# Managing Student/Teacher Co- Construction of Visualizable Models in Large Group Discussion *

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# Managing Student/Teacher Co- Construction of Visualizable Models in Large Group Discussion (Proceedings of the AETS, 2002)

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This paper describes issues that have arisen in attempting to develop a markedly different approach to teaching biology at the middle school level. We have embarked on the development of a 7th grade curriculum titled "Energy and the Human Body" that deals with pulmonary and cellular respiration, circulation, and digestion (Ramirez, Clement, Nunez, and Else, 2001) . One of our goals is to address some of the conflicts teachers feel in responding to the call for both inquiry and conceptual understanding under the new national standards. Teachers often feel pulled in two different directions: on the one hand they are urged to teach content in a deeper way as measured by standardized tests; on the other hand they are urged to adopt student directed inquiry methods. They often feel that open-ended methods are incompatible with strong content goals that they are asked to fulfill.

The strategy used in our curriculum takes an intermediate position. The strategy is one of student-teacher co-construction that elicits student generated model elements as well as some that are introduced by the teacher (Rea-Ramirez, 1999; Steinberg & Clement, 2001; Clement & Steinberg, in press). I will further articulate this strategy and some of the issues it raises in what follows. Other aspects of the approach are described in Nunez, et al. (2002), and Else, et al. (2002).

## Content Goals and Target Models

We are taking content goals seriously in this project, as reflected by our plans to attempt to measure conceptual change using pre and post tests during the curriculum trials. Content goals are expressed as descriptions of target models. Each target model is a desired knowledge state that one wishes students to posses after instruction. This may not be as sophisticated as the expert consensus model currently accepted by scientists. Instead of logical relationships used in formal treatments of the topic, an educator's view of the target model reflects qualitative, simplified, analogue, or tacit knowledge that is often not recognized by experts.

The curriculum must deal effectively with the problem that content goals in science are sometimes frustrated by the presence of student alternative conceptions (sometimes termed misconceptions) which are in conflict with the target model. However we also are alert for useful student conceptions that are compatible with current scientific models and that can be used as building blocks for developing the target model.

Van Zee and Minstrell (1997a,1999b) have discussed a number of strategies for promoting large group whole class discussion by drawing out students' ideas within the context of teaching for conceptual change in the presence of alternative conceptions. Hammer (1995) has documented some impressive thinking processes that can occur under such conditions in a secondary physics course. Further work is needed, however, on how large group discussions can feed model construction processes that are aimed toward content goals. Here I want to examine some different ways to describe some of the different roles teachers can play when they allow student ideas, both correct and incorrect, to be taken seriously in classroom discussions (where by 'correct' I mean largely compatible with the target model for the lesson).

## Instructional Approach Used

The topics covered in our curriculum include digestion, pulmonary respiration, the distribution of oxygen and sugar by the circulatory system, and microscopic respiration in the mitochondria. The instructional strategies used include hands-on activities, analogies, discrepant events, model building, and computer generated animations, supported by scaffolding and probing questions. In this paper we will focus on a short example of the approach used in the *pulmonary respiration sequence* to illustrate some of the discussion leading decisions faced by the teacher.

### Pulmonary Respiration Tutoring Sequence

A principle teaching method used to aid mental model construction is to have students invent models of body systems that could perform functions like breathing or delivery of nutrients to a limb. They are asked to do this on their own initially before receiving information from the teacher. Almost always this involves making drawings. The teacher then uses the students' initial models (including misconceptions contained therein) as a starting point to foster a series of model criticisms and improvements. Eventually enough changes are made to approach the target model for the lesson.

Figure 1 shows a typical part of the lungs teaching interaction. In an initial model constructed in a drawing by the students, the lung is mostly hollow (an incorrect "balloon" model of the lungs), with veins and many hairlike structures on the interior surface to "filter bad stuff out of the air." There is also a hole at the bottom of the lung. The teacher then asks a "discrepant question." "What is this hole at the bottom here? What would happen to the air there?" The students then begin to worry about air leaving the lung there and decide to modify their model by closing the hole. This is an example of an indirect and mild but focused intervention by the teacher. Some students think that the two parts of the lung might actually be joined together to in effect form one large cavity. At that point the teacher asks another discrepant question: "Are there operations where they remove one lung?" Students agree they know of such operations and decide that there must be two separate lungs.

