FRAMING DISCOURSE FOR OPTIMAL LEARNING IN SCIENCE AND MATHEMATICS

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[This excerpt describes the classrooms featured in Colleen's research, providing context for the following excerpts, which analyze classroom practice using whiteboard pictures and transcripts of actual student discourse. I also included those segments which discuss the main themes in the manner most relevant to teachers, skipping sometimes dozens of pages of more technical language. MG]

INTRODUCTION

This study examines what the structure of talk in classroom discourse surrounding whiteboarded representations reveals about the shifts in students' thinking and reasoning as they progress toward a model-centered understanding of the Newtonian force concept, which is central to understanding physics as a whole. Discourse analysis, in the traditions of microethnography and Pragmatics, is used to examine the change as it unfolds.

Reform based methods—constructivism—inquiry—student-centered learning—collaborative learning—cognitively guided instruction: these are influential ideas that have the entered the pedagogical lexicon in the past two decades (Baker & Piburn, 1997). Many of us who currently teach physics know that these ideas can be important elements of effective practice, but most of us were not taught by educators for whom these ideas were a significant element of their own teaching practice. Many teachers lack an effective approach for incorporating such ideas into their own classroom routine. Some try anyway to build them into their teaching practices. Others play it safe and stick with the traditional didactic methods that their own teachers modeled for them.

Modeling Instruction has evolved from a single physics teacher's classroom teaching experiment 20 years ago into a 'movement' with close to 2000 trained practitioners who employ this method to teach physics, chemistry and mathematics. The modeling method incorporates all the ideas mentioned above, offering effective strategies for designing a more collaborative, inquiry-based, student-centered learning environment that supports the cognitive processes that take place as students construct a coherent understanding of science and mathematics concepts. FCI average gain scores for students who learn physics via modeling instruction are one to two standard deviations above those of students taught using traditional approaches ("Modeling Instruction in High School Physics," 2001). This much is known. Little is understood (empirically) about how and why Modeling Instruction works for these students. This study will attempt to shed some light on the answers to this question by studying two of the key features that make the approach unique: the centrality of whiteboard-mediated small group student discourse and the organizing principle of models.

Optimizing Discourse

Physics teachers are routinely confronted with the gap between what we think our students understand and what they can actually demonstrate that they understand. Every time we sit down with a stack of tests, assignments or lab reports to read, we are struck by the tenacity of students' misconceptions.

Unfortunately, however, by the time these misconceptions show up on a test, any feedback we might give students about them is unlikely to have a substantial impact on their thinking. We need a way to weed out misconceptions before the take root in students' knowledge structures.

We cannot pull weeds that we cannot see, however. We need a way to detect them before they become established.

Enter whiteboard mediated classroom discourse.

Listening to student conversations that are centered on tasks involving key concepts is an opportunity to attend to "cognition in the wild" (Hutchins, 1995). As students share their thinking with one another in an attempt to build a coherent model of the relationship they are exploring, the listener has an opportunity to identify the metaphors students are using to organize this information (Lakoff & Nunez, 2000). They can hear how students assemble these building blocks into knowledge structures, and they have an opportunity to interrupt the formation of inappropriate constructs before these constructs have a chance to be reinforced.

It is a fundamental tenet of discourse analysis that the smallest particles of "language-in-use" are the ones that are used most unconsciously. The seeds of students' cognition-on-the fly lie within these unconscious utterances. These utterances are grounded in students' inventories of fundamental conceptual and experience-based metaphors and the representations to which they are connected (Lakoff, 1987).

For this process to succeed several conditions are necessary:

- An opportunity to listen to students engaged in productive inscription-mediated discourse about some task that will lead to model construction;
- A clear picture of how the model of this phenomenon ought to look in the mind of the listening teacher (i.e., the key elements necessary for completeness and usefulness and how they are connected);
- A grasp of the catalog of metaphors and how they encode the language that students use, and an awareness of the points at which the inherent ambiguity of this language can lead to misunderstanding among students;
- An ability to steer discourse without giving answers (questioning strategies);
- An ability to connect student inscriptions to their thinking about the models they are constructing;
- A grasp of the cultural models of schooling that students *bring into* the physics classroom with them and the new cultural models that *can be brought about* as a result of skillful management of classroom discourse.

