Giving Science Students Access to the Tools of Knowledge Production
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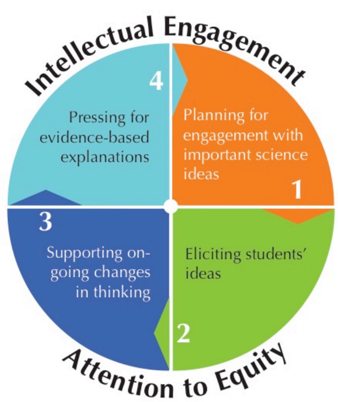
In our preparation program for secondary science educators, we as instructors are explicit about framing teaching as "working on and with students' ideas." This implies that teachers must know what students' ideas are about phenomena in the natural world, how they reason about these events and processes, talk about them, and relate them to everyday experiences they have had. Teachers then, have to develop ways of selecting and representing these ideas publicly, orchestrating productive forms of discourse about them, and comparing students' ideas to one another as well as to canonical concepts without over-writing their thinking and reducing everyone's efforts to the reproduction of textbook explanations.

From a disciplinary standpoint it means that in these classroom, ideas in the forms of hypotheses, partial theories, claims, and models are meant to be revised over time in response to new evidence, information and to the logic of others around you in the community who are puzzling about similar questions. This view of teaching is consistent with theories of disciplinary literacies (Bain, 2000; Lee 2007; Lemke, 1990; Luke, 2001) in which science is constituted by specialized forms of discourse and knowledge production requires fluency in making and interpreting knowledge claims and communicating knowledge (Kelly & Bazerman, 2003; Moje et al., 2004). Learning is reflected in the increasing capacity to use a variety of representational forms to communicate ideas, to synthesize ideas across texts and people, to express new ideas, and to question and challenge ideas by others (Moje, 2008). Importantly, all of this knowledge production is done through interaction with others.

These images of teaching are attractive to novice educators, however they remain merely aspirations until they are embodied in structured and responsive performances with students. In our program we apprentice beginners into four sets of teaching practices (what we refer to as the foundations of *Ambitious Teaching*) that have two important features. First, each is tightly linked with the research on conditions that support students' learning and participation. Second, the four practices work together to form a coherent "whole" in terms of how instruction unfolds over time towards valued goals.



Because the scientific practice of *obtaining, evaluating and communicating information* (OECI) is embedded within this larger framework of teaching, we describe these instructional practices below. We then elaborate on how each teaching practice supports students' efforts at obtaining, evaluating and communicating information. Among the supports appearing in various forms are 1) providing relevant and compelling contexts for students to seek out and evaluate new information, 2) using a variety of public representations of students' ideas that make visible how new information is being made sense of or compared against other ideas, 3) employing scaffolds and specialized routines for reading texts, preparing to write explanations, and giving time and opportunity for all learners to participate in the on-going refinement of ideas.

Practice set 1: Planning for student engagement with important science ideas

The first practice is a collaborative planning activity to organize instruction in which teachers select from the curriculum science ideas that have the greatest explanatory power in the domain under study. The teachers then select a puzzling event or process—of sufficient complexity—that can serve to anchor instruction over a period of weeks. Each teacher's goal is to support students as they collectively develop and revise causal evidence-based explanations for the anchoring event. An example here is to shape a high school chemistry unit about the Gas Laws around the unusual event of a railroad tanker car that had mysteriously imploded after being steam cleaned and accidentally sealed shut. Most of the reading and writing activity throughout the unit is believed by students to contribute, directly or indirectly, to an understanding of this event. Put another way, students do not feel that reading and writing tasks are arbitrarily assigned.

How is this practice related to OECI?

One of the principles underlying the productive reading of texts or the interpretation of scientific representations is that learners are more able to generate meaning if they understand the larger purpose of the effort. In classrooms where our beginning teachers have used anchoring events, the students are far more likely to know why they are reading particular texts, and developing representations such as data displays, models or lists of currently plausible hypotheses (supporting for example the pre-reading activities of scaffolded reading experiences). American science instruction is notorious for engaging students in activity that is disconnected from science ideas and from previous activity done in the classroom. This is not the case where Ambitious Teaching is implemented.

Practice set 2: Eliciting students' ideas and adapting instruction.
This is the first of three teaching practices that are enacted with students in the classroom. The teacher introduces some representation of the anchoring event (video, image, story) and uses a range of discourse strategies designed to elicit students' initial ideas about the event as well as to get students to talk to one another. Selected ideas of students are then represented publicly. Following the lesson, the teacher adapts subsequent instruction based on the partial understandings or lived experiences that students have had with the content.

