FRAMING DISCOURSE FOR OPTIMAL LEARNING IN SCIENCE AND MATHEMATICS
by Mary Colleen Megowan

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There are two ways that the whiteboarded information described above is typically shared with the whole class: formal presentations, where groups take turns and members of each small group all stand in front of the class and present what they have written on their boards; and board meetings, where the class forms a circle so that everyone can see everyone else's whiteboard at the same time and compare the different boards with one another. These will be described separately in the next two sections.

Whole group whiteboard presentations

The activity structure of whole group whiteboard presentations is fairly rigidly scripted. The teacher controls the floor by nominating some group to present their whiteboard. The group comes to the front of the room and one of its members takes the floor, initiating the Presentation. Often the speaker begins by reading the question that their whiteboard presentation is about. Lemke calls this External Text Dialogue (Lemke, 1990), where the text or worksheet itself is given a voice in the presentation (usually a proxy voice for the teacher). The tone of the presentation changes audibly between External Text Dialogue and Presentation, presumably because the Presentation requires the student to outline their own reasoning about the question while the recitation of the External Text Dialogue is simply a restatement of the information that is given. The presentation typically consists of however many separate parts there are to the problem that is being solved. If the whiteboard presentation is for Going Over Homework, the problems often have multiple parts. Each is described as a separate exercise often preceded by its own bit of External Text Dialogue. Within the Presentation, the speaker usually first identifies the formula that they will use, the pieces of known information that are necessary to solve the problem, and finally, the type of information The Answer is, i.e., a force, or a velocity. Sometimes the speaker will say how they know the various pieces of information that they have identified as necessary, i.e., from the graph, or from the answer to the previous problem. Then they briefly describe how they solved the problem, usually talking about steps in the computation process. They finish with The Answer, which is followed by The Pause, or a Bid for Questions that is followed by The Pause, typically a two to five second interval of time in which Questioning is expected to begin. It is important to note that in whole group whiteboard presentations, the speaker is usually looking at and talking to the teacher. This was true in all three of the classes that employed this format for whole group whiteboard sharing.

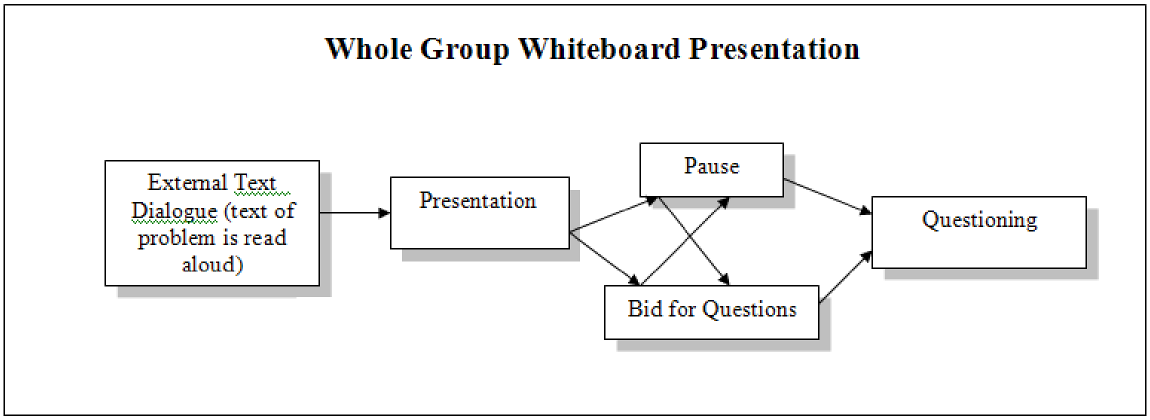

Figure 1. The typical structure of a whole-group formal whiteboard presentation.

Different classes handled The Pause in different ways. In the middle school mathematics class, students often waited for the Speaker or the Teacher to Nominate them before speaking, raising their hand to indicate that they had something to contribute. In the high school classes, students who had questions sometimes just called them out and at other times raised their hands, but most of the time they sat silently, without making eye contact with the presenters, with their teachers, or even with each other, apparently waiting, either for the teacher to ask the questions or for the group that presented to be allowed to take their seats. The community college class did not employ this formal presentation format so their response patterns will not be considered here.

