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"It's all human error!": When a school science experiment fails

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Abstract

This paper traces the sophisticated negotiations to re-inscribe the authority of Nature when a school science experiment fails during the enactment of a highly rated science curriculum unit. Drawing on transcriptions from classroom videotapes, we identify and describe four primary patterns of interaction that characterize this process, arguing that these patterns recall the process of entextualization by which inscriptions in science become facts, and by which any cultural text (e.g., Weyewa placation rites) gains coherence.

Keywords: Science; Education; Linguistics; Authority; Inscription; Entextualization; Culture

1. Introduction

Linguistic and sociocultural studies of science have documented the process by which knowledge claims in science come to be accepted, and written about, as facts or "black boxes" in the literature (Bazerman, 1988; Latour & Woolgar, 1979).[1] A lucky knowledge claim in science gradually is detached from its experimental context, and becomes a decontextualized and objectified fact, by means of a complex sociocultural – ideological, linguistic, interactional – process of inscription or entextualization (Kuipers, 1990; Silverstein & Urban, 1996). This sort of understanding of fact genesis – as a feat of collective, intertextual negotiation – is quite different, of course, from how a particular research paper presents the "discovery" of a fact and, to be sure, how scientists themselves might describe the process (Viechnicki, 2002). In particular, the research articles that appear in scientific journal articles are highly scripted affairs that present a hypothesis

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as a question the answer to which was not known at the time of the experiment. Of course, this ideology is not entirely consistent with the realities of scientific inquiry in as much as the question asked may be constructed after the fact, for publication purposes.

The social and cultural foundations of the entextualization of facts in school science have received considerably less attention. "Entextualization" first appeared as a term in the late 1980s and early 1990s to describe "the process of rendering discourse extractable, of making a stretch of linguistic production into a unit – a *text* – that can be lifted out of its interactional setting;" and "text" as "discourse rendered decontextualizable" (Kuipers, 1989; Bauman, 1987; Bauman & Briggs, 1992:73). Since that time, entextualization has developed as a useful analytical model for describing the process by which the decontextualization of discourse is linked to the broader sociocultural dynamics of authority (Kuipers, 1990; Silverstein & Urban, 1996). To be sure, there have been rich studies of how educational practices deploy language to inscribe knowledge as authoritative. Collins (1996), Mertz (1996) and Mehan (1996) for example, investigate vivid examples of how elementary school reading instruction, law school pedagogy, and special education classification practices each reveal institutional trajectories by which culturally and linguistically constructed definitions of "reading" "legal case" and "disability" take on textual authority. But little is known about the linguistic and cultural processes by which children learn to build authoritative texts in the epistemologically privileged contexts of science (but see Lemke, 1990).

We focus in this paper on an example of the inquiry-based curricula now popular in U.S. science education. Inquiry-based science education dates at least to work by Dewey (1910), and more recently, Bruner (1960), and Schwab (1962). Broadly, its goal is to involve students in the *doing* of science. Students learn "the methods employed in the collection, analysis, synthesis, and evaluation of evidence" (Duschl, 1990), often by ritually reenacting the experiments the scientific community has agreed nicely demonstrate that fact. As in traditional curricula, the facts or concepts that students learn in inquiry units are decontextualized, that is, no longer associated with the researchers who discovered them, or with the experimental particulars of their revelation. But the point of inquiry-based curricula is to offer students a chance to experience just those experimental particulars for themselves. Students enacting these kinds of units ideally recognize certain claims as authoritative by seeing evidence of them "with their own eyes," and recent research on inquiry-based curricula has shown that they are effective in different settings (Klentschy, Garrison, & Ameral, 1999; Stohr-Hunt, 1996; Wise, 1996).

All inquiry-based units are not the same, however, as the degree of teacher guidance in formulating questions, designing investigations, and constructing explanations for the evidence gathered may differ. The more responsibility that students hold for these activities, the more "open" the inquiry; the more that the teacher structures these activities, the more "guided" the inquiry (Schwab, 1960). Yet in any inquiry unit, the outcome of the experiments is pre-determined; that is, it is known at least to the teacher, who necessarily orchestrates students' investigations in order that particular concepts be illustrated in the laboratory. Though students are reenacting an epistemological move from results to conclusions, viewed from above, the move is in fact in the opposite direction. That is to say, since the conclusions are known, the experimental results of the students' work are interpreted in light of them, and assessed as accurate only insofar as they support those conclusions.

But what happens when an experiment fails to produce the expected results, and students cannot close the intended "black box" solely on the basis of their lab experiments? Science educators have noted the various strategies that students and teacher use when confronted with anomalous data (e.g., Chinn & Brewer, 1998), but the nature of our dataset presents a unique opportunity to witness in detail the process by which the authority of the facts of science is collectively negotiated and preserved in these instances. This paper is based on video data of middle school science students as they deal with the spectacular failure of a lab over the course of 3 days, while they enact an inquiry-based curriculum unit that has been highly rated by the American Association for the Advancement of Science.

We argue that the process by which the students and teacher make sense of this failure, together preserving the authority of the lab (its results and the conclusion to be drawn from them), recalls and refracts the process of entextualization by which certain inscriptions in science come to be known as facts. When the expected results are not forthcoming, the highly contextualized student-run labs give way to a teacher-led demonstration lab, and finally to a highly decontextualized ritual chanting of a scientific law. Thus, though denied the intended inductive experimental experience, the students nonetheless have a "lived experience" of the ideologically favored trajectory from highly contextualized knowledge claim to decontextualized fact over the course of the lesson.

