to change students’ thinking over time, then you need to know what your students understand about the core science ideas in the first place. You as a teacher can’t work on students’ thinking if you don’t know what they are thinking.

<table>
<thead>
<tr>
<th>Topics from curricula</th>
<th>Consequential aspects of the core science ideas, that can be leverage points or stumbling blocks for learning— these are what you want to elicit ideas about</th>
<th>Puzzling event, story, question, image, activity, and sample starter questions</th>
</tr>
</thead>
</table>
| Plate tectonics       | • Earthquakes transmit energy  
  • This energy travels in waves  
  • There are different kinds of waves that affect man-made structures differently  
  • Earthquakes result from sudden shifts in tectonic plates  
  • These plates make up the earth’s crust                  | Video taken in Japanese grocery store during an earthquake.  
  Sample questions:  
  --What is happening to the items on the shelves at different times?  
  --What might cause the different types of shaking?  
  --Do we know how close this store was to the center of the earthquake? |
| Gas laws              | • All gases are made up of molecules  
  • Molecules are in constant motion  
  • Heat energy can make molecules move faster  
  • In contained systems, molecules bump up against container, causing a force  
  • There are forces exerted from outside the container too  
  • Changes in volume or temperature create changes in frequency of the “bumps” | Can crushing activity (heating water in soda can then inverting it in cool water bath)  
  Sample questions:  
  -What do you see?  
  -What would happen if we did not heat the can first? Why?  
  -If you had microscope eyes, what would you see? |
| Forces, dynamics      | • Anything with mass exerts gravitational force on other nearby objects  
  • Forces can be pushes or pulls by another object, or by magnetism, or gravity  
  • Some objects may not move because they have balanced forces acting upon them from opposite directions | Roller-blader going down a hill.  
  Sample question:  
  -What are the different pushes or pulls that are acting on this person? |
| Natural selection     | • All organisms have structures or behaviors that help them survive  
  • Usefulness of structures or behaviors are applicable in particular environments  
  • If environment changes, the traits may no longer help the organism to survive  
  • Organisms pass down traits to offspring if they get a chance to reproduce | Story about peppered moths in Industrial England.  
  Sample task:  
  - In small groups, after reading peppered moth story, hypothesize what you think has happened to the populations of these different colored moths today, and why. |

**How to get ready to engage students in this discourse:**

Once you have selected your core ideas and an anchoring event/process, you have to do some creative work to develop a rich task for students—a task that should have the
potential to open up the broadest range of thinking by students on the target ideas. The rich task can be questions directly about the anchoring event itself. Or, you can select a related phenomenon, demonstration, story, object, puzzle, image, or experience that can be an entry point for conversations and speculations by students about the core science ideas. The task should be about something the students have experienced before, can relate to in some way, or will experience together as part of the task.

A rich task has two characteristics.
- **Accessibility.** Accessibility means that students can be expected to know enough about the task or question to reasonably speculate or hypothesize about it.
- **Power to reveal consequential ideas.** This means the task or question can get students talking about facets of understanding that will be crucial in developing the core ideas of the unit (i.e. reveals partial understandings, alternative conceptions, everyday language, everyday experiences related to the target idea).

Above are examples of topics commonly found in curricula (left-hand side of table). In the next column are core ideas associated with these topics, and on the far right are samples of scenarios, rich tasks and questions that can open up students’ existing ways of thinking to you. These tasks and questions are accessible, in that students can use everyday knowledge to speculate about important aspects of the core ideas through such tasks.

**What is the sequence of talk and tasks?**
There are 5 phases to the practice of eliciting students’ ideas and adapting instruction. Each accomplishes an important goal in probing and extending student thinking.

These are
1. Introducing the puzzling event and eliciting observations
2. Eliciting hypotheses about “what might be going on”
3. Pressing for possible explanations
4. Summing up ideas and selecting the forms of ideas to make public
5. Adapting further instruction (after class)

On the following pages we provide a description of each phase and a possible sequence of talk to guide you. It’s important the first time you try this with students that you anticipate their general responses and plan for them. That’s what the conversation trees are good for (see the next page).

We emphasize that these are not scripts. In our work with teachers we have never seen the same conversation with students twice, even using the same topics and curriculum. Some of these phases may take place in less than two minutes, others take longer. Expert teachers flow smoothly and seamlessly as the conversation in one phase sets up the conversation in the next phase.
It’s also important to note that teachers are trying to get students to talk to each other, not just to respond to the authority figure in the room. This happens in small groups and can be designed into whole class conversations.