LITERATURE REVIEW

The Culture of the Learning Environment

Conventional schooling in the United States is a cultural paradigm that is well understood and can be described with great fidelity by children of all ages. An informal poll of the neighborhood children (who visited my house last Halloween) reveals that schooling consists of going to a place with lots of other kids, and spending most of one's time in a classroom with other children who are all about the same age, learning reading, writing, mathematics, history, and science from the teacher—usually a woman. Their classrooms contain tools, such as books, papers, pens, pencils, whiteboards, calculators, rulers and computers. Expectations in their learning environment include sitting, being quiet, listening to the teacher, following directions, filling in blanks, raising their hand, waiting their turn, getting the right answer, knowing their place, finishing in the allotted time. The teacher sets the agenda and calls the shots. The main thing about schooling for these children appears to be following the rules, getting the answers right and getting the teacher to give them points.

By the time most students reach high school they are experts at playing "the school game". They know how to suss out a teacher's expectations and boundaries, and they are adept at identifying the classroom practices that will yield for them the biggest effect (translation: buy them the most points) in exchange for the least effort. In general, motivated students are those who, by the teacher's definition, are interested in succeeding in a class (translation: earning lots of points), and success is frequently defined in terms of a student's grade for a course. If a student gets an "A" in mathematics, she has achieved success. Many teachers measure their own success by how many of their students earn A's in their classes (Tschannen-Moran, Hoy, & Hoy, 1998).

It is a longstanding complaint of corporate America that the bulk of young people (products of the American educational system) who enter the nation's labor force lack the most basic of thinking skills, and yet they possess diplomas that certify that they have succeeded in the classroom (Ray & Mickelson, 1993). One inference that might easily be drawn from this corporate indictment of public education is that conventional schooling may not have taught students how to think in ways that are most valued in corporate interests, but rather how to think in ways that earn points. The meaning is clear in the message. Points are given for behaving according to classroom rules. Success is measured in points earned. If you want to succeed in school, find ways to get points. (Of course, corporate culture rewards those who adhere to its norms as well, so they are not entirely innocent in this respect.)

As with all cultures that frame the many worlds in which we live, the culture of the classroom is co-constructed by its participants—teacher and students. There is a default culture, a conventional schooling 'paradigm', that exists if no alternative culture is deliberately negotiated between teacher and students (Gatto, 1992), but this default culture can be and is regularly replaced by some other set of social norms when teachers and students make the effort to do so.

A Question of Motivation - To Engage or not to Engage?

For modeling to happen and models to be constructed, students must opt to engage in the classroom discourse enterprise. How does modeling instruction induce engagement? One key feature of this instructional approach is its emphasis on doing physics as physicists do. Students are encultured into the ways of physicists rather than just taking physics class. Sociolinguist James Gee likens traditional physics instruction to "reading a manual for a videogame that you will never play". Modeling physics is more akin to encouraging students to play the game of physics before reading the manual.

Personal Constructs theory (Kelly, 1955) suggests that people hypothesize about the outcomes of situations, which they test and revise as they engage in activities connected with these situations and this guides decisions about the nature and extent of future engagement. Kelly's theory explicitly links emotions and motives with cognition. This plays out in classrooms when students opt to engage in some learning experience (or not) based on their assessment of its value as "academic fun", i.e., their likelihood of success in the context of this activity (Middleton, 1992; Middleton, Lesh, & Heger, 2003). According to Middleton, et al, students evaluate academic fun based on the levels of arousal and control that it affords them. Arousal is a function of whether or not an activity is stimulating and/or relevant to their interests or experiences. Control has to do with whether or not an activity is too easy or too hard, or whether there are multiple opportunities and/or ways to succeed.

Anther area in which control is a factor in modeling instruction classroom discourse is in who has the floor (Edelsky, 1981). In traditional didactic classrooms, except for rare instances, the teacher always controls the floor. In modeling classrooms, the students may have the floor for extended periods during small group and whole group discourse.

The tasks that students are given in modeling physics afford some measure of both arousal and control. They are embedded in familiar contexts, and the modeling cycle that is utilized allows students to continually express, test and revise their model as they construct it. They play the game of physics as they learn its rules.