This well-documented move in science is but one example of how any cultural text more generally gains coherence. The research on entextualization described above suggests that the decontextualization process is pervasive, consequential and integral to sociocultural systems of authority more generally. To demonstrate this more general point, we turn to ethnographic data from the eastern Indonesian island of Sumba, where the inscription process that occurs in Weyewa ritual speech events bears unmistakable similarities to what goes on in the middle school labs we analyze here. When faced with a sudden, shocking and incomprehensible misfortune, ritual specialists use speech to seek initial explanations from their ancestral spirits. These highly interactive, contextualized and introductory conversations eventually give way to more formal, monologic and authoritative accounts of the "cause" and "source" of the calamity, culminating in a chant embodying the "words of the ancestors" (Kuipers, 1990). Likewise, by the end of the failed educational ritual of experimentation that we describe here, our students similarly invoke scientific authority by means of decontextualized chanting.

As the teacher resorts to more traditional pedagogical techniques involving literacy events and recitation, many of the same linguistic and discursive features emerge that characterize both highly decontextualized and authoritative facts in science writing, as well as the Weyewa "words of the ancestors." We present a close analysis of this 3-day event, and discuss various formal linguistic devices that are involved as the lab, and this Law of Nature in particular, is entextualized as authoritative: (1) parallelism (syntactic and prosodic); (2) tense and aspect shifts; (3) de- and re-localizations of responsibility (pronouns, reported speech); (4) register shifts; (5) nominalizations. We show how each one of these linguistic processes function as ways of removing the classroom discourse from the "here and now" of its immediate circumstances of use, and require the audience to recontextualize it in a different, more authoritative interpretive framework (see Bauman and Briggs, 1992). We document the elaborate linguistic and rhetorical infrastructure by which the appearance of open-ended inquiry in particular is maintained and preserved in the face of this massive failure of the data to cooperate.

Drawing on a broadly sociohistorical perspective to the discourse of education (Vygotsky, 1978) in which learning occurs as part of a process of participation (Lave & Wenger, 1991), we introduce the setting and participants (curricular text, teacher, and students) first, and then the story of this failed experiment, drawing loosely upon the metaphor of dramaturgy set out in Hilgartner (2000). Looking at classroom behavior from the actors' (students') point of view, we focus on linguistic, sociolinguistic and metalinguistic distinctions that make a difference to the children in the ongoing system of activity at the laboratory table. We draw some preliminary conclusions for the field of science education; namely, that the dialogicity of the learning process *even after* the "rigged" nature of the lab is overt calls into question the stark evaluative boundary between "good" constructivist curricula and "bad" traditional pedagogy. Furthermore, the complex rhetorical and linguistic moves by which teacher and students preserve the appearance of open-endedness highlight for cultural studies of science the importance of the ideology of answer-unknown inquiry and how it is reproduced in school science.

2. The scene

An eighth-grade science classroom in a middle-class suburb of Washington, D.C. There are twenty-seven 13- and 14-year-old students in this class that meets right before lunch. The students sit at lab tables arranged around the perimeter of the room. The table we videotaped sits at the back of the room, pushed up against the wall.

3. The participants

Three students sit at a lab table near the back of the room. First is Philip, an African American boy.[2] Philip is classified by the school district as gifted and talented; his classmates seem to unanimously classify him as a "nerd."

Next is Natalie, a self-identified Hispanic girl who is bilingual in Spanish and English. In doing the labs, Natalie often appears to be most concerned with filling out the worksheets or homework assignments about the labs; she frequently asks her seatmates, "what did you put?" or "what are you writing?".

Third is Sean, a white boy who is seldom prepared and never brings his papers to class. Sean frequently appears sleepy and disconnected in class. Philip tries to socialize with him occasionally, though Sean's responses typically are limited to one-syllable responses.

The fourth member of this lab group, Gloria, a self-identified Hispanic, also bilingual in Spanish and English, is absent on this first day of this lesson (she is present on days 2 and 3, however).

The teacher is Melanie, a white woman and 3-year teaching veteran who generously agreed to allow us to videotape her class for this study. The terms of the study require her to observe "fidelity of implementation" in enacting this curriculum unit, and by all appearances, Melanie generally complies with this request. The lesson upon which we focus, however, was rewritten and changed due to earlier failures. As we see below, the labs that the students are doing for this lesson are different from those specified in the written curriculum unit.

Today, Philip sits in the middle of Sean and Natalie, facing the side of the room. Natalie sits closer to the front of the room with her back to the wall, and Sean faces forward.

4. The curriculum

On this day, the students are in the middle of enacting a curriculum unit called Chemistry That Applies (CTA), a 6- to 10-week long unit (State of Michigan, 1993). This guided inquiry unit is aimed at 8th- to 10th-grade students, and focuses on the Law of Conservation of Matter (LCM). This law states that "matter can neither be lost nor gained, it can only change from one form to another." So within a closed environment, regardless of what is done to the things inside, the weight (as a proxy for the mass of the objects) stays the same. By first observing, then weighing,

[2] All names are pseudonyms.

and finally modeling, four different reactions under different conditions, students enacting this unit are supposed to realize that matter is conserved, and (in later lessons) that the rearrangement of atoms and molecules can help one to understand how that works.

As implemented, the unit is structured into three clusters. In the first cluster, students observe physical and chemical changes without collecting data, and in the second cluster, they test hypotheses about weight changes in those same reactions. At this point in the unit, the concept of atoms and molecules and the LCM are introduced as authoritative facts – a pedagogical interlude of sorts – that offers students an explanation for the results of their earlier laboratory experiments. Then, in the third part of the unit, students build molecular models of those same experiments, using the concept of atoms and molecules and the LCM to deepen their understanding of the lab experiences they had in the first two clusters of the unit.