**Introducing the puzzling event and eliciting observations**

Get the demo, video, image, or activity ready. If applicable, begin by referencing how today’s activities build upon or are connected to what has recently been studied in class. Then start with:

- “I recently saw something that puzzled me…”
- “We are going to do an activity that will help us understand…”
- “Let’s think about this story and what kind of sense you make of it…”

As the demo, video, image, or activity is enacted, you start observation questions—and only observation questions—so all students feel safe contributing.

**Diagram: Observational Questions**

- What do you see going on here?
- What did you notice when ___ happened?
- When did ___ occur?
- Where did ___ happen?

Students cite relevant features

Students cite irrelevant ideas or indicate they cannot understand the representation/problem

Redirect focus to particular features.

Be explicit about conventions used in representations.

Students give inferences rather than observations

Refocus them on observation for now; help distinguish between obs. and inference.

Can you say more?

Begin to mark some specific features and vocabulary if necessary. “OK so we agree that…”
Eliciting hypotheses about “what might be going on”

In this next step, you move beyond observation and description. Here you ask students to extend their thinking to “what if” scenarios or thought experiments in which key elements of the story, activity or puzzle are changed in ways that will reveal more about their thinking. Note: This set of questions and tasks could be done in small group work.
Pressing for possible explanations

In this step you are explicitly asking for causal hypotheses. After an initial conversation, have students in small groups of two or three draw out what they think is happening. Be prepared to offer them a template, but do allow them to express their current understandings rather than reproduce what might be in a textbook. Treat these ideas and drawings publicly as hypotheses so students feel more at ease offering them.

- What might be going on here that we can’t see?
- Why do you think this happens this way? (emphasize cause)
- What do you think causes ____?

Students offer simplistic cause-effect: Example: "Why does water boil?" "Because you put it on the stove."

Students offer explanations congruent with scientific explanation

Subtly mark and amplify the response to bring it to the forefront of discussion. "So you think that ____ has something to do with it..."

"You are telling me the beginning and the end of the story, what happens in the middle to cause____?"

Kids offer explanations that involve alternative conceptions.

Note this respectfully without elaborating on it.

If you can readily think of an observation that immediately puts this alternative conception into question, then offer that. "But did you notice____?" "How would your theory be possible if...?"
Summing up and selecting the forms of ideas to make public

In this step you ask your students to help you
1. summarize what ideas have been put “on the table”
2. consider what questions you have now about the phenomenon, and,
3. identify what kinds of information or experiences you might need to have to learn more.

In the mid-to-latter stages of this practice the teacher would make some form of students’ thinking public. This might be a list of possible hypotheses that students expressed or a sparse consensus model in pictorial form. Both of these are community tools for further intellectual work; either one can be developed, added to, subtracted from, or re-organized by students as the unit progresses.

Option 1:
“What are some things we are not sure about here?”
“How could we test our hypotheses?”
“What kinds of information or experiences do we need to learn more?”

Option 2:
Public models/hypotheses: Find "clusters" of similar student ideas and record them publicly as: What do we think we know?
Refer to these as hypotheses or models that we need to "work on".

Option 3:
Private models/hypotheses: At end of class, give all students an exit slip (can be an index card), Re-pose questions from the "Pressing for an explanation" conversation.
You can have them represent their ideas in text or labeled drawings. "If you have an idea that is your own, this is the time to let me know."
Adapting further instruction

After class the teacher takes stock of students’ contributions. The teacher considers what students expressed in terms of partial understandings, alternative conceptions, linguistic resources (academic language, everyday vocabulary, ways of arguing) they used to make sense of the initial puzzle or event, and everyday experiences that they related to some aspect of the phenomenon (or perhaps vicarious experiences from the media).

The teacher must weigh out the possibilities of working with these various ideas and experiences to develop the content storyline, based on their prevalence among the students, the enthusiasm with which students referenced these resources, and their relevance to the science itself. The direction from which the anchoring phenomenon was thought to be best approached by the teacher may no longer be optimal after doing this type of quick analysis. The sequence of instruction is, then, co-produced by the teacher and the students.