Later when students realize the lungs are more "meat like" than "balloon like," they may make the air passageways too small or few in number to hold enough air. At that point the

**CO-CONSTRUCTION IN PULMONARY SYSTEM**

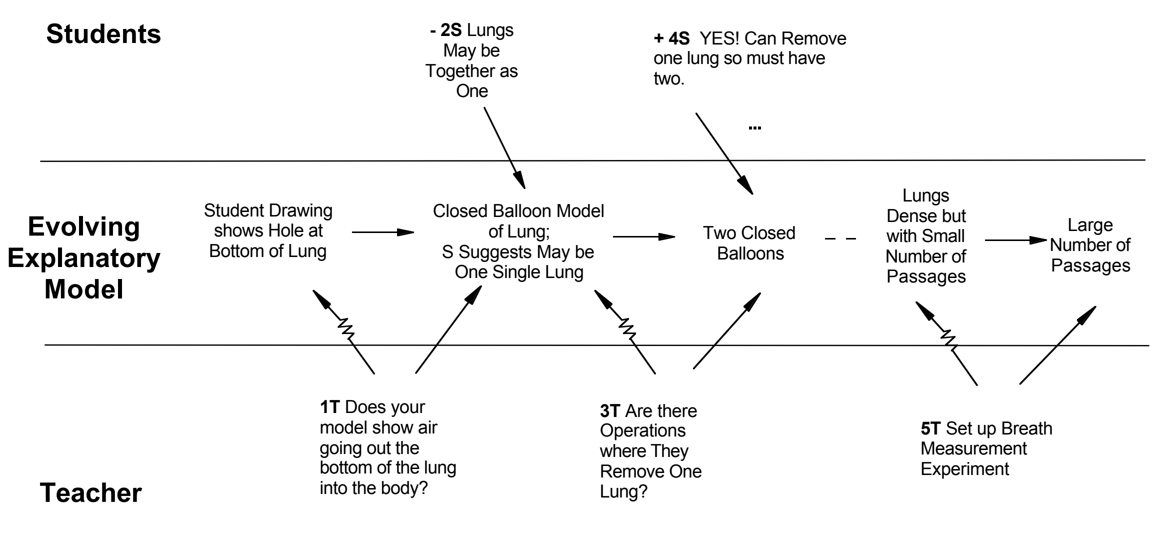


**Figure 1**

teacher sets up a breath measurement experiment where they use long plastic bags to measure

how much air is contained in a deep breath, showing that there must be many pervasive tubes and passages indeed. Thus the discussion led by the teacher modifies the model in small steps, making it more and more like the target model for the lesson. In describing this process two aspects of Figure 1 are noteworthy:

- The sophistication of the students' explanations grew steadily during the instructional treatments. We can view the students' conceptual changes here as producing a sequence of progressively more expert-like models. This suggests a view of learning that has model evolution as its central feature, where students are able to build on knowledge that they had developed in earlier sections.
- Discrepant questions or events were used to motivate model revisions. These included the breathing capacity measurement. We modeled effects of the discrepant questions as internal dissonance with an existing conception. These are shown as jagged lines in Figure 1.

## Distinguishing Between A Student Directed Agenda And Student Generated Ideas

We believe that part of the dilemma faced by teachers faced with both content goals and calls to use student centered inquiry strategies may be solved by increasing the precision of the vocabulary that we use to describe classroom interactions.

Two important but different ways to talk about student centeredness in a curriculum are the extent to which :

1. Activities are teacher or student directed (Who is setting the questions and the agenda?)
2. Ideas are teacher or student generated (Who is generating and evaluating the explanations and ideas in the learning?)

These are separate dimensions for describing a classroom but they are often confused. A way of describing the intent of the present curriculum is that it is teacher directed about 85% of the time--the teacher carefully directs the attention of the students to most topics and activities in a planned sequence. Thus it is quite teacher directed. Yet its ideas are teacher generated directly only about 40% of the time: within each topic students are encouraged to propose as many ideas as possible and then to modify and improve them, so that they may end up proposing 60% or more of the ideas. Thus the knowledge developed is largely student generated but at the same time the agenda is largely teacher directed.

This is a bit like the efficient structure of a meeting for an organization that has a chairman but that needs strong input from its members. The chairman sticks fairly faithfully to the agenda for the meeting, but opens the floor for input on each agenda item. Creative responses are encouraged. In addition the chair draws out or reminds the members of constraints that force reconsideration or modifications in some of the ideas that come up. This structure combines openness to ideas with the efficiency of an agenda that allows one to achieve goals and prevents aimless wandering of the topic. The structure contrasts to more dictatorial ones in that the members feel an investment in the outcome in that they have had an input to the process.

