Whiteboarding: A Tool for Moving Classroom Discourse from Answer-Making to Sense-Making

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In 1998 I had been teaching science for 13 years. I was a good teacher: I had the plaques and certificates to prove it. But often I felt like an imposter (which I have since learned is not unusual—70% of all people feel like a fake at one time or another1). While my students could solve problems and ace tests, every June when I sat down to look at their Force Concept Inventory2 (FCI) results, I was confronted by how little they had actually learned in my physics classes. It was this annual reality check that drove me to pursue my first Modeling Workshop3 in summer of 1998. For four weeks I was a physics student again—every day, for six to eight hours a day, I (re)learned to think aloud, to “speak physics” and to listen to how I and others (students) spoke physics.4 That summer changed everything. When I returned to my high school physics classroom equipped with a new way of teaching in September of 1998, I was excited. I felt like I had the key to the perfect year—I wouldn’t be an imposter anymore.

Within a week of implementing Modeling Instruction for the first time, I realized I would need a great deal of practice before I could manage student discourse as adeptly as I had seen it done in my summer workshop, but even in those first halting weeks, I saw significant differences in what students knew and were able to do. The way we talked with each other in my classroom and what we talked about was fundamentally different: my students had shifted from answer-making to sense-making, and it seemed to me the difference-maker was student whiteboarding.

**Sense-making versus answer-making**

By the time students reach high school physics, they are experts at answer-making. The default culture of schooling has taught them that Teachers Want Answers—this is why they ask questions, this is what they give points for. Answers lead to A’s and A’s lead to good college recommendations and ultimately, hopefully, acceptance to that “dream school.” Answers are the traditional currency of the classroom economy. They are quick and easy for the teacher to keep

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1. Unnamed reference
2. Force Concept Inventory
3. Modeling Workshop
4. Unnamed reference
track of, easy to assign a value to, easy to reward. They do not, however, tell us very much about a student's conceptual understanding. Sometimes all an answer reveals is whether a student can perform an algebraic manipulation or replicate a procedure. Answer-making is a closed-ended activity. What's the answer? 42. Done. End of story. We can disconnect from this problem and do something else.

Sense-making is more open-ended. It requires that students not only connect the elements, operations, relations, and rules that knit the problem into a coherent whole, but that they recognize and make explicit the way in which each problem is one instance of a particular type of relationship (a conceptual model), e.g., if an object is moving at a constant velocity, then it shares certain characteristics with all objects moving at a constant velocity and these characteristics allow for predictability.

**Whiteboarding**

Whiteboarding is an opportunity for distributed cognition—the "cognitive unit" is not bounded by a single skull—it is distributed across three or four students, their utterances, gestures, and the things they draw or write/rewrite on a whiteboard. Students work together in groups to represent laboratory data or solve problems. They think aloud together as they express, test, revise, and coordinate various representations of their solution.

Whiteboards, as a tool for mediating this sense-making activity, have some advantages over paper and pencil: they are large, erasable, and their content is shared and negotiated.

Whiteboards are large enough for several different representations (graphical, diagrammatic, and mathematical) of the same problem, and large enough that multiple students can draw or write on them simultaneously. This allows for the conversation that takes place among students within the group to focus on more conceptual matters such as how various representations correspond with one another, rather than on procedural matters such as whether or not an algebraic manipulation has been performed correctly.

Whiteboarded content is easily erased and rewritten. This enables students to share partially formed ideas that can be extended or improved upon in consultation with the group until they arrive at something that illustrates their thinking to everyone's satisfaction.

Students doing small group work are more apt to discuss concepts than procedures when discussing shared representations such as those created jointly on a whiteboard, regardless of whether the representations are spatial or mathematical, than when discussing individual work, e.g., solving problems on a worksheet.

Whiteboard content is shared and negotiated. A finished whiteboard contains the consensus conceptual model of the small group that prepared it. In order to complete a whiteboarding exercise, all members of the team participate in the conversation and agree about the representations on the whiteboard because any one of them might be called upon to explain what it shows to the entire class (Fig. 1). The necessity for developing a shared model is critical to promoting discourse within small groups.