We finish this section with a note of caution. Certain discourse moves or forms of classroom talk can be counter-productive in accomplishing the goals of eliciting student ideas:

1) Any initial use of scientific language that shuts students out from the conversation (e.g. p-waves, atmospheric pressure, force systems, natural selection).
2) Lifeless requests for definitions and vocabulary—“Who can tell me what [photosynthesis, chemical equilibrium, torque, sedimentation] is?”
3) Directionless questions: “How many of you have ever heard of _____?”
4) Premature attempts to get students to talk about abstractions—“What do you think the structure of an atom is?”
5) Sniffing out right answers (I-R-E dialogue).

FYI: What the research says about eliciting practices (note, this is in “researcher language”)
If you are interested in the origins of this type of discourse practice, we present here the research background that supports it:

An important goal of teaching in science is to help students refine their thinking about the natural world over time. Relevant to this undertaking is one of the most robust findings in all of educational research—that what a person already knows about the subject matter has an enormous influence on how they respond to instruction and what they eventually learn (Ausubel, 1968; Bransford, Brown, & Cocking, 2000; Gage, 2009). It seems logical then that teachers should cultivate practices that reveal students’ existing ideas and just as importantly their ways of reasoning about phenomena.

Post-Sputnik science education literature barely acknowledged that students came to the classroom with conceptions relevant to the curriculum, but by the 1980’s, new theories
had developed around the assumption that children’s minds were at work outside of school hours and often on science-related ideas. This began a wave of studies about students’ conceptions on every scientific phenomena imaginable (Anderson, 2007). Theories about children’s ideas gradually evolved from being descriptive, to explanatory, to instructionally prescriptive (Hewson, Beeth, & Thorley, 1998; Posner, Strike, Hewson, & Gertzog, 1982). Eliciting what students think became important, but it was couched in terms of revealing prior conceptions about natural phenomena that would often require special forms of remediation—this weak form of attention to student ideas is alive and well today in the form of pretests. Although limited in their aims, strategies developed during this time began to signal that teachers should be interacting with students’ ideas during instruction rather than merely evaluating them.

The focus on revealing and confronting errant learner conceptions gradually shifted, first to a recognition that in the mind of the learner pre-existing conceptions were plausible and, even though fragmented or inconsistent in application, had explanatory power in familiar everyday contexts (NRC, 2005; Smith, diSessa, & Roschelle, 1993). But even this literature tended to focus on distinctions between students’ conceptions and those of experts without considering the full array of cognitive, linguistic and experiential resources that students bring to the classroom (Atwater, 2000; diSessa, 1993; Louca, Elby, Hammer, & Kagey, 2004; Metz, 1995, 2004; Tytler & Peterson, 2004) and how these might be put to use in creating more coherent and flexible theories about the world (Danish & Enyedy, 2006; Hammer & Elby, 2002; Tang, Coffey, Elby, & Levin, 2010).

The idea of “resources” now appeals to the research community because it acknowledges a broader range of assets that students work with in developing their own understandings. Scholars taking this view draw upon the growing literature on science learning experiences outside of formal schooling (NRC, 2009) and note that this line of thinking has become increasingly resonant with emerging theories of student agency in learning. Maskiewicz and Winters (2012) describe one class of resources as concrete, phenomenon-specific intuitions and experiences that can serve as referents to inform class-constructed scientific theories (diSessa, 1993). Other resources are epistemic (e.g., that knowledge about the natural world can be constructed rather than received from authority figures) and hypothesized to support the ability to participate in activities related to the generation of knowledge (e.g., analogy work, argumentation, modeling) that can guide the direction of the classroom’s inquiry activity (Louca et al., 2004; Hammer & Elby, 2002; May, Hammer, & Roy, 2006). Maskiewicz and Winters (2012) use the term “resources” rather than “expertise,” “knowledge,” “beliefs,” “skills,” or “conceptions,” to emphasize that students’ contributions are often composed of small-grained, disjoint, context-sensitive ideas that can, with instructional guidance, serve as building blocks for productive theorizing. Students’ ideas are resources not just for teachers but for their peers as well. To be used as such, thinking has to be made visible to others (Danish & Enyedy, 2006; Linn & Hsi, 2000; Radinsky, Oliva & Alamar, 2010) and teachers have to help everyone in the classroom develop the habits of appropriating and critiquing the partial understandings of others.
Being productively responsive to what students bring to the classroom is now being viewed as fundamental to effective teaching. Responsiveness, however, has several meanings, some of which do not necessarily advance the goals of ambitious teaching. It can mean showing respect for students’ ideas, letting all students have a chance to share their thoughts, or being affirmational in classroom conversations. These moves can be seen in the videos of five American science classrooms released by the TIMSS Project (Roth et al., 2006). Each teacher is indeed respectful of student contributions, but there are no instances in which a teacher (or peer) treats a student idea as a resource for the thinking of the class. Instead, student questions are treated as requests for information—queries that should immediately be answered (or otherwise dispatched with so as not to disrupt the flow of instruction). Responsiveness is still vaguely conceptualized in the literature and in need of a more explicit definition that is congruent with ambitious teaching. Pierson (2008), for example, characterizes responsiveness as the ongoing “attempts to understand what another is thinking, displayed in how a conversational partner builds, questions, probes, clarifies, or takes up that which another has said” (p. 25). A responsive classroom is guided in part by the ideas, questions, and everyday experiences that students relate to the subject matter. The teacher listens carefully to students’ talk, considers how to represent ideas publicly for examination by the whole class, and assesses what possible instructional moves might be warranted by the ideas in play. Despite this attention to decision-making by the teachers, the expert practitioner is becoming defined, in part, by the ability to turn over the intellectual work to students by having them consider, respond to, and challenge each other’s ideas (Lampert, 1990; van Zee, 2000).