Thus, this puts the approach midway between pure "lecture" and pure "discovery learning", where by the latter I mean students inventing all the ideas without teacher input. The approach represents an intermediate position on whether ideas in classroom discussions should be teacher generated or student generated since it advocates both sources as important. In general, the aim is to have as many of the ideas be student generated as is practical, given the

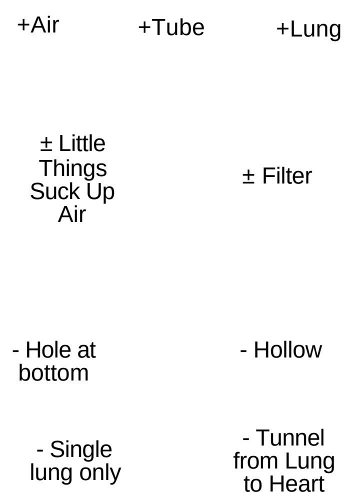


Figure 2 Mosaic of Student Generated Ideas for Structure of Lungs

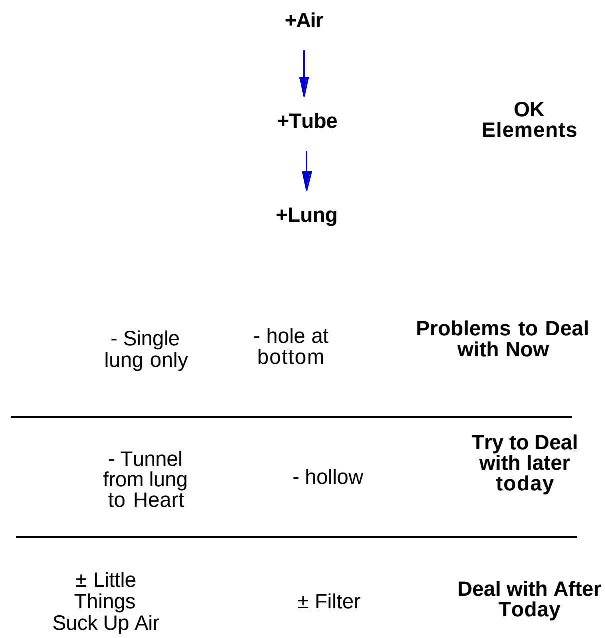


Figure 3 Teacher's Agenda Organization of Mosaic of Ideas for Structure of Lungs

constraints of limited time for each curriculum topic. This serves the larger goal of fostering active learning and reasoning as a way to increase sense making, comprehension and retention. To do this the curriculum provides some guidance as to which ideas the students may be able to construct and which ideas usually require teacher introduction. Throughout discussions the teacher monitors the students' ideas, offering mild or if necessary, stronger support tactics to promote student construction until the next targeted model is reached.

## New Descriptive Images of Large Group Interactions

In this section I try to paint images of large group discussion that may help teachers think about their role in the process of student model construction. At this stage the following ideas are in the form of initial theoretical concepts formed in reaction to open ended classroom observations of curriculum trials. We plan to evaluate and refine these ideas in the context of more structured observations in the future.

### The Mosaic of Student Ideas Generated by Large Group Discussions.

When students are encouraged to generate ideas in open ended discussion, a collection of unnervingly diverse ideas can be offered by students. The diagram in Figure 2 shows an example of what Maria Nunez calls a "Mosaic" of student ideas that the teacher is dealing with at any given moment. The Mosaic of ideas has the following features:

- The Mosaic outlines the present collection of "Ideas in the air" in the large group discussion.
- Some of the ideas are largely correct in the sense of being close to the target model. Others are largely incorrect, and still others are partly correct.

*Key for Figures 2 & 3:*

+ = Largely correct idea
- = Largely incorrect idea
± = Partially correct idea

To help steer their decision making within this somewhat complicated mix, teachers may impose an organization on these ideas in their own mind to help deal with them, as depicted in Figure 3, raising the following additional issues:

- There may be natural connections between the largely correct ideas according to biological structures or functions (as indicated by the arrows). These can form a rough initial model to work from.
- Teachers can sort the largely and partially incorrect ideas into 3 categories: Those we can work on now, work on later today, or work on after today.
- The last category implies that teachers can postpone dealing with certain misconceptions until students are prepared to deal with them. Rather than trying to immediately replace all of the misconceptions, the strategy aims at working on one at a time, and either modifying the misconception or replacing it.