After seven years of practice managing whiteboard-mediated discourse in my own classroom, I had the opportunity to spend a year observing and analyzing student whiteboarding in a number of other teachers' classrooms (while conducting research for my PhD thesis), in an effort to understand why it works so well. What follows is a quick summary of what I learned.

**Getting started**

It goes without saying that to do whiteboarding, whiteboards are needed (at least a dozen—I ended up with four dozen so I could hold them over from one class period to the next so my students didn't have to erase them at the end of the class period and rewrite them again the next day). Whiteboards can be made by cutting a sheet of shower board (4 x 8 ft, a.k.a. tile board, ~$14/sheet at Lowe's or Home Depot) into six equal pieces (24 x 32 in). You will also need lots of dry erase markers (red, green, blue, and black work best—other colors can be difficult to see at a distance) and a handful of shop towels or old rags that can be used for erasers.

But even the best whiteboards are not of much use without good whiteboarding tasks. You don't have to be a Modeler (i.e., use Modeling Method of Instruction) to learn how to use whiteboarding productively. If you have your own collection of physics labs and problems you want to use, here are some of the characteristics of good whiteboarding tasks you can use to help you decide whether yours are appropriate, or to help you adapt them so that they will be better vehicles for generating sense-making conversations.

Good laboratory tasks for sense-making, sometimes called "paradigm labs," allow students to explore and describe or define the relationship between two quantities—one that they can manipulate and one that they can measure (unlike traditional verification labs that specify a procedure that students must follow in order to confirm some law, rule, theory, or physical constant that a student has already been taught is true). A sense-making laboratory activity is introduced with a demonstration of some phenomenon. The class as a whole arrives at a question that characterizes the relationship between quantities. Once the investigation

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Sample paradigm lab questions:

- What is the relationship between position and clock reading for a battery-powered car moving across the floor?
- Or what is the relationship between position and time for a ball rolling down a ramp?
- Or what is the relationship between the mass of an object and the force reading when it is hung on a spring scale?
has been framed in terms of this question, students are given
the apparatus and they work together with their lab group to
design a procedure, collect data, analyze it, and whiteboard
their results (unlike a verification lab, in which students are
told what data to collect and how to analyze it).

Good problem-solving tasks allow for multiple representa-
tions and, if possible, multiple pathways to the solution.9
While any problem can be whiteboarded, two types produce
unusually rich whole-group discussions: practice-with-the-
model problems, which require students to apply the model
they articulated in their paradigm lab to new or more complex
situations, and “questionless” problems, where students are given a situ-
ation to represent—graphically, mathematically, diagrammatically—and then they come up with as many questions as possible that they can answer using their representations.

If you have a good problem-solving task, you can assign the
same task to the entire class and there will be enough variabil-
ity in each group’s problem-solving strategy to produce a rich
whole-group discussion.

**Norms**

There are just a few established norms with respect to what
a whiteboard should contain, and even these are the source
of ongoing debate among teachers who use whiteboarding:
1) whiteboards should contain multiple representations of
the information that they are trying to convey (e.g., a graph, a
diagram, an algebraic expression), 2) representations should
be appropriately scaled and labeled with quantities and units,
and 3) representations should be coordinated—that is, they
should all be “telling the same story” or illustrating the same
conclusion. There are other rules that some teachers use, e.g.,
some like their students to include data tables when represen-
ting laboratory results, some insist that students state their
conclusion in a sentence or two.

**Managing student discourse**

The management of whiteboard-mediated discourse is
key to the advancement of sense-making. There are two kinds
of discourse: small group (typically three or four students;
three works best) and whole group (the entire class). Both are
mediated by the use of whiteboarded representations. White-
boarding allows student thinking to be exteriorized, giving
the teacher an opportunity to listen and learn about students’
conceptual models as they are in the process of being built
and tested.

Whole-group discourse sets the stage for each whiteboard-
ing session—setting up the lab activity or determining the
problem to be solved. Whole-group discourse also follows
small-group work, giving students the opportunity to help
one another make sense of how a particular model applies
to a problem situation and to consolidate what they have
learned from each exercise. It is important to validate each
student’s contribution to a whole-group discussion. This can
be done by jotting a key phrase on the board, restating the
idea in a few words, or offering a brief affirmation. Positive
reinforcement is an effective inducement to encourage broader
class participation.