If there was any teacher questioning, it usually followed The Pause. Often the first question the teacher asked was, "Any questions?" If the audience still had nothing to ask there were several questioning strategies that the teacher employed. He might begin questioning a particular member of the presenting group that he felt had not yet contributed, or just address a question to the presenting group as a whole or he might ask the class what they thought about some detail of the presentation. Sometimes this evolved into a Triadic Dialogue with one or more students, where the teacher asked a question, a student answered and then the teacher offered some sort of evaluation of their reply. This triadic dialogue might take on the form of "target practice" where the teacher has a particular answer in mind and he keeps rephrasing the question until the responding student gives him the answer he is looking for. In most cases, the signal to end The Presentation came from the teacher, either by way of an expression of thanks to the students or directions to the class to "give this group a hand." Sometimes the students stole this turn from the teacher by starting to clap during The Pause, usually when the presenting group looked like they were making preliminary moves toward their seats. Sometimes the teacher vetoed this by beginning the questioning and other times he would let it go and call on the next group of presenters.

TEACHER: Let's go on to number 4.
Paul: For number 4 we used final velocity equals acceleration times time value plus initial velocity. Then we plugged in the given numbers and got 9.05 m/s. (Pause) Anybody have any questions?

Their board says:
$V_f = at + v_0$
$3.0\ m/s = (-2.1\ m/s^2)(t) + 22\ m/s$
$\underline{-19\ m/s} = \underline{(-2.1\ m/s^2)(t)}$
$-2.1\ m/s^2 \quad -2.1 m/s^2$
$t = 9.05\ m/s$

TEACHER: No questions?

Bob: Nope.

TEACHER: Alright. Let's give these guys a hand.
…
Olivia: Okay, so the problem is an airplane starts from rest and accelerates at a constant 3 m/s^2 *for 30 seconds before leaving the ground. How much runway does the plane cover before it lifts off? So we know the initial velocity is zero meters per second and we know the acceleration is 3 m/s*^{2} *and we know the time is 30 seconds. What we're trying to find is the change in x so…*

The WB says
5. $v_0 = 0\ m/s$ $\Delta x = 1/2at^2 + v_0t$
$a = 3\ m/s^2$ $\Delta x = ½(3m/s^2)(30s)^2$
$t = 30\ s$ $\Delta x = 1350\ m$

Sean: …it's plug and chug…

Olivia: The change in x equals 1350…One thousand three hundred and fifty meters…

Sean: (Pause) Questions? (after about a second of silence) That's it. (They sit down as their classmates clap. The next group gets up and go to the front.)

(DHS 9-30-05)
In most whole group whiteboard presentations of Going Over Homework, students seemed to be more interested in producing proof (for the teacher) that they solved the problem they had been assigned, than they were in sharing their solutions with their peers. In both the above excerpts, taken from the same class period, the students directed their presentation to the teacher, while the teacher's requests for questions were addressed to the class. Very little time passed (less than 2 seconds) between when the teacher asked if there were questions and when he dismissed the presenting group. Although he went through the motions of asking for questions, is it possible that he did not really expect students to have any?

Whole group board meetings

The activity structure for whole group board meetings is somewhat different from that of formal whiteboard presentations. This activity is usually reserved for occasions when the entire class has worked on the same problem—usually a laboratory exercise or Practicing With The Model problem assigned in class.

The Board Meeting begins when the teacher calls the class to attention and has them get to stand or sit in some sort of circular configuration that allows them all to see each other's boards. Classroom seating arrangements made this somewhat awkward in all but one of the classrooms observed—the community college classroom—which had a large area of open floor space in the center of the room where students could roll their chairs into a circle. They placed their whiteboards on the floor in front of them resting against their knees.

The meeting opened either when the teacher Nominated a particular group of students to begin, when someone volunteered to be first (this latter occurrence was only observed in the community college class) or when someone asked a question of another student group about something shown on their board. The Initial Presentation, if there was one, was fairly similar to the sort given in the whole group whiteboard presentations described in the previous section, but The Pause, was followed by a comparison of the other boards in the circle with the one just presented.

