

FRAMING DISCOURSE FOR OPTIMAL LEARNING IN SCIENCE AND MATHEMATICS

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Clues to students' mental models

Whiteboards illustrate or at least imply:

1. How students see the problem space—the elements of the conceptual model that they bring to the problem space and how well or poorly they are defined
2. How they fit together (structure, or at least correspondence)
3. How the information in the problem space maps onto these elements of their conceptual model
4. How they navigate their conceptual model to answer the question that the problem poses

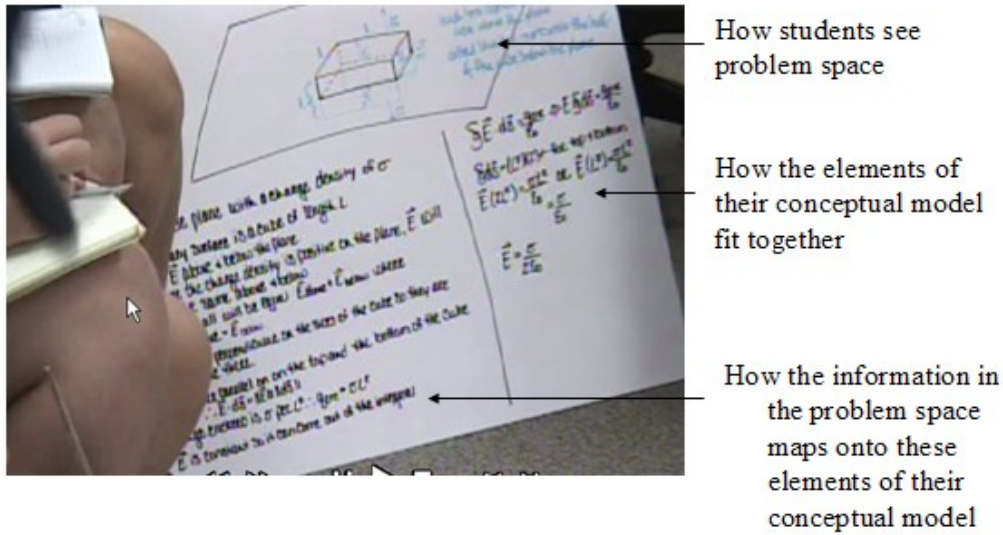
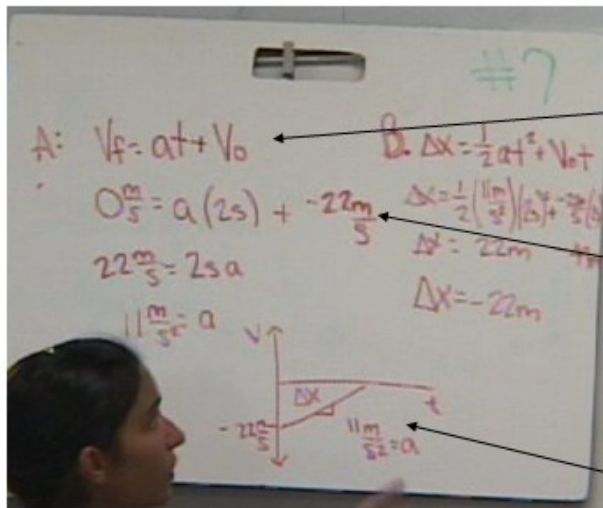


Figure 1. EMCC college physics students conceptualize electric field

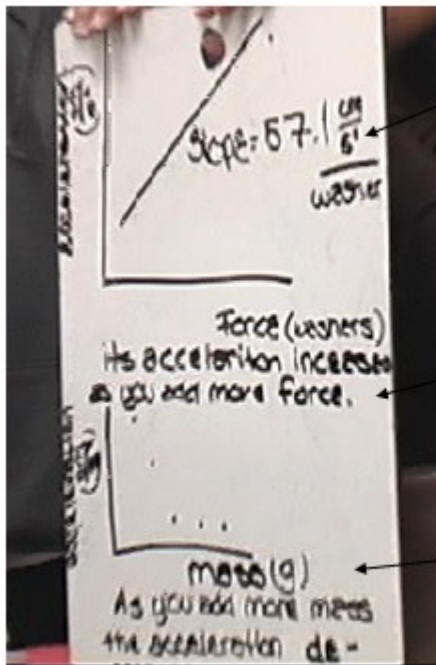


How the elements of their conceptual model fit together

How the information in the problem space maps onto these elements of their conceptual model

How students see the problem space

Figure 2. DHS physics students consider the case of an object moving backward and slowing down



How the elements of their conceptual model fit together

How the information in the problem space maps onto these elements of their conceptual model

How the students see the problem space

Figure 3: CCHS science students grapple with the relationship between force and acceleration

TEACHER: I got a different solution.