Small-group discourse permits individuals to work as a
team to find a solution pathway all can agree upon. Grouping
students makes it possible for the teacher to move around the classroom, listening
to students’ conversations and observing the solution strategies that each group
attempts. Grouping also gives the teacher an opportunity to suggest ideas or questions
to individual students or groups who may have a unique view of the problem, or encourage individuals
to volunteer their thoughts during the whole-group discus-
sion. For students, there is less potential embarrassment in
conversation with a small group of peers than there is in a
whole-group discussion. Thus students who might other-
wise remain silent are more likely to try out explanations,
ask questions, or make suggestions when working with their
small group partners. This is an opportunity for the teacher
to gain insight into her students’ thinking as she moves from
group to group listening to them think aloud as they prepare
their whiteboards.

At the beginning of the school year, when students are
called together for a board meeting (during which students
gather for discussion in a circle so that they can see and com-
pare each other’s whiteboards, Fig. 2), the teacher may need
to jump start the discussion by asking, “how do you know...?”
or “what if...?" or “why did you choose...?” or “what do you mean by...?” questions when a student group presents their
lab findings or the solution to a problem. If it is made explicit
to students that questioning and ultimately sense-making is
actually their responsibility (not the teacher’s), they will gradu-
ally take over the task of questioning, providing the teacher
an opportunity to listen to the group’s sense-making as it de-
velops and limit her participation in the conversation to giv-
ing it a verbal nudge in the proper direction when it strays off
course. When the discussion winds down, a student is usually
asked to summarize the group’s shared understanding. This
can either provide good closure or reveal lingering doubts
that need further clarification. The expectation should be
that the burden of developing an adequate interpretation or
solution is on the students (not on the teacher). The point of
whole-group discourse is to map the problem onto a shared
conceptual model, and then manipulate this model to find a
solution that everyone understands (not to figure out an an-
swer that everyone can write down on their paper).

Another approach to whole-group sense-making involves
formal presentations by small groups of students where a sin-
gle group comes to the front of the classroom, displays their
whiteboard, describes how they worked out the solution, and then answers whatever questions their teacher or students might ask them. This method is less effective than board meetings for stimulating student-to-student conversation.

**Zooming: Keeping their eye on the model**

Students often have difficulty finding the right “focal length” to view a problem space. They have a tendency to “zoom in” and focus on the algebraic details they find in a problem statement. They often forget to “zoom out” and view the big picture—the spatial and temporal structure of the problem space.

Students who can keep their eye on the overarching conceptual model, reframing their view by zooming in and out as needed, demonstrate greater conceptual understanding and are more readily able to transfer what they have learned to novel contexts than classmates who remain zoomed in on the algebraic details of the model.5,10

My observations in numerous classes that use whiteboarding have revealed that students who start by constructing spatial representations (diagrams) to assist their reasoning are more apt to demonstrate a coherent grasp of the conceptual model under investigation than those who prefer to rely on propositional representations (algebraic expressions) of the model. They find it easier to “zoom out” from the algebraic details to a “wide-angle” view of the problem space.

Teachers can help students “zoom out” when they get stuck on the mathematical details by asking questions that redirect students’ attention to the physical interpretation of data they are manipulating.

**Negotiating shared understanding**

Whiteboards are an important cognitive and communicative tool for both teacher and student. They are a place for students to represent what they have discovered or negotiated in collaboration with their peers. They show the processed data that maps a problem space as they have come to understand it and illustrates the group’s assertions about the problem. Whiteboards are where private mental models become shared conceptual models and they afford the teacher a valuable window on student thinking as it is happening.

I have been using whiteboarding in my teaching practice for 16 years now. I think I stopped feeling like an imposter about 13 years ago. Coincidence? I think not.

**References**


After teaching high school for 23 years, Colleen Megowan-Romanowicz went to Arizona State University to study Physics Education Research under Professor David Hestenes, founding director of the Modeling Instruction Program. She earned her PhD in 2007. She remained at ASU as an assistant professor, developing a Modeling-based content-focused master’s program for middle school science and mathematics teachers. In 2014 she retired from ASU. She is currently the Executive Officer of the American Modeling Teachers Association, Sacramento, CA.

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