Today, the students are working on one of the last experiments in the second cluster before the introduction of the LCM and atoms and molecules. In this experiment, they are supposed to compare the mass of substances before and after a series of physical and chemical reactions (by weighing mixtures before and after those reactions). They are to observe that the gases created by the various reactions have weight. Specifically, the students do a series of experiments involving open and closed systems in order to observe that the open system reactions lose weight as gases escape a container. The closed system reactions, on the other hand, should not gain or lose weight, as the gases that are created have remained in the system. Consequently, these closed system reactions should lose weight once the lids are removed from the beakers.

As an example of an "inquiry-based, conceptual change" curriculum unit, CTA stresses the importance of direct experience in the laboratory in changing students' conceptions about the nature of matter. Specifically, the lesson that Natalie, Philip, and Sean are doing on this day is key, insofar as it is designed to give them "direct experience" with the LCM by way of evidence involving weight changes in reactions. Thus, for students to have direct experience with the LCM, the experiments must be successful: that is, the weight of a closed system must remain the same before and after a reaction, and the weight of an open system must decrease. The idea is that students will compare their predictions about what they *thought* would happen to what *actually* happened, triggering the sort of puzzlement that jumpstarts a conception-changing moment about matter and its conservation. As we will see below, however, things do not quite work out as planned.

Transcription conventions follow those outlined in Edwards and Lampert (1993). In the transcript segments that follow, T stands for the teacher, Melanie; P is Philip; N is Natalie; G is Gloria, and S is Sean.

5. The story

After eliciting students' (mis)conceptions about the conservation of matter in closed systems, the teacher, Melanie, writes them on the overhead projector without comment. Because CTA is a conceptual change unit, this step is a required part of each lesson, and Melanie regularly writes students' ideas on the overhead projector, usually commenting on them only a little. Based on the admittedly small sample we have of Melanie's regular teaching style (we videotaped this class for the 3 weeks prior to the implementation of CTA), this does not seem atypical. Students offer ideas and feedback at various times, and Melanie does entertain them, but perhaps because this class occurred relatively early time in her teaching career, Melanie does not often appear to allow student-led discussions to continue for any length of time. Students' ideas are always heard, recorded, and then are sometimes commented on in a general way.

After eliciting their (mis)conceptions, the teacher then frames the activity that follows, telling the students what the purpose is of the lab they are about to do. “Here’s the deal,” she says, “This lab is meant to do two things.”

Teacher: See how well you can perform lab tasks like measuring volume, finding weight and also to see how accurately you can get answers to questions from this lab. Okay so I’m really looking for best lab practices today when you’re working on this.
T: But with a specific reason in mind.

Melanie repeatedly makes clear to the students on this first day of the lesson that the meaning of the laboratory exercise is constituted by the experimental procedures that the students are performing. If the experiment fails, it is because students have failed in their performance of “lab tasks”—characterized in vaguely scientific-sounding terms as “best lab practices.”[3] That is, the only outcome truly in doubt is whether or not the students will engage in an appropriate enactment of the methods—whatever happens, the LCM certainly will not be invalidated. Similar to the interpretation of failed prayers for rain among the Weyewa, one always assumes that there is a faulty implementation of procedural detail, and not the practice itself, or its underlying model. And as we shall see as this lab unfolds, and fails spectacularly, this is exactly what occurs.

Note in the above stretch of talk that the teacher is looking for “answers”—not results, for example. The outcome of the experiment is known, at least to the teacher, and now it is up to the students to get it. This is strikingly akin to the model of questioning in middle class language socialization, in which parents and teachers routinely engage in the distinctive pattern of pedagogical discourse in which the teacher asks a question to which she already knows the answer (Heath, 1983; Mehan, 1979). Later, the teacher even says, “Everybody can do this lab and get answers. I’m looking for you to make it the most accurate,” thereby setting up the eight or so lab tables in competition: who is going to achieve the most accurate results – that is, get the right answer – by performing these ritual movements absolutely perfectly? The resemblance to the structure of the U.S. educational system is inescapable: students are now pitted against one another to see who can attain an answer that is already known.

However, the teacher seeks “accurate” answers, and not “correct” ones—why? We suggest that it has something to do with the work that must be done to preserve the ideology of “real” science in this kind of curriculum unit. It seems as though in the first part of her utterance above, Melanie inhabits the usual role of the teacher—looking for students to demonstrate their lab skills, to get “answers to questions from the lab.” But with the second part of her utterance, marked by “okay” (Schiffrin, 1987), Melanie constructs for herself a role as a science “coach” of sorts. The focus shifts to the students’ open-ended lab activities: contrast “when you’re *working* on this” to “how well you *perform* lab tasks.” The progressive aspect of “working” seems to index the open-ended nature of the students’ “real” scientific inquiry (as they engage in “best lab practices”), especially in contrast to the non-progressive aspect of “perform,” which indexes the decidedly not open-ended process of evaluation. A close analysis of the indexical import of the teacher’s lexical and aspectual choices in this stretch of talk thus illuminates the balance that must be struck, when implementing this kind of inquiry-based lab science, between conducting “real” science in

[3] This is an interesting use of a term common in teacher administration. Since the students do not likely know the phrase’s typical context of use, its use here more likely indexes something along the lines of “real” science—some activity that demands methodological rigor.

a just-as-real classroom setting. This is just the first of many such instances where we document the discursive work done in order to preserve the ideology that "real" scientific inquiry is open-ended.

