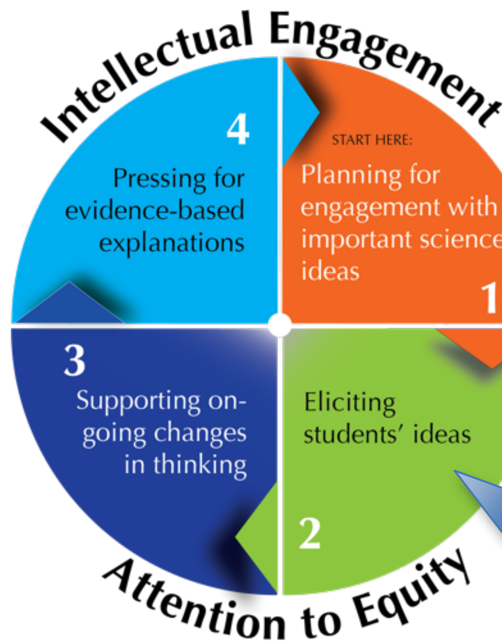
Teaching practice set: *Eliciting students' ideas and adapting instruction*

Overview

Teachers have regular routines that are referred to as *practices*. We have studied how expert teachers work with their students, and we 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 here are grounded in research and in studies of the work of experts. You will see that these practices are in many ways unlike traditional forms of instruction.

The practice set we begin with here is *eliciting students' ideas*. This practice is used at the beginning of a unit of instruction. The 3 practices that make up the set are:

1) Eliciting students' ideas
2) Selecting and representing students' ideas publicly
3) Adapting upcoming instruction based on students' ideas



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 a unit you plan to teach around a set of big science ideas and selected a compelling anchoring phenomenon that your students will develop evidence-based explanations for.

Goals

Your main objective as a science teacher is to change students' thinking over time. So you need to know what your students understand about the core science ideas before launching the unit. The goals of this practice set are to reveal a range of ideas, experiences, and language that students use to talk about the anchoring phenomenon, and to activate their prior knowledge about the phenomenon.

Here is what you are tying to elicit:

- 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.

How to plan for eliciting students' ideas

You will be eliciting students' ideas about the anchoring phenomenon for your unit, but you can't just show any part of that event and say "Tell me what you think." You have to do some creative work to develop a *rich task for students* about the anchoring event—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).

In the table below we show samples of scenarios, rich tasks and questions that can open up students' existing ways of thinking to you (left column). You may want to ask yourself, are these tasks and questions accessible to students? Do they have a chance to at least begin hypothesizing about them? Making observations? Can students use everyday knowledge to speculate about these questions? In the right column are sample ideas. You want to hear how students talk about and reason about these. You are not trying to find out if they have "correct" versions of these ideas. We'll give you more help on this later.

Rich tasks related to the anchoring event: These are puzzling events, stories, questions, images, activities, and sample starter questions	**Core ideas related to the anchoring event that you could elicit thinking about**
(Original curriculum topic was plate tectonics) • *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?	• 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

(Original curriculum topic was gas laws) • *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?	• All gasses 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"
(Original curriculum topic was forces and dynamics) • *Roller-blader going down a hill.* Sample question: -What are the different pushes or pulls that are acting on this person?	• 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
(Original curriculum topic was natural selection) • *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.	• 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

How to enact the practice of eliciting students' ideas

There are three phases to this conversation with students. Each one has different kinds of questions and discourse moves that you would use. Don't skip any of these! Each accomplishes an important goal in probing and extending student thinking.

Your conversations with students should flow through these phases in order:

- Introducing the puzzling event and eliciting (only) observations
- Eliciting hypotheses about "what might be going on"
- Pressing for possible explanations

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 tables 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 an entire class period. Expert teachers transition smoothly and seamlessly from one phase to the next as the ideas in one phase sets up the conversation in the next.

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 can happen in small groups and can be interwoven with whole class conversations.

1. 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 one of these:

- "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.

In the table below we show three different pathways that exchanges with students can take. In one class period you may likely experience all three. Encourage students to talk to each other, not just with you. You should be patient about eliciting contributions from ALL students. It always helps to have students turn and talk to their partners for a couple of minutes, it gives them courage to then offer ideas in the whole class discussion.

Teacher: What do you see going on here? Have you seen anything like this before? What did you notice when ____ happened? When did it seem to occur?		
Students might cite relevant features of the event. If so, then you might try the responses below.	**Student*****t*** might provide inferences rather than observations. If so, then you might try the responses below.	**Student*****t*** might cite irrelevant features or indicate that they don't even comprehend the representation you've shown them. You might try the responses below.
Teacher: Can you say more? Do others agree? Would anyone like to add on to that comment? Begin to mark some specific features and vocabulary if necessary. "OK, so we agree that this is what we're seeing?"	**Teacher:** Acknowledge their enthusiasm, then focus them on observations for now. Help them distinguish between observations and inferences.	**Teacher:** Provide more context. Redirect their focus to particular features of the event or process. Be explicit about the conventions used in the representations.