The dialog we refer to is not natural for students or teacher; it requires social arrangements and new registers of talk that facilitate sharing and critique. There are a number of examples in mathematics, science, and literacy, in which teachers use responsive strategies to transform how children talk, interact, and, ultimately impact what they learn (Ball, 1993; Jacobs, Lamb, & Philipp, 2010; Pierson, 2008; Sherin & van Es, 2009). From an equity perspective, teacher moves such as eliciting students’ ideas, asking students to explain their reasoning, and asking students to reflect on their current state of understanding has lead to deeper engagement in the content (Atwater, 2000; Duschl & Duncan, 2009) and to sophisticated reasoning by learners who do not typically participate in the academic life of the classroom (Chapin & O’Connor, 2004; Cobb, Boufi, McClain, & Whitenack, 1997; Lampert, 2001; Lee, 2001).

Creating a responsive environment cannot be accomplished without specialized repertoires of talk that teachers and students share some competence with. It is hard to overstate the important role that talk is now recognized to play in all aspects of science instruction. Recent research in the areas of student learning, expert teaching, and knowledge construction in the disciplines, has converged on the notion of classrooms as communities in which the careful orchestration of talk by teachers mediates increasingly productive forms of reasoning and activity by the students (Engle, 2006; Leinhardt & Steele, 2005; Minstrell & Kraus, 2005; Mortimer & Scott, 2003; Sfard & McClain, 2002). In this view, sense making and scaffolded discussion are “the primary mechanisms...
for promoting deep understanding of complex concepts and robust reasoning” (Michaels, O’Connor, & Resnick, 2008, p. 284).

This discursive mediation is also critical for engaging learners in the characteristic practices of the discipline—that is, “to formulate questions about phenomena that interest [students], to build and critique theories, to collect, analyze and interpret data, to evaluate hypotheses through experimentation, observation, measurement, and to communicate findings” (Rosebery, Warren & Conant, 1992, p. 65). When students are allowed some control over discussions, and are scaffolded to engage with one another in productive ways, they determine the range and flow of ideas, explore their emerging understandings of the scientific question under study, and can “go public” with confusion. Driver et al. (1996) observed that “[s]tudents benefit from considering a range of ideas that their classmates may have to describe the same phenomenon and developing ways of evaluating these explanations. Through such interactions, students can come to appreciate the criteria on which judgments in science are made” (p. 22).

The positive effects of productive discursive practices on science learning and achievements of all students, particularly those of non-dominant groups is well documented (Ballenger, 2009; Gallas, 1995). These forms of discourse are rare, however, even in the classrooms of experienced teachers (Alexander, Osborn, & Phillips; 2000; Banilower, Smith, Weiss, and Pasley, 2006; Weiss et al., 2003; Roth & Garnier, 2007). Teachers often dominate the talk environment and in doing so reduce opportunities to learn about how their students are thinking and what resources they are reasoning with. In common practice, students are rarely asked to substantively engage with one another’s ideas (e.g., Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999; Hogan, 1999; Lemke, 1990). This inhibits their willingness to do so when put in situations that would otherwise facilitate these interactions (Hogan & Corey, 2001; Rosenberg, Hammer, & Phelan, 2006).