This stretch of talk also makes sense in light of the larger context of the implementation of this unit in this particular classroom. Recall that CTA is being implemented in classrooms throughout the district as part of a research project that demands teachers' fidelity to it for experimental purposes; in fact, teachers are regularly exhorted to "stick to the script" as much as possible. In addition to the significant administrative attention, Melanie in particular is being videotaped, and no doubt feels a certain amount of pressure to follow the teacher's manual and let the students guide the inquiry as much as possible. Evidence from other days of this unit indeed suggests that Melanie takes seriously her task of apprenticing the students into the nature of scientific inquiry, frequently highlighting the "real" scientific nature of the labs they are doing in various ways. Yet she also must be aware that as part of this research project, her students are to be evaluated for how well they understand the larger point of the lab, and doubtless wants her charges to do well. Moreover, though the ethnographic part of this project is purely descriptive in nature and not evaluative, and focuses primarily on the students, there may well also be some self-consciousness in this regard as she is being videotaped and her classroom analyzed in detail. So, Melanie is indeed looking for "best lab practices" here, "but" (and note that this is the connector she chooses, instead of "and," for example) the evaluative aspects of this endeavor (both for her students and herself) are clearly not far from her mind. We will see that Melanie routinely inhabits dual participant roles: as the teacher who needs to get the point across, and as a fellow observer of Nature, at least in part as a function of the larger contextual factors framing this lab.

The teacher next instructs the students to make some changes to the lab instructions in their handout. They are going to substitute vinegar and baking soda for the water and Alka Seltzer called for by the curriculum. Melanie says,

T: It just, doesn't work that well with the um Alka-Seltzer, so what they gave us instead is denture cleaner. Denture cleaner does the same thing, it makes bubbles just like Alka-Seltzer, but it doesn't make enough, for us to see a difference.

So the Alka-Seltzer supplied by the curriculum developers has been replaced once already—by denture cleaner, and now the denture cleaner is being replaced with baking soda and vinegar. To say that the lab does not "work that well" implicates that there is a "perfect" lab that the students are to reenact. And clearly, by working well, what is meant is that these materials generated the "right" results. This prior failure, note, does not invalidate the LCM: it is a matter of failing to produce "enough" bubbles for observers to be able to "see" the difference [in weight]. Again, in school science, because the results are known, the teachers in effect work *backwards*. That is, since they know what the results should be, they investigate what should be changed about the methods and materials so that they can reliably get those results.

5.1. First failure: "I would say the initial thing that it said"

The first of the two experiments that the students perform, the open system reaction, works for most tables; that is, when the reaction is supposed to lose weight, it does. In the closed system reaction, though, when the weight of the mixture is supposed to stay the same, our group's concoction loses weight by point three milligrams. Philip hurries off to get the teacher, and as he walks her back to their table, he is explaining how “for a second” it looked like their mixture had only lost one milligram, but then it lost two.

Philip: Ours like for a second-for a second it [had a] point one difference. [. . .]
P: And then it went down to that- then it went point one down more.
T: I would say the initial thing that it said-
P: Okay.
P: Cuz that, cuz this, this -this is-this is like it went down like two. [That]-that was probably like human error or something.
T: Yeah. Yeah I would say that.

When the conservation of matter is not illustrated in this case, Philip suggests that it was their (particularly human, and hence possibly error-ridden) enactment of those methods that is to blame: “human error or something.” Though the teacher impressed on the students the importance of taking special care with their procedures, and told them that their accuracy would be evaluated, when the results are not what are expected, their enactment of the procedure is what is (successfully) used as the *reason* the results are wrong. However, it is not “Philip’s and Sean’s and Natalie’s error,” but a more generic “human error” that is to blame. Though this term denotes the error caused by human hands, it effectively avoids placing the blame on any particular pair of hands. It is by referring to their own subjectivity, interestingly, that the students effectively desubjectivize or “de-localize” their results.

Just as there are highly codified rules in a courtroom about what and how something may count as admissible “evidence” (Philips, 1992), there are rules about what evidence “counts” in science. But it does seem as though Philip and Melanie are using the scale atypically. The number at which a scale eventually settles is usually the number that is understood as the weight of whatever object rests atop it. This is the accepted and authorized use (authorized not just by the scientific community, but by anyone who uses a scale) of this particular inscription device. But Melanie colludes with Philip in this instance, and authorizes a non-conventional use of the scale, using her authority as a teacher to override the authority of the inscription device. Note that she refers to the “initial” reading from the scale, and not the “first” reading, thus lending her pronouncement even more teacherly authority by using a “big word.”

Philip recognizes what Melanie is suggesting, and tries to construct an explanation for this obvious fudging, using a traditional scientific notion to do so (this idea of human error). That is, Philip recontextualizes her comment as a move that scientists would make in a similar situation. He clearly is trying to make sense of Melanie’s suggestion, filling in words for her that she might have said, but did not: “Cuz that. Cuz this. . .”. In other words, “we are going to do this obviously unscientific move *because*. . .”. The demonstrative pronouns in Philip’s utterance (“cuz *that*, cuz *this*”) also reflect Philip’s residual discomfort with the seemingly easy decision to disregard the number (staring at them) on the scale. Over and over, Philip verbally “points” to the offending inscription—“that” or “this” number is what needs to be explained. The data in science are supposed to “speak for themselves,” but Philip and Melanie find a way to keep this one quiet, by invoking “human error.” Though seeming troubled by the lab’s failure, that Philip colludes with Melanie (here, and later in the lab) in preserving the appearance of outcome-unknown inquiry, may be a function of his generally positive attitude toward science. Specifically, we know that both his parents are scientists, and that he appears to like science class, coming into Melanie’s classroom during his lunch hour, for example. It seems fair to say that Philip, perhaps more than the other students, really wants this lab to work.