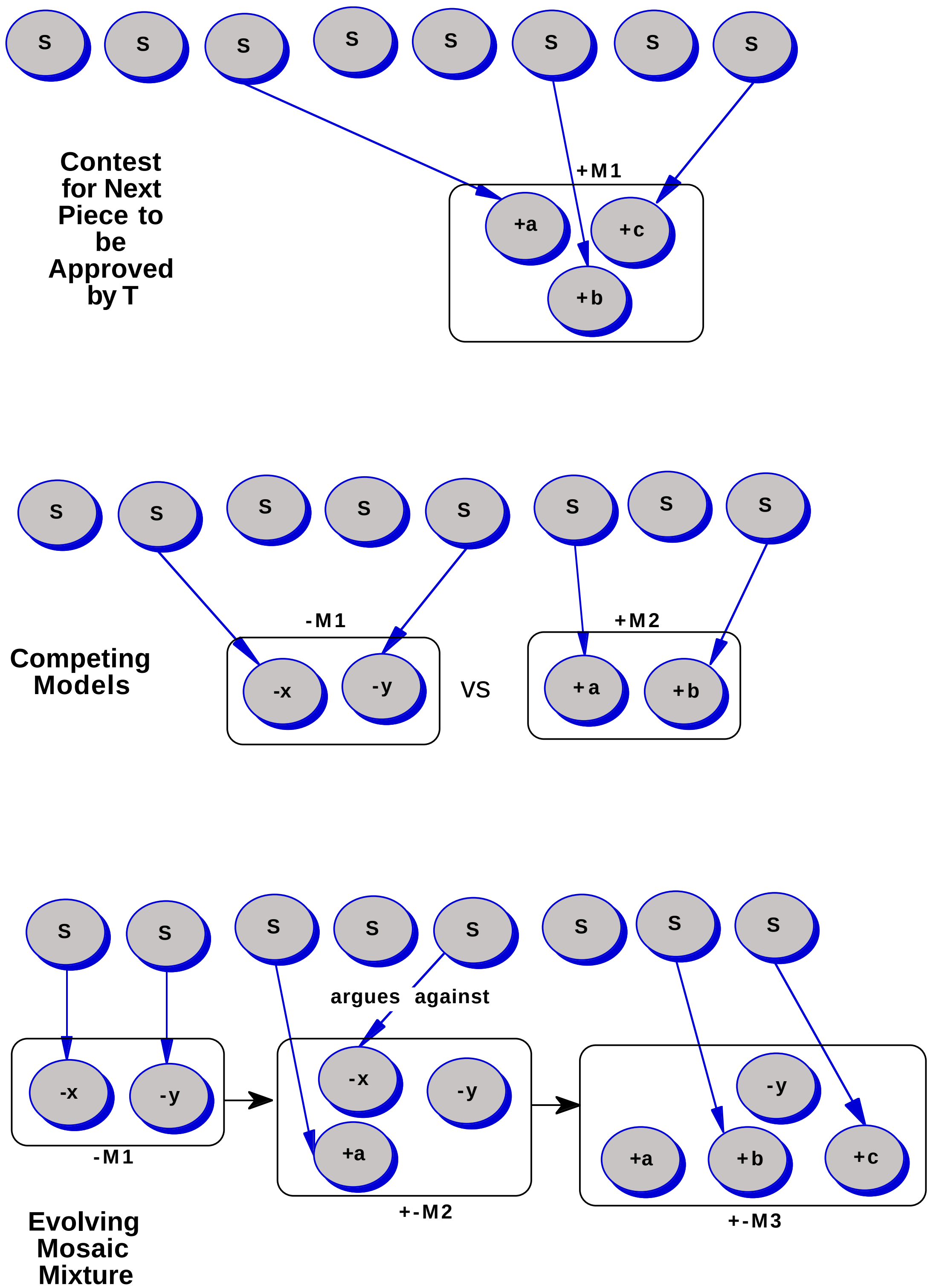


Figure 4 Three Views of Model Construction in Whole Class Discussions

Three Views of Large Group Model Construction in the Classroom

Figure 4 shows three modes of large group model construction patterns that have been suggested by classroom observations of our curriculum trials. These refer to large group discussions led by the teacher where the teacher is asking for ideas about the structure of the body, such as: "How does our body use the air we breathe to send oxygen to the cells?" or "How does blood get to the big toe to provide nourishment to it?" These questions are asked early in a unit before most students have studied anything about the topic, so there is an opportunity to elicit student preconceptions and creative model constructions. The overall approach is to present a function of the body (providing nourishment to the big toe) and ask students to construct a structure in the body that could perform the function.