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:

No: Initial use of scientific language that shuts students out from the conversation (e.g. p-waves, atmospheric pressure, force systems, natural selection).
No: Lifeless requests for definitions and vocabulary-- "Who can tell me what [photosynthesis, chemical equilibrium, torque, sedimentation] is?"
No: Directionless questions: "How many of you have ever heard of ______?"
No: Premature attempts to get students to talk about abstractions-- "What do you think the structure of an atom is?"
No: Sniffing out right answers (I-R-E dialogue).

2. Eliciting hypotheses about "what might be going on"

This is a subtle but important shift from just asking for observations. Here you can 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.

This is where partial hypotheses from students are stated publicly and these help other students "activate" relevant prior knowledge. This means that students start to search their existing knowledge to suggest their own hypotheses or to simply understand the contributions of others. This set of questions and tasks could be done in small groups.

<table>
<tr><th colspan="3">Teacher:
How do you think this happens?
What would you predict about ___?
What has happened here (at the level of inference)?
What would happen if ____?</th></tr>
<tr><td>Students might cite relevant facets of core ideas. If so, then you might try the responses below.</td><td>Student might exhibit alternative conceptions.</td><td>Student might make connections to what they know or have already experienced. You might try the responses below.</td></tr>
<tr><td>Teacher:
Can you say more?
Do others agree? Would anyone like to add on to that comment?
Begin to mark or amplify some specific features and vocabulary if necessary.</td><td>Teacher:
Probe them further to see what their reasoning is--Can you tell me more?
Don't amplify alternative conceptions, but give the student a chance to express their reasoning.</td><td>Teacher:
Can you tell me how you see your experience connecting to the big ideas today?
Mark this mentally as a "leverage point"—meaning a possible context for other students' understanding of the phenomenon in upcoming lessons.</td></tr>
</table>

3. Pressing for possible explanations

In this step you are explicitly asking for causal hypotheses (What is going on we cannot see?). Help students understand that these can be fragments of explanations—that's ok. After such a conversation, you could have students in small groups of two or three draw out (an initial model) 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. These drawings are their initial models that they can then refine over the course of the unit.

Teacher: What might be going on that we cannot see? Why do you think it happens this way? What do you think causes this?		
Students might offer scientifically correct explanations. If so, then you might try the responses below. **Teacher:** Do NOT respond with "Correct!" "That's right!" Subtly mark and amplify their responses, or parts of them. Revoice: So you think it has something to do with___?	**Student** might offer explanations that consist of alternative conceptions. **Teacher:** Probe them further to see what their reasoning is--Can you tell me more? If you can readily think of an observation that would put this alternative conception into question, then offer that, but you are not trying to "fix" anyone's ideas here.	**Student** might offer a simplistic cause and effect statement. Example: Why does water boil? Because you put it on the stove. **Teacher:** You are telling me the beginning of the story and the end of the story, can you tell me the middle of the story? Can you say what's going on that we can't see?

How to enact the practice of selecting and representing students' ideas publicly

There are three options for making students' thinking public, so it can be "worked on" throughout the unit.

Option 1. You could have selected students share out their *small group models* that they've drawn. You might select who shares out to get as many different hypotheses out in the air.

Option 2.You, as the teacher, could create a whole class *list of their hypotheses* (like 4 or 5). To get this started you put up two sentence frames on the board, so students know how to participate in this science discourse. One is: "We think [the phenomenon] has something to do with________." The other is "We think [the phenomenon] happens the way it does because ________." The first of these two is easier for students to contribute to, because it does not require a causal story.

You, as the teacher moderate this list by NOT writing everything that students say, but rather you ask the whole group "Is this hypothesis different from the others? How? Can we combine your hypothesis with theirs? Do you mean…? What are some things we are not sure of?" Only after having students talk to each other about whether hypotheses are different or how they are related might you then add a hypothesis to the list.

Option 3.The third option is for you to sketch out a *whole class consensus model*. This can be very sparse because the whole class will fully agree on very little. Ask the students, "What should I label? What can we agree on that we observed? Can we agree on what might be going on that is unobservable? What are we not sure about, or need to learn more about?"

All three of these options 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. Refer to these as "Ideas we need to work on together."

No matter which of the three kinds of representation you create with students, you can ask at the very end of class: "What questions we have now about the phenomenon? What kinds of information or experiences might we need to learn more?