How is this practice related to OECI?
During this practice, the teacher eventually asks groups of students to communicate ideas in a form that is distinctive to science—the explanatory model. We have several conventions that we ask student to embed in their models. Some of these conventions have disciplinary roots, for example the notion that "to count" as a model the drawing of a phenomenon should include what is observable, but also what is unobservable (in the case of the railroad tanker car these would be things like molecules moving at various speeds, the transfer of heat, condensation, atmospheric pressure). These unobservables are what we believe causes the observable events (implosion of the tanker, the release of sound, the fact that the tanker does not crush all the way down to zero volume). Some of the model conventions we encourage help support the written explanations that accompany the drawing. We often ask students, for example to draw out a 3-panel "before-during-after" version of the event. We have found that students are much more able to represent the full extent of their thinking in the drawing this way, that they are much more able to write explanatory text that accompanies each of the three panels, and that they more readily see what gaps they currently have in their thinking. Occasionally we first ask students to express their ideas in the forms of initial hypotheses rather than models, especially if they are not yet used to the idea of modeling. This is often done in whole class settings where we use scaffolds (sentence starters) to help students express their initial ideas.

Practice set 3: Supporting students' on-going changes in thinking.
Here the teacher often introduces new ideas to reason with via presentation or engagement with various texts. Students are then asked to conduct investigations that can generate data and/or that provide a material context within which to explore the instructed idea. Students are asked to use knowledge products they create (new ideas, conjectures, data) to revise their existing models and explanations. This practice is used multiple times throughout a unit as students interact with new ideas or data and make revisions to their thinking individually and collectively.

How is this practice related to OECI?
We know that reading is essential here. Our novices rely on the idea that students will understand that any use of text will inform their understanding of the anchoring event introduced earlier. Our novices analyze the academic language demands of the text, then consider how to use *scaffolded reading experiences* to engage their students with the text and then with each other's ideas after reading the text.

The material and social activity that students engage in following their experience with new ideas in the text is designed to support the development of those ideas, rather than to act as some confirmatory experience for textbook explanations the teacher has selected. We provide teachers with a discourse primer (a document about classroom talk) in order to help them use questions and prompts during small group work to get their students to use new concepts and connections from text to make sense of the activity itself.

The goal of introducing new ideas via text and new forms of data via material activity is to return to the models that had been created and to revise those based on this information. This arrangement is authentic to science but foreign to students. In order to help students communicate changes to their models, they use supports such as sticky-notes that can be put on their models or on the models of their peers, in order to express where they think new ideas should be added, removed, or revised. Our novice teachers have developed sentence-frame scaffolds that help their students express these ideas on the sticky-notes. We have found that the use of sticky-notes to revise models is helpful to English Language Learners and other students for whom the pace of oral discourse is too brisk to keep up with or contribute to—it slows the pace of dialogue because that dialogue is now in the form of written notes. It encourages more thoughtful reflection on how ideas are changing and in response to what kinds of evidence.

Practice set 4: Supporting students' evidence-based explanation. Near the end of a unit of instruction, the teacher asks students to look across all sources of information and ideas they have engaged with, and to finalize a causal, evidence–based explanation. This explanation is always represented in two complementary forms: a drawn model (could be a diagram, pictorial representation, flow chart, etc.) and an extensive written account.

How is this practice related to OECI?
We believe that students need practice writing explanations to express their ideas, and that they should get feedback on their writing. We have developed routines around producing explanations and we have different kinds of scaffolds for this. Given that the *Next Generation Science Standards* will encourage students to write evidence-based causal explanations, students will need support for this particular form of explanation. In our final teaching practice, students are asked to incorporate multiple forms of evidence and multiple ideas into the explanation. We do not simply have students explain one lab activity. They are aware that they eventually have to use all the texts and lab activities to build an explanation for the anchoring event. To help them with this aspect of the explanatory writing, we use a *summary table*. This is a table that is co-constructed by the students throughout the unit. After each activity the students create a row on this public document. For the first cell in the row, students collectively decide how to describe the activity with a name or phrase. In the second column, they decide what observations they made during the activity. In the third cell, they decide how to express what they thought was going on in the activity from a science perspective. In the final cell, they decide how the activity helped explain one aspect of the anchoring event for the unit. All of this is whole class activity and is moderated by the teacher. The ideas and words are carefully chosen so that they "belong" to the students. Using this teaching routine, students in the class can see how peers make meaning out of activity and text, then express that on the summary table. When students construct their final evidence-based explanations they are asked to reference the summary table and to use ideas developed with multiple activities to support their arguments.

For further information on Ambitious Teaching see Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a Theory of Ambitious Early-Career Teacher Practice. *American Educational Research Journal*.

For further information about how we use 1) public representation of student's thinking, 2) discourse practices, 3) models and modeling, or 4) anchoring events, see the home page of http://tools4teachingscience.org

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