The focus in all of this, note, is on the inscription that the students should “say,” that is, write down on their worksheets. One of the most interesting utterances in this stretch of talk is the teacher’s response to Philip and Natalie’s questions. She says, “I would say the initial thing that it said.” Consider what Melanie could have said: “Use the first number.” Instead, Melanie uses the first person singular pronoun, “I,” the verb “to say,” and the conditional tense of that verb, and this seems marked, pedagogically speaking. That is, when a student calls a teacher over to answer a question, a common response is simply to tell the student what to do, using an imperative. In this inquiry-focused curriculum unit, however, the students are supposed to have experiences with relevant phenomena, and to make predictions and draw conclusions about the data on their own. The elided protasis of the conditional, “were I you...” aligns Melanie with the investigator-students in a hypothetical world: this is what I would do, were I in your shoes. This interpretation gains some currency when the verb is considered, “say,” which focuses on the worksheet that the students must fill out; the concern is with what the students ought to write down on their papers. We might imagine a fuller version of her comment to look something like this: “Look, we all know that we’ve got to get through this, this lab doesn’t seem to be working out. If I were you, and these were the results I got, I would just fudge it, and put point two on my worksheet.” But because she is the teacher, and because the conditional tense is a common way to politely issue directives (e.g., “I wouldn’t do that...” instead of “don’t”), the students, or at least Philip, accept this comment as a directive. This one comment thus positions Melanie as “just” a fellow observer of Nature, while effectively telling the students what to do in her role as the teacher.

By getting the teacher when the mixture loses point two milligrams, note, and by suggesting that they ignore that loss and “say the initial thing it said,” the implicature generated is that the point-two loss is “wrong,” in other words, that it is not the number that was expected. Thus, the scaffolded nature of school science – that the outcome is indeed known, and that the teacher has access to what the answer should be, and can judge students’ results as not quite right – is let out of the bag, so to speak. But the way that Melanie phrases her comment, “I would say,” on the other hand, functions in the opposite direction, preserving the autonomy of the students at their lab benches: the nascent scientists. The extent to which students ‘buy’ the fiction of the open-ended lab, of course, ultimately is not knowable; however, as we will see below, the students do work with the teacher to maintain this ideology it in various ways (bracketing errant data, for example), even as they talk and act as though the outcome is known.

5.2. *First failure, redux: “But look”*

After Melanie leaves the table, Natalie presses Philip as to what they are supposed to write on their worksheets. She asks several times what number they should “put”: point one or point two, that is, the second or the first number displayed on the scale. In the meantime, the scale changes again, and now reads (the even more “inaccurate” number) zero.

Natalie: What do we put point two or not?
P: Hm. Okay so I think we [need to remove the lid] now. Hm?
N: [Point one or two?]
N: I didn’t put point one, because the-
P: Hm.

N: X point one, it's point one.
P: No. She-
P: said to put the ah-the first thing.
N: But look.
P: She said put point two because that-because that's-because it-because the point-because point two is probably a human error.
P: Or something.

It is striking to note here how Philip struggles to explain why they are discounting the data. Philip begins his explanation to Natalie five times "*because* that- *because* that's *because* it- *because* the point- *because*...". These verbal hesitations may reveal that Philip is at least a little unsure about why they are being allowed to fudge the data in this way.

As Natalie and Philip are going back and forth, Melanie happens by and, overhearing, rejoins their table discussion. Upon hearing that the mixture has lost even more weight, she suggests redoing the experiment.

T: You [know I-]
N: [XX one] and then it went to zero. One to zero.
T: Oh==.
N: So that's [why-]
P: [Yeah] [this thing is a little fickle.] No it went-it went from two to one and a second ago it went from one to zero [back up XXX.]
T: [I thought it went from two to one.] [So we know what we] want our answer to be, but-
T: [but we don't-] but we don't have it.

Natalie's continued questioning about what number to write on her worksheet throws into relief the earlier collusion between Philip and Melanie, where they decided to "take the initial" reading from the scale. Though Natalie was present for that conversation, she continues to focus on the inscription she reads on the scale. The authority of her senses and the authority of the instruments are in open disagreement with the authority of the teacher, at least as represented by her generally reliable, and generally smart fellow student. When Philip says, "She said to put the ah-the first thing," Natalie's response could not be clearer, "But look" (right here, right now, at the scale sitting in front of us!).

Natalie's observations in fact reveal an even greater failure than they had realized: the weight of the mixture has now decreased by *point three* milligrams. Philip tries to blame the inscription device, "this thing is a little fickle," but when Melanie realizes that the mixture now has lost point three milligrams, she says, shoulders collapsing a bit, "So we know what we want our answer to be, but- but we don't-but we don't have it." Certainly, Melanie knows what the answer should be, and it seems reasonable to conclude that Philip does, too, but it is not clear whether Natalie and Sean would count themselves in that "we." But by using "we," Melanie performatively indexes that all four of them are the "we" who know what the answer should be. So even if Sean and Natalie do not, in fact, know that this result is wrong, Melanie talks to them *as if* they know, thereby apprenticing them into this peculiarity of school science, where the outcome is known. Inclusive "we" is a common feature of teacher talk that presupposes shared knowledge while simultaneously creating it, and in this case, the important shared knowledge is that they all know what ought to have happened. But it seems as though she wants the students to think about what they are doing as "real" science:

T: So why don't you re-do it.
P: Hm? Okay.
T: [We know] what we want it to be, something must have gone wrong so let's redo it one more time. Okay?

Her first comment seems like a pretty straightforward directive, but at Philip's comment (perhaps just his vocalization sparks the immediate shift, for he seems to be the group's guardian of authentic science), Melanie shifts back to using the first person plural "we" in an "if. . .then clause" that implicates that this is what scientists would do in the same situation. Her teacherly directive ("why don't you re-do it") becomes a scientific-sounding principle, uttered in a singsongy intonation associated with the recitation of "truths" about the world (e.g., to a child, "when it rains, you bring your umbrella"). The final "okay" strengthens this interpretation: Melanie has positioned herself as a fellow scientist: "*let*'*s*" redo it, "okay"? The teacher calls on a notion of "replication" as a scientific principle that is going to help get the students out of the jam that they are in, but interestingly, the idea of replication in science is not (at least ideally) premised on the idea that the answer is known ahead of time.[4]

Melanie then brings the focus to the students' performance of the procedures:

T: Think about speed when you pour it into here and then twist the cap on, so Sean should be ready with the cap the [second that], somebody else has poured in [the baking soda.] [Okay this should be a team effort.]