All this suggests that teachers who want to “work on students’ ideas” require not only require specialized forms of content knowledge, discourse skills, and a workable relationship with students, but also a student-thinking lens on their own practice. As we noted earlier, large scale observational studies indicate that most teachers are currently not eliciting students’ ideas or experiences as resources for instruction. As with other aspects of ambitious teaching this is not surprising because they have likely never seen it modeled, it is not typically part of teacher training, and these nuanced and interactive moves can hardly be specified in curriculum materials. Even with extensive training many experienced and novice teachers remain unable to use students’ ideas (Penuel, et al., 2009; Roth et al., 2009; Thompson, Windschitl & Braaten, 2013). This points to some of the most important unanswered questions in science teaching research. How and why do teachers take up a student thinking focus? What does it afford them in their practice and what are the implications for student learning over time? Why are some teachers able to take up such a perspective, while others appear unwilling or unable to do so? Teacher subject matter knowledge must play a role in responsive instruction and ambitious teaching in general, but this relationship is far from clear.
Summary
The field is moving from an image of teaching as revealing and remediating students’ everyday conceptions to uncovering a broader range of resources that students bring to the classroom and using these to support knowledge-building by the classroom community. The competent teacher in this view is not one who merely “hooks” students or “gets them excited about science” but one who elicits a variety of experiences and ideas that learners have about some event or question, then makes strategic adaptations—both in the moment and over the longer term—to exploit these resources in the knowledge-building activities that follow. The demands on the teacher’s skill here are substantial, and the research, in sum, strongly suggests that new images of expertise around these capabilities are emerging. Early in a school year for example, a teacher would need to understand and frame knowledge production and the social norms that would support it in their classrooms. Early in each unit of instruction they would have to craft ways for all students to have initial access to complex science ideas and in the process manage diverse forms of talk that allow transactions about ideas among students. Teachers would employ strategies to make key parts (but not all) of student thinking visible and public, then consider how to respond to these ideas as they adapt instruction for the next few days. Clearly, the skills required for ambitious teaching are more sophisticated, flexible, and grounded in deeper subject matter knowledge than in traditional conceptions of the competent professional.

Many questions remain unanswered about how teachers uncover and use students’ ideas to guide instruction, however we do know enough about what is productive in the classroom to represent key pieces of the knowledge base as a “candidate” core practice. As with our previous example of a practice, this rendering is necessarily simplified, but does embed a sequence of tasks, talk, and tools that can be shared, tested, and modified (based on evidence of students’ participation and learning) by a community of practitioners. Our placeholder name is “eliciting students’ ideas and adapting instruction.” We note here that this practice would likely be enacted at the beginning of a unit of instruction, however elicitation and adaptation moves continue to happen throughout the learning experience. Also, using these strategies presupposes that the teacher has already identified in the curriculum the key scientific ideas and an anchoring phenomenon of sufficient complexity and richness to sustain students’ intellectual engagement throughout a unit. Reading our description, it will become evident that the “grain size” of a teaching practice is undefined by the field. Our selection is on the comprehensive side of the continuum (i.e. larger in scope). A reasonable interpretation of the practice we present is that it may actually be three practices, each with sub goals, that support an overarching purpose—1) eliciting students’ ideas, 2) representing publicly selected elements of students’ thinking, and 3) adapting subsequent instruction based on the partial understandings students appear to have with the content.
**Research-based Principles** that should guide all variations of this practice

- Young learners have a range of resources they can use to communicate about and make sense of phenomena.
- Adapting instruction means responding to students’ intellectual needs by engaging resources they bring to the learning enterprise in order to understand challenging material.
- Discourse is the primary social mediator of reasoning.
- For the class to “work on students’ ideas”, current thinking must be made visible and public.
- Eliciting traces of students’ reasoning provides greater insights and instructional leverage for teachers than does the elicitation of products of reasoning (“answers”).
- The trajectory of an effective curriculum is co-determined by subject matter considerations and by adaptations to instruction based on the current reasoning and resources employed by students.

**References**