How to enact the practice of 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.

FYI: What the research says about eliciting practices (note, this is in "researcher language")

If you are interested in the origins of these practices, 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

Alexander, R., Osborn, M. & Phillips, D. (2000) *Learning from Comparing: New Directions in Comparative Education Research*. Volume 2: Policy, Professional and Development. Wallingford, Oxford: Symposium Books.

Anderson, C. W. (2007). Perspectives on science learning. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 3 – 30). Mahwah, NJ: Erlbaum.

Atwater, M.M. (2000). Equity for Black Americans in Precollege Science. *Science Education, 84*, 154-179.

Ausubel, D.P. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart & Winston.

Ball, D. L. (1993). With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics. *Elementary School Journal, 93*, 373–397.

Ballenger, C. (2009). *Puzzling moments, teachable moments.* New York, NY: Teachers College Press.

Banilower, E., Boyd, S., Pasley, J. & Weiss, I. (2006). *Lessons from a decade of mathematics and science reform : A capstone report for the local systemic change through teacher enhancement initiative*. Horizon Research International. Available at http://www.horizon-research.com/reports/2006/capstone.php.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school (expanded edition)*. Washington, DC: National Academies Press.

Chapin, S. & O'Connor, M. C. (2004). *Project Challenge: Identifying and developing talent in mathematics within low-income urban schools*. Boston University School of Education Research Report No. 1, 1–6.

Cobb, P., Boufi, A., McClain, K., & Whitenack, J. (1997). Reflective discourse and collective reflection. *Journal of Research Into Mathematics Education, 28*(3), 258–277.

Danish, J. A., & Enyedy, N. (2006). Negotiated representational mediators: How young children decide what to include in their science representations. *Science Education, 91*(1), 1–35.

diSessa, A. (1993). Towards an epistemology of physics. *Cognition and Instruction, 10*, 105–225.

Driver, R, Leach, J., Millar, R., & Scott, P. (1996). *Young People's Images of Science.* Buckingham: Open University Press.

Duschl, R. & Duncan, R. (2009). Beyond the fringe: Building and evaluating scientific knowledge systems. In S. Tobias and T. Duffy (Eds.) *Constructivist instruction: Success or failure?* (pp. 311-332). New York: Routledge.

Engle, R. A. (2006). Framing interactions to foster generative learning: A situative explanation of transfer in a community of learners classroom. *Journal of the Learning Sciences, 15*(4), 451-498.

Gage, N. (2009). *Conceptions of teaching*. Springer.

Gallas, K. (1995). *Talking their way into science. Hearing children's questions and theories, responding with curricula.* New York: NY: Teachers College Press.

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 169–190). Mahwah, NJ: Erlbaum.

Herrenkohl, L. R., Palincsar, A. S., DeWater, L. S., & Kawasaki, K. (1999). Developing scientific communities in classrooms: A sociocognitive approach. *Journal of the Learning Sciences, 8*(3 & 4), 451-493.

Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for conceptual change. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 199–218). Dordrecht, The Netherlands: Kluwer.

Hogan, K. (1999). Sociocognitive roles in science group discourse. *International Journal of Science Education, 21*(8), 855-882.

Hogan, K., & Corey, C. (2001). Viewing classrooms as cultural contexts for fostering scientific literacy. *Anthropology & Education Quarterly, 32*(2), 214-243.

Jacobs, V. A., Lamb, L. L. C., & Philipp, R. A. (2010). Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education, 41*(2), 169–202.

Lampert, M. (1990). When the problem is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal, 27*(1), 29–63.

Lampert, M. (2001). *Teaching problems and the problems of teaching*. New Haven, CT: Yale University Press.