In the middle school and high school classrooms, the conversation that followed The Pause, if any, was usually followed by a teacher-initiated discussion of how other boards were either like or different from the one presented. In the middle school and the two high school classes, the teachers usually retained the floor throughout most of the discussion, periodically calling on different individuals to participate. The middle school students at times managed to sustain discourse without teacher intervention for short periods. When the conversation stalled periodically, the teacher restarted it by asking a question or series of questions. Middle school students did not seem exhibit as much hesitation about taking the floor as the high school students did, as mentioned previously they did not seem to care about whether or not they appeared smart to their classmates.

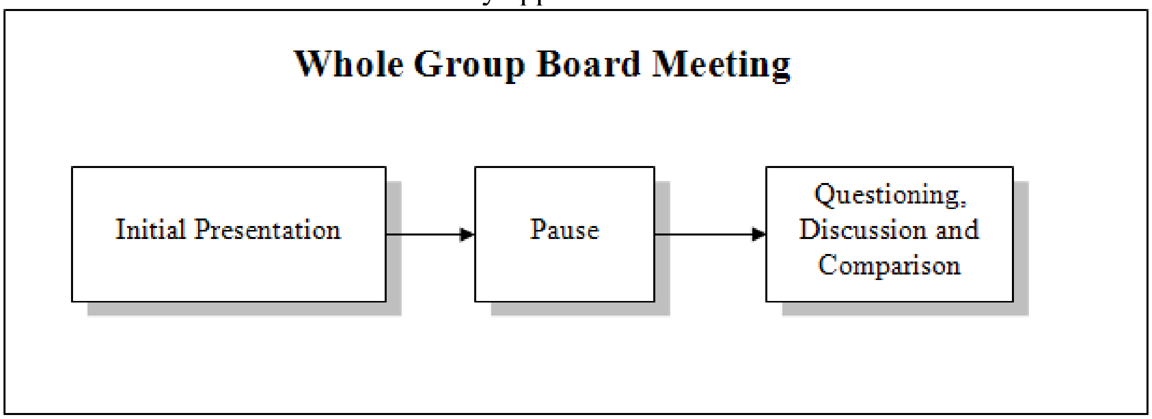

Figure 2. The typical activity structure of a whole-group board meeting.

In the community college class, The Pause was usually brief and questioning by students of one another was spontaneous, often interrupting and asking for clarification while the Initial Presentation was in progress. These differences did not seem to depend on age and maturity so much as on teacher expectations and established classroom norms. The community college students I observed were together as a class for a year before I began collecting data in their classroom. It was a small group and they seemed comfortably familiar with each other. On the few occasions when they had very little to say to each other at board meetings, the teacher prodded them to engage, and chided them if they failed to do so. He watched the non-presenting students closely during The Presentation and if he saw signs of puzzlement on anyone's face, he asked that individual specific questions about the content or the meaning of The Presentation when the follow-up discussion stalled out.

> *TEACHER: (Kiki is done presenting her whiteboard.) All done? Everybody got it? I see some quizzical looks. What about you John?*
>
> *John: Makes sense (his tone is tentative).*
>
> *TEACHER: So does it matter how high above your infinite plane you are?*
>
> *John: No.*
>
> *TEACHER: Does that make sense to everybody? A situation where no matter how high you are something's always the same? (Long pause while most of the students sit staring straight ahead) I know it's Monday.*
>
> *John: When you have a line of infinite charge, length didn't matter.*

TEACHER: Length didn't matter…that's good. If I drop my keys right here (about 3 feet off the ground) how would the acceleration of gravity compare if I dropped me keys from up here (holds his keys above his head)? How do we calculate force of gravity? (someone murmurs) A little louder.

Student: Mass times acceleration.

TEACHER: Mass times acceleration of gravity. So it wouldn't matter if it was here or here. So what are we pretending the earth is, when we're doing that?

Student: Infinite.

TEACHER: An infinite flat plane…which we're saying the force is the same. Is the earth really an infinite flat plane?