When the procedures fail to get the expected results, the teacher suggests that it is the performance of the procedures that has failed. It is not the case that the procedures are not able to reveal the correct results, but that the students' enactment of those procedures was perhaps lacking. Despite the fact that the students' particular performance is called into question, however, the linguistic form of Melanie's directive nonetheless serves to departicularize the failure: she uses the nominalization "speed" rather than something like, "think about how fast *you* pour(ed) it in there." This decontextualizing move recalls Philip's "human error" comment above. Though referring to procedural particulars on the one hand, the effect of both "human error" and "speed" is a decontextualizing one. Philip quickly picks up on the gist of Melanie's comments (their performance is to blame for the failure), and inserts a subject into her desubjectivized comment. It is not just "speed" that is to blame, but *Natalie*'*s* speed in particular: "It looks like *she* was putting it a little slow in there," Philip says.

5.3. Second failure: "There must be a leak or something"

When the students re-do the closed system reaction, however, the "right" results are again not forthcoming: the closed system reaction again loses weight. Philip says, "Okay it screwed up twice." Now the lab as a whole is what has failed, at least for Philip ("*it* screwed up"); their enactment of the procedures is no longer the problem. In fact, as Philip moves to get the teacher, he tries to explain what happened by saying, "There must be a leak or something." It is now not

[4] The ideology in science, of course, is that anyone reading a published account of an experiment should be able to replicate it by following the outlined procedure. But the reality of science (in particular the difficulty one would have getting funding for such an endeavor) is such that these replication experiments are rare.

just their performance of the ritual, but the apparatus being used in the performance, which is to blame.

Natalie, focused still on the instrument and its reading, points out that this really *is* the number on the scale, saying, “Not moving either,” referring to the numbers on the scale. In other words, they are not going to be able to do what they did before, that is, explain away the errant inscription on the basis of “human error.” This one comment reveals that, though Natalie was perhaps not complicit in the decision to fudge the results originally, she certainly has realized what they did. And, whereas Philip (and presumably the teacher) used the notion of “human error” to explain that interpretive move, Natalie recalls instead the flickering of the numbers on the scale as the reason why they were able to fake the results before.

When the teacher comes over and learns that their closed system reaction has lost weight, Philip says,

P: So==, I don’t know. So I think that’s a bit insig-I think it’s insignificant because it’s hard-hard to get this on right before any X gets out.
T: Mhmm.
P: So I think that should count as insignificant.
S: Um-
P: So-
T: Alright.
P: So- [Melanie walks away from the table at this point]

The responsibility for the failure to get the “right” result is no longer located in their enactment of the procedures, it seems, but in the procedural script itself. In fact, responsibility for the failure seems to be moving farther and farther away from the participants themselves: first it was their enactment of the procedures, then the instruments (“there must be a leak”), and now it is a failure of the whole set-up of the lab. Philip does not say, “*we* had a hard time getting this on right,” but “*it*’*s* hard-hard to get this on right”—it would hard for *anyone* to get it on right, in other words.

5.4. Third failure: “If gas left a first time, it should leave a second time”

Philip, Sean and Natalie now move on to the next part of the lab, where they are supposed to remove the lid from the closed system and observe a subsequent weight loss. The first part of the closed system reaction already has failed, and amazingly now, this part does, too: the mixture fails to lose any discernible weight when the students take off the cap.

After removing the lid, Philip reads the numbers on the scale, which are identical to the numbers they had before the lid was removed.

Sean: What is it?
P: One one six point eight. That’s weird.
P: I don’t think that’s right.
P: Because if gas left the first time when-when the lid was off it should leave a second time.

Philip here seems to know what outcome they are supposed to get from this lab, and when they fail to achieve that, he tries to extract a principle from their specific results, which he expresses in an “if. . .then” clause. Though this lab is not going as intended by the curriculum developers, at least one student is trying to make sense of the errant results by articulating a principle about how gases ought to be behaving in this experiment.

The mixture finally does lose point one milligrams, but that is not enough; a point one milligram weight loss will be counted as "insignificant." Philip moves immediately to summon the teacher, who is at the next table. When Philip and Sean overhear that the neighboring table's results were also wrong, Sean, galvanized by the pandemonium of the lab, leans back in his chair and crows, "It's all human error!" Although he may not understand the lab the way that Philip does, Sean's response seems to indicate that he understands at least that the lab is not going as expected, for them or anyone else. For his part, once the teacher comes over, Philip blames the lack of baking soda ("Oh I don't think there's enough bake-baking powder to get really good results"), a reason to which the teacher simply agrees, "Okay."

This string of failures has the potential to topple the authority of the lab, and of the scientific fact it was designed to illustrate. However, the LCM is not questioned. Instead, students and teacher together work to bracket errant data (as "insignificant," or the result of "human error"), and they question their performance of the procedures, the procedures themselves, the instruments, and the ability of these procedures and (the quantity of) the materials to reveal the right results—everything, that is, except question whether the conclusion really holds. The teacher and students seem to have worked together in a way to preserve the ideology of pure, open-ended scientific inquiry. Perhaps if earlier labs had similarly failed, or had this simply been a different group of kids, the authority of the LCM might have been in more serious jeopardy.

5.5. Shifting the locus of responsibility: "Insane wrong things"

At the end of this first day, the teacher sums up what has just happened and more or less officially tells the students that their results were not what she had been expecting.