Modeling Instruction done well produces discourse that is consistent with an activity that is intrinsically motivating. Modeling Instruction done less well can produce the sort of engagement, and as a result, the sort of discourse, that is more characteristic of extrinsic motivation, where the object of the game is answers, points, and grades. There is a self-regulatory component to this outcome that seems to be related as much to teacher expectations as to perceived arousal and control. This merits further exploration.

OBSERVATIONS

A tale of four classrooms

In the next two chapters, I will paint a picture of students and learning environments in four separate classrooms that on the surface seem quite different but upon closer inspection share many characteristics.

The data are images and transcripts of videotaped mathematics and science classes where students are routinely engaged in small group collaborative problem solving activities followed by whole class presentations and discussions of their thinking.

It is a diverse data set: a 7th and 8th grade mathematics resource class, a 9th grade physical science class, an 11th and 12th grade honors physics class, and a community college engineering physics class.

In each of these classes, teachers employ Modeling Instruction and students routinely share their work with peers on 24” x 32” whiteboards. It will become apparent, however, that these teachers’ interpretations of Modeling Instruction differ widely from one another and these differences affect how students engage in the discourse and visual representing that is central to cognition. In this chapter, I will try to capture the flavor each of these four discourse communities with an extended vignette that describes a typical day in each classroom. In chapter five, I will examine the structure of the whiteboard-mediated discourse as it unfolds and highlight how distributed cognition happens. I will illustrate how inscriptions and, at times, the metaphors that underlie them can shape and sometimes limit students’ communication and reasoning about space, time and interactions. I will explore how power relations, among students, and between teachers and students, affect the nature and extent of classroom discourse. And I will highlight what is optimal in each of these settings.

[A detailed vignette of a day in each class as well as a more detailed analysis of the culture of each classroom by Colleen are deleted here because they were too long to include in the excerpt. These vignettes and analysis are highly recommended reading. Colleen's dissertation is available from http://modeling.asu.edu/Projects-Resources.html.]

Summary

In the vignettes above, we see students, from middle school through community college, engaged in a variety of modeling activities appropriate to their courses of study. The tools they used for communicating—whiteboards, language and gesture—were similar. Students’ behavior toward each other varied somewhat. This was probably a function of their age to some extent. Their behavior toward the teacher and the tasks in which they were engaging varied as well, and this may have been related to the cultural models at work in these four very different learning environments.

The demeanor I brought to the middle school mathematics class was as much scoutmaster as teacher. My interest was in introducing these students to new experiences that I felt would result in learning. I was not concerned with points or grades. I wanted them to acquire new skills—modeling skills, communication skills, thinking skills. I took them on an extended field trip so that they could earn their whiteboarding “merit badge”. Students responded in kind. They joined in and followed along. Most bought into the idea that it was a skill set worth acquiring and they practiced it together as well as they were able.

Mr. Mendoza’s class resembled a family of which he was the father. There were routines, chores and house rules. Students were comfortable with themselves and each other. They were occasionally playful, competitive or eager to please and at times moody, demanding or contrary, but by-and-large they engaged in the classroom routines and did their “chores” without complaint. They could tell that their teacher cared about them and they usually made the effort to live up to his standards and expectations.

Mr. McEvoy was more like the coach of a team that is used to winning. From the beginning of the school year, he cultivated students’ communication skills. As they practiced these, he critiqued their form. The students treated him with respect and worked hard to acquire and demonstrate the skills he valued. They knew that teamwork and performance counted, and when they presented their whiteboards, they tried hard to do a good job and look good doing it. They believed that his game plan would win them the game and they tried their best to follow it.

Professor Donnelly’s demeanor was that of a foreman or general contractor. He had a set of blueprints to build something that the students needed (physics) and he broke it down into a series of tasks that allowed the students to build it for themselves. Working together was a given. Doing what was necessary was expected. Students were journeymen, accomplished in the use of the tools of their trade. They had the right stuff and they persisted until they got the job done.

All these groups were steeped in the culture of schooling. They could not help but bring it along. Nevertheless, teachers and students in each of these classrooms negotiated unique cultures that served to structure their interactions and frame the learning experience. These frames were not accidental—they were deliberately brought about in each of these settings. The next chapter will examine how they affected whiteboard mediated cognition and modeling in these classes.