Jen: Oh, I was looking at number one. Sorry.

TEACHER: That's everything else stays but you put the number in wrong—7 times 1.5 is 10.5

Jen: I just copied down the wrong number. Same answer. I just put the wrong one... (after a pause, the class claps politely and the students return to their seats.)

24

$$V_f = a \cdot t + V_0$$
$$V_f = (-5.5 \frac{m}{s^2})(7.0 s) + 20 \frac{m}{s}$$
$$V_f = 10.5 \frac{m}{s} + 20 \frac{m}{s}$$
$$V_f = 30.5 \frac{m}{s}$$

31

$$V_f = a \cdot t + V_0$$
$$20 \frac{m}{s} = (-5.5 \frac{m}{s^2})t + 0$$
$$20 \frac{m}{s} = -5.5 \frac{m}{s^2} t$$
$$t = 5.09 s$$

Figure 5. No spatial representation is presented here by Jen and Bonnie, and none is asked for.

(DHS 9-30-05)

One way to know where a student's thinking begins or what they think is most important is to look at what is written largest on the board and what is written on the top left side or top center of the board. This is not a foolproof strategy as students may go back and redo their whiteboard after they have agreed upon what it should say and how it should look, but, in general, I found that the whiteboard scribe started in the upper left quadrant of the board, or in the upper center of the board.



Figure 6. In general, the scribe starts in the upper left or upper center quadrant of the whiteboard.

Another clue to what students' believe is important is how they talk to the class about what they have shown on their board. If their board shows a graph, a motion map and an algebraic solution,

and all they mention is the algebraic solution, this may mean that this is the only information on the board that they think counts for the listeners.

While the teacher must be aware of *what is missing* in the activity of modeling and model sharing—i.e., what are the elements, relations, operations and rules embodied in the model that the student brings (or not) to the problem space, and which of these are missing from the whiteboard explication—it is not necessarily optimal for the students if the teacher assumes the entire burden of questioning about these aspects. Students must know how to probe one another, and they must feel that asking these questions is expected of them.

They learn how to do this probing by imitation. In virtually all of the classrooms I observed, the students who were active participants in small groups employed the same questioning strategies that the teacher employed.

In the DHS 12-08-05 transcript excerpt, above, of Hannah explaining energy transfer, she questions Ara and Jimmy as she helps them think through the problem:

HANNAH: What happened, as it was moving down the hill? Well, for one I just said, like you would, it moved. So you're going to have what?

ARA: I do not understand the question?

HANNAH: What, what kind of energy do you always have when something is moving?

(DHS 12-08-05)

These questions mirror the sorts of questioning that their teacher routinely does in whole class discussions and whiteboard sessions. Here is the teacher questioning the class on the previous day about a lab activity they had just completed:

Teacher: When we let the cart go, what happened to that energy in the system?

And a few minutes later:

Teacher: What kind of pattern are you seeing?

Students in the community college class frequently questioned each other during whiteboard preparation and board meetings with the types of questions their teacher liked to ask:

Student: So would the concept work both ways?

Teacher: Would it be okay to pretend that it's an infinite plane?

Ninth grade Physical science students question each other as their teacher does also:

Student ...still if you were there, it would be like that, but since you're on the globe would it?

Teacher...I'm holding it here, right from the bottom here, Antarctica means I'm down there, so does it, ... when I hold it, is it going to be like that?

One strategy some teachers employ to stimulate student participation is to call on them by name and ask them if they agree with the whiteboard presenter, what they think about some point in the presentation, or what something means. Another strategy involves calling out students who look puzzled or confused and prodding them to share their doubts with the whole group. Since translating their conceptual structures to spatial representations is the step that students most often eschew, this is good place to press for additional input with respect to sense-making. Here are two examples in which teachers use this strategy—one from the community college from the discussion about the infinite plane and the second from the 9th grade physical science class in which students try to come to grips with gravity:

TEACHER: All done? Everybody got it? I see some quizzical looks. What about you Jack?

JACK: (tentatively) Makes sense.

TEACHER: So, does it matter how high above your infinite plane you are? Does that make sense to everybody? Have you ever seen a situation where no matter where you are something is always the same?...

JACK: I'm still a little confused.

(EMCC 10-3-06)

TEACHER: Why do you say yes, James?

JIMMY: I didn't say yes.

TEACHER: You didn't say yes? You threw your voice?

JIMMY: Uh-huh.

TEACHER: Okay, so you're saying no?

JIMMY: I don't know.

TEACHER: Does it treat both of these the same?

JIMMY: Yes.

TEACHER: Why are you saying yes then? (laughter)

JIMMY: I don't know. Gravity is pulling...?

(CCHS 3-01-06)