Student: No.

TEACHER: Not unless you want to go back to the flat earth society. So is it at times okay to pretend something is what it is not? And the answer is…what do you think? (students look at each other but no one speaks for about 10 seconds. Finally someone speaks.)

Student: I guess it's okay.

TEACHER: Okay—three laps around the building till you all wake up…I ask you a simple question like that I don't expect this (blank stare) Is it okay to pretend something is infinite when it's not?

(Murmurs of "yes")

TEACHER: (throws a WB in the middle of the floor…) Let's pretend that it has a charge on it… would it be okay to pretend that this is an infinite plane?

All: yes

TEACHER: Under what conditions?

Student: When it's not a conductor.

TEACHER: Doesn't matter. This is a geometric argument not a physics argument…pause… we're pretending the earth is an infinite plane to accommodate gravity…is it flat? Or even…is the earth flat? …(students shake heads)…hmmm….so when is it ok to pretend that's an infinite plane?

Ann: When you have to assume it to reach a conclusion?

TEACHER: Well….okay…when you have to…that's a start…that's a mathematical reason…now let's see if we can think of a physical reason.

Ruben: When it's the whole universe?

TEACHER: That's not the whole universe, thank heavens…it'd be awful crowded to fit 4 billion people on there…when can we consider that an infinite plane? What's the definition of an infinite plane?

Mark: When [ ]

TEACHER: Right—does that go to infinity in all directions?

Mark: No

TEACHER: And a plane is how thin?

Mark: Infinitely.

TEACHER: Alright…so that's probably its most plane-like feature it has is it's thinness….so when's it ok to consider that an infinite plane?

(EMCC: 10-03-05)

Advantages and disadvantages of the various architectures

Participation, in the form of contribution to the reasoning or problem solving process, was constrained in all cases by the dominance of some person (sometimes a students but often the teacher) who was perceived to have the floor, and by whether or not that person was willing to give it up their control of the floor to someone else. In small group whiteboard sessions, where students were whiteboarding homework problems, there was frequently one student who took the lead, referred to above as The Decider. She was the member of the group who seemed to be most confident in her answer and her ability to demonstrate for others the procedures and reasoning she used to arrive at a solution.

Typically, the Decider held the floor by taking the lead in preparing the whiteboard and answering the questions of other members of the group. When there was more than one member of a group who exhibited confidence in their understanding of the problem, two people might write on the whiteboard at the same time, one making the graph or diagram while the other wrote the equation and computed the answer. However, when two people were working to prepare the board simultaneously, The Decider was the usually the equation writer and solver, and most often The Answerer of questions posed by other group members. In general, except in the community college class, it appeared that students valued the algebraic solution over the spatial representation—more time was spent talking about it, and there were more conversational references to it than there were to diagrams in both small group and whole group discussions. On the other hand, when conversations turned to questions such as "how do you know…?" or "why did you do that?" The Answerer would often refer to how the diagram was constructed as justification for the algebraic choices made in solving the problem.

More time and attention were given to procedural concerns and algebraic reasoning in cases where students valued getting numeric answers over representing the problem space. This may have been a function of the types of problems they were assigned, i.e., if the problem asked for the acceleration of a 500 gram block sliding down the frictionless surface of a 30 degree incline, students knew that their goal was a numeric value. Problems of this type were the usual fare in the middle school and high school classrooms where worksheets that had been assigned for homework were used as classroom whiteboard exercises. The paradigm labs were exceptions to this, but even these usually resulted in some numeric answer, i.e., “the slope of my graph, which demonstrates that the relationship between change in position and change in time in this situation is directly proportional, was 22 centimeters per second represents the velocity of my battery powered car.” With the exception of the community college students, whose whiteboard exercises most often resulted in diagrams and derivations of formulas rather than “answers”, the students observed showed a strong preference for answers. In the words of Jimmy:

Jimmy: I’m just happy that my answers are right. That’s all that matters.

It was the first thing they compared with each other before they began whiteboarding a worksheet problem in small group and “what did you get for number ___?” was the most often asked question when the sat together in their small groups and worked side by side on worksheets during class.