Lee, C.D. (2001). Is October Brown Chinese? A cultural modeling activity system for underachieving students. *American Educational Research Journal*, *38*(1), 97-141.
Leinhardt, G. & Steele, M. (2005). Seeing the complexity to standing to the side: Instructional dialogues. *Cognition and Instruction, 23*(1), 87-163.
Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.
Linn, M. C., & Hsi, S. (2000). *Computers, teachers, peers: Science learning partners*. Mahwah, NJ: Lawrence Erlbaum Associates.
Louca, L., Elby, A., Hammer, D., & Kagey, T. (2004). Epistemological resources: Applying a new epistemological framework to science instruction. *Educational Psychologist, 39*(1), 57–68.
Maskiewicz, A & Winters, V. (2012). Understanding the Co-Construction of Inquiry Practices: A Case Study of a Responsive Teaching Environment. *Journal of Research in Science Teaching, 49* (4), 429–464.
May, D. B., Hammer, D., & Roy, P. (2006). Children's analogical reasoning in a 3rd-grade science discussion. *Science Education 90*(2), 316–330.
Metz, K. E. (1995). Reassessment of developmental constraints on children's science instruction. *Review of Educational Research, 65*(2), 93–127.
Metz, K. E. (2004). Children's understanding of scientific inquiry: Their conceptualization of uncertainty in investigations of their own design. *Cognition and Instruction, 22*(2), 219–290.
Michaels, S., O'Connor, C., & Resnick, L. (2008). Reasoned Participation: Accountable Talk in the Classroom and in Civic Life. Studies in Philosophy and Education. 27 (4): 283-297. Read more: http://www.clarku.edu/academiccatalog/facultybio.cfm?id=15#ixzz0KPZQlrC9&C
Minstrell, M. & Kraus, P. (2005). Guided inquiry in science classrooms. In M.S. Donovan & J. Bransford (Eds.) *How students learn science in the classroom*, (pp. 475-514). Washington DC: National Academies Press.
National Research Council (2005). *America's Lab Report: Investigations in High School Science. Committee on High School Laboratories*: Role and Vision. Susan R. Singer, Amanda L. Hilton, and Heidi A. Schweingruber, Eds. Board on Science Education. Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academies Press.
National Research Council (2009). *Learning Science in Informal Environments:*
People, Places, and Pursuits. P. Bell, B. Lewenstein, A. Shouse, and M. Feder, *(Eds.).* Washington, DC: National Academies Press.
Penuel, W. R., Fishman, B. J., Gallagher, L. P., Korbak, C., & Lopez-Prado, B. (2009). Is alignment enough? Investigating the effects of state policies and professional development on science curricu- lum implementation. *Science Education, 93*(4), 656–677.
Pierson, J. (2008). *The relationship between patterns of classroom discourse and mathematics learning*. Unpublished Doctoral Dissertation, The University of Texas at Austin.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211 – 227.

Radinsky, J., Oliva S., & Alamar, K. (2010) Camila, the earth, and the sun: Constructing an idea as shared intellectual property. *Journal of Research in Science Teaching, 47*(6), 619–642,

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *Journal of the Learning Sciences, 2*(1), 61-94.

Rosenberg, S., Hammer, D., & Phelan, J. (2006). Multiple epistemological coherences in an eighth-grade discussion of the rock cycle. *Journal of Learning Sciences, 15*(2), 261-292.

Roth, K. & Garnier, H. (2007). What science teaching looks like: An international perspective. *Educational Leadership*, *64*(4), 16-23.

Roth, K., Chen, C., Lemmens, M., Garnier, H., Wickler, N., Atkins, L., Calabrese Barton, A., Roseman, J. E., Shouse, A., & Zembal-Saul, C. (2009, April). *Coherence and science content storylines in science teaching: Evidence of neglect? Evidence of effect?* Colloquium and paper presented at the annual meeting of the National Association for Research in Science Teaching (NARST). Garden Grove, CA.

Roth, K.J., Druker, S.L., Garnier, H.E., Lemmens, M., Chen, C., Kawanaka, T., Rasmussen, D., Trubacova, S., Warvi, D., Okamoto, Y., Gonzales, P., Stigler, J., & Gallimore, R. (2006). *Teaching science in five countries: Results from the TIMSS 1999 Video Study* (NCES 2006-11). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Sfard, A. & McClain, K. (2002). Analyzing tools: Perspectives on the role of designed artifacts in mathematics learning. *Journal of the Learning Sciences, 11*(2&3), 153-161.

Sherin, M. G., & van Es, E. A. (2009). Effects of video club participation on teachers' professional vision. *Journal of Teacher Education, 60*(1), 20–37.

Smith, J. P., diSessa, A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in pieces. *Journal of the Learning Sciences*, *3*(2), 115–163.

Tang, X., Coffey, J., Elby, A., & Levin, D. (2010). The scientific method and scientific inquiry: Tensions in teaching and learning. *Science Education, 94*, 29–47.

Thompson, J, Windschitl, M. and Braaten, M. (2013). Developing a Theory of Ambitious Early-Career Teacher Practice. American Educational Research Journal, 50(3):574-615.

Tytler, R., & Peterson, S. (2004). From ‘‘try it and see’’ to strategic exploration: Characterizing young children's scientific reasoning. *Journal of Research in Science Teaching, 41*(1), 94–118.

van Zee, E. H. (2000). Analysis of a student-generated inquiry discussion. International *Journal of Science Education, 22*(2), 115–142.

Weiss, I., Pasley, J., Smith, S., Banilower, E. & Heck, D. (2003). *Looking Inside the Classroom: A Study of K–12 Mathematics and Science Education in the United States*. Horizon Research, Inc., Chapel Hill, NC.