T: For those of you I asked to redo it again thank you for not getting too frustrated with it, but it is-it is frustrating.
T: Because if it changed by point two we're saying that's a significant difference. Let's say you make bubbles, the bubbles leave, when you have the cap off, it decreased by point two.
T: But then for some of you when you have the cap on it also decreased by point two.
T: There should be a difference in those two answers.
T: So I don't want to say that point two is insig-is insignificant.
T: But at the same time I don't have any groups that got what they should have, and I don't think that you're doing insane wrong things at your lab stations.
T: I think you should be getting accurate results.

Note how the responsibility for the lab's failure shifts in this one narrative stretch. In line 3, Melanie says, "*we're* saying that's a significant difference," but by lines 9 and 10, the problem has been characterized as Melanie's alone, "*I* don't want to say. . ." and "*I* don't have any groups. . .". It is no longer the students' enactment of the procedure that is at issue (too many of their experiments failed for that to be the case). The problem lies with the lab, and as the teacher, Melanie assumes responsibility for its failure.

Yet, as becomes even clearer over the next 2 days, Melanie seems quite willing to share at least some of the responsibility for the lab's failure with the curriculum developers, or perhaps her superiors in the school district who work with this research project in organizing the implementation of this unit. For example, the first person pronoun and the possessive "have" in, "I don't have any groups that got what they should have," call up a context in which Melanie might be talking to her colleagues, after classes, perhaps, in the teacher's lounge. That is, teachers might refer to their lab groups as possessions ("I have eight groups of four in this class," a teacher might say, "can you believe it?"). And in Melanie's case, at this point, none of the groups is getting the "right" answer. And, she continues, it is not the students' fault: they are not doing "insane wrong things." The shift in responsibility for the failure could not be clearer: no longer is this the students' problem, but hers (or those administrators who chose this curriculum unit, or this unit's developers, and so on).

Melanie ends this first day by promising to do the lab as a demonstration the following day, using a large amount of Alka Seltzer (instead of the baking soda and vinegar the students used today), in an effort to "see if the results work any better." The focus shifts from the procedures to the results. Yet, since she will do the demonstration lab, it is the teacher's procedural elegance that will be on display the next day.

5.6. Teacher as scientist-magician: "Prove to you the way it should have been"

The highly rated unit endorsed by district officials let Melanie down the day before, and she must now pull the lab off, so to speak, without resorting to lecture format, for recall that the students are to appreciate the LCM based on their lab experiences. She begins this second day by re-framing what happened the day before, and setting up what she will do in the class today:

T: Yesterday didn't go so-as planned, because there was something I wanted you to be able to prove to yourself in lab, about gases having weight and the weight of the reactant versus the product. So did the weight change if we ke-caught all of our gas by using the lid, and it didn't necessarily work the way it should have.
T: But I still want you-I want to use this lab to prove to you the way it should have been.

Most striking here are the two forms of the verb "to prove," and the pedagogical shift indexed by the contrast between them. The reflexive form of the verb in the first part of the teacher's utterance ("prove to yourself") constructs the lab as one might expect in a "guided inquiry" context, where students interrogate Nature in order to prove something to themselves. Although the students perhaps are not officially supposed to know that the closed system reaction would not lose weight, the phrase "prove to yourself" implies that at least some of the students knew the right answer to begin with; this highlights the delicate balance which a guided inquiry curriculum must forge between outcome-known inquiry versus outcome-unknown inquiry.

The non-reflexive, transitive form of "to prove" in the second part of the utterance ("prove to you") reflects a shift to a more traditional pedagogical technique that might be called transferal, that is, a one-way knowledge flow from teacher to student. Today, the teacher is going to prove something to the students, whereas yesterday, the students were trying to prove something to themselves, constructing knowledge by means of direct experience with Nature. Now the teacher plays a role akin to the 18th-century gentleman scientist, demonstrating the truths of Nature for an audience, and "policing the production of knowledge" (Shapin, 1994): left to draw conclusions from yesterday's data, the students would incorrectly reject the LCM.

5.7. Fourth failure: "This lab is cursed"

In this new role, Melanie now collects all of the lab tables' results for the closed system reaction and averages them. Once the class average has been recorded on her overhead projector, she says, "All right, class average for this one. . .yikes. [. . .] Holy cow. Our class average is completely wrong." The new, decontextualized inscription produced by means of a mathematical process of averaging is no closer to being right than the students' individual results. Averaging the data in order to reduce the import of individually errant results, is not unlike calling on a notion of human error to bracket "inaccurate" inscriptions, insofar as both are moves to set the particulars of the failure at some remove. Furthermore, that there was an expected result for this lab is no longer hidden from the students: "That is not right," she says plainly.[5]

When the class average is wrong, Melanie says,

T: All right we're going to do this one again, because it didn't end up right.
(a student): What are we supposed to end up with?
T: Well I'm going to show you.

Like yesterday, the notion of replication is invoked as a scientifically accepted step when the number did not "end up right." This statement prompts a student to ask the $ 64,000 question: "what *are* we supposed to end up with?" Apparently not all of the students knew why Melanie was redoing the lab, or what had gone wrong the day before. Nobody asked this question yesterday, however, only today, as the scaffolded nature of school science is increasingly revealed. And Melanie's response clearly indexes the new pedagogical context: this new demonstration lab will "show" the students the correct result.

For the demonstration lab, Melanie uses different materials, and she tells the students that this enactment of the procedure will be "more controlled." A student helps to set up the lab, and then is asked to walk around the room, showing the class the bubbles, and demonstrating "good" procedural swirling and shaking.

T: Alright, I want you to just swirl it around and walk around the class, just to show them it's making bubbles.
T: Don't shake it up and down, though. Just swirl it around. [. . .]
T: [We want to make sure that we see all the gas]. [. . .]
T: Do another lap. [around the classroom] We want to make sure we see all the gas, we know it's there and that we're not letting any escape, so we want him to screw the lid on nice and tight.