Figure 4 uses the following key:

S = Student articulated idea
+a , +x = Largely correct idea
-a, -x = Largely incorrect idea
+M = Largely correct Model assembled from ideas as components
-M = Largely incorrect Model assembled from ideas as components
±M = Model that is partly correct and partly incorrect

The top portion of the figure represents a pattern where the teacher is selectively approving of only those articulated student ideas that are correct. He or she may then summarize or draw and add them to a collective model here labeled M1. Incorrect ideas are ignored. This is the most natural mode we have observed for the teachers to operate in, although we lean against using it too often because it can prevent meaningful discussion or comparison of models and elements.

The middle portion of Figure 4 represents a competing models pattern. The teacher recognizes both correct and some incorrect ideas as worth considering without passing judgement on them. These are clustered into competing models which can be drawn or summarized by the teacher. The teacher then solicits further discussion to foster student evaluation of the two competing models. The teacher may then have all students vote on the model they think is more viable.

The bottom portion of Figure 4 represents an evolving mosaic mixture pattern. Here a series of false to partially correct to more correct models are developed progressively, as was illustrated in Figure 1. Incorrect ideas form the first model M1 (although this has been oversimplified for the diagram; usually M1 would be a mixture of correct and incorrect ideas). Discrepant questioning on specific issues by the teacher may trigger student generated corrections or additions to part of the model to form intermediate model M2. This process continues to form more intermediate models until the target model is reached.

The aim here is to keep students in a "Reasoning Zone". Building on Vygotsky's ideas, I define the Reasoning Zone as an area of discussion where students can reason about ideas and construct new ideas productively (or at least contribute to its production in a group). Not all move in the direction of the target, but if thinking in the Reasoning Zone includes idea evaluation and modification, then progress toward the target should occur. If the question or topic chosen by the teacher is too large or too hard, it will be outside of this zone. This is what makes it important to utilize a strategic agenda as illustrated in Figure 3 to keep the students in a reasoning zone where they are able to make inferences and corrections to the growing model. Even so, sometimes when discussion starts it gets bogged down quickly. In this case the teacher attempts to provide just enough support in the form of a leading question, hint, new observation, reference to an earlier comment, discrepant question, etc. in order to get student reasoning going again.

Co-construction

The patterns shown are somewhat idealized in that all or most of the ideas are coming from the students and not the teacher. In practice some of the corrections may be made by the teacher in this process if specific content goals are a priority, a student correction cannot be elicited, and the teacher feels they are ready for it. Such patterns represent a process of co-construction in which both teacher and students contribute ideas and evaluations of ideas.

The curriculum we are developing is rich in visualizable models, therefore we believe it is important for the teacher to help students communicate with each other by drawing what students are describing (whether correct or not) on the board in front of everyone or having students draw their own models on the board. This provides a visual as well as a verbal communication channel to foster discussion. Drawings can then be modified to reflect modifications as the discussion proceeds.

## Conclusions

All three patterns in Figure 4 are unusual in the extent to which they use student generated ideas. There is some danger that Pattern I can become a guessing game in which students throw out guesses to compete for the next piece to be approved by the teacher, without really evaluating the models themselves. Patterns II and III involve student generated evaluations as well as student generated ideas or model components. Pattern III along with a Mosaic Agenda and discrepant questioning seems to be the most difficult to orchestrate and yet holds much promise as a pedagogical strategy. We are exploring the possibility that teachers can learn to orchestrate these patterns starting from pattern I and eventually working up to pattern III as they gain skills and practice.

We think it is important to examine the effectiveness of these strategies and the conditions under which each one may or may not be useful. In future research we think that tapes of large group discussions can be analyzed toward these goals. As we learn more about how to describe different kinds of classroom interactions that involve a large number of student generated ideas, we should be in a better position to recommend specific pedagogical strategies that respect the students' power to recall and generate useful ideas but that also take seriously specific conceptual goals in the form of target models .

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