A balance is maintained between, on the one hand, constructing this lab as a true demonstration, where the students are spectators, and on the other hand, making the lab a joint venture, where the students are virtual participants, and the teacher is simply one of the observers of Nature. Compare: "*I* want *you* to just swirl it. . . to show *them*," and "*We* want to make sure that *we* see all the gas." The students are at once discursively constructed as a skeptical audience in need of convincing, and as co-performers of the lab. Furthermore, the pronouns create a context in which – like the teacher – the students know *what* they are looking at ("we want to. . .see all the gas"),

[5] Note the informality of these comments ("completely wrong" and "holy cow") in contrast to those at the beginning of the lab, where the teacher was in search of "accuracies" and "best lab practices."

and *the procedural particulars* that will help to achieve the right results ("we're not letting any escape").

Stunningly, the lab fails yet again. The mixture loses point two milligrams.

T: Okay, it didn't work. We have to do it again.
P: This lab is cursed.

No longer able to appeal to decontextualized averaging, replication, or procedural perfection, Philip and Melanie interpret this latest failure within the conventional framework of magic: "this lab is cursed," indeed.

5.8. Fifth failure: "Ye===y it worked"

The teacher now redoes the demonstration lab with slightly less fanfare, and it fails yet again. "Reading" the scale from the front of the room, however, Melanie says, "[Ye===y it] worked." That Melanie faked these results was revealed to us only after taping. It is not clear whether the students knew that these final results did not arise in the usual manner, though Philip's vocalization seems suspicious in hindsight. Referring to the weight of the mixture before and after the reaction, Melanie says:

T: What I started with was the same as what I ended up with.
P: Mm.
T: That is the whole point of the closed system.

The first utterance of Melanie's here (which she repeats several times on this and the following day) is characterized by a singsong-like rising and then falling intonational contour. This kind of authoritative prosody indicates that this is what should have happened all along; this is the truth about the world (the LCM) that this experiment was designed to illustrate. However, lest the students fail to participate in recognizing this comment (and the results of this fifth experiment) as authoritative, Melanie states it yet more plainly, "That is the whole point of the closed system." She has tried to remain faithful to the spirit of this flawed lesson, but this lab has been a mess, and by God, her students are going to get the right point at the end of the day. Driver (1983) writes about the "intellectual dishonesty" required of teachers when they teach these sorts of units, in which "on the one hand pupils are expected to explore a phenomenon for themselves, collect data and make inferences based on it; on the other hand this process is intended to lead to the currently accepted law or principle" (p. 3).

By this point, however, the students have written on their papers about this closed system part of the lab *four* different sets of results: the original lab numbers, the numbers they got from replicating the lab, the numbers from the first demo lab, and the numbers from the second demo (the faked one). The students are awash in data from this particular part of the lab. So as they set to work on their conclusion questions, the teacher makes clear which numbers or results they should use in answering those questions. Melanie thus has the students identify which of the many results to use by drawing a "smiley face" next to the final (faked) results. This is the felicitous, or happy, result that will enable the students to have the right conception-changing moment, that is, to draw the correct conclusion about Nature from their experimental data.

Melanie next directs the students to read a section of their textbooks, and to underline what they think is its "point." The "point," not coincidentally, is the conclusion to which they should have been led by the laboratory results: gases have weight, and "what you start out with equals what you end up with." The students are explicitly instructed not to talk as they do this: "Find and underline. This is something that should be done silently, so you're doing it on your own," the teacher says. Thus, in case the lab failed to trigger the right conception-changing moment, the teacher choreographs the pedagogically more traditional private literacy events that hopefully will do the job.

Melanie next directs the students to copy the LCM from their textbook materials:

T: [. . .] One of the most fundamental laws of chemistry that we are going to work on your understanding of for the rest of the unit is the law of conservation of matter.
T: You need to highlight this. You need to just put some stars by it.
T: Down below where it says <READING Law of conservation of matter READING> I want you to copy it.
T: Every time you rewrite it it goes in your brain a little bit more.

The lab barely managed to prove the LCM, but it is crucial that the students understand it, so the teacher deftly switches gears, and moves to decontextualize the LCM so that its authority is no longer tied to the problematic lab results. These moves (to have students read, underline, and copy from an already authoritative text) echo the authority-building process in science and elsewhere. For example, as a knowledge claim in science becomes more and more authoritative, its contextual particulars gradually are effaced and it becomes more and more decontextualized (Latour & Woolgar, 1979).

The students next are asked to recite the LCM to each other, "Say it to the person next to you and then have them say it back to you," the teacher instructs. Though this highly decontextualized ritual chanting is certainly far removed from the particulars of the lab, it is no less highly a collaborative and social event: the students are to recite the LCM *to each other*. That is, though recitation or chanting is a move to decontextualize the LCM, of course the act of recitation is itself richly contextualized.

The disconnect between the first day's experimentation, and today's highly decontextualized underlining and recitation is revealed in one particular comment of Philip's. Reflecting out loud on what he has learned, Philip says, "I just didn't know they had a law about it." "They" have a law about it, he says, instead of "my particular results, or even the teacher's demonstration results, led me to conclude that matter is conserved." But note how Philip *recontextualizes* that decontextualized law by referring to his prior and current knowledge of that law ("*I* just didn't know. . ."), and by referring to the scientists to whom the law apparently "belongs" (". . .they had a law about it.").

In reciting the LCM, its authority is effectively established without recourse to the pesky (and contradictory) laboratory-based data; it is safely removed from the sullying particulars of the experiment, and tied instead to traditional pedagogical rituals: private literacy events involving reading, underlining, copying down, and recitation.

In terms of the structure of this unit as a whole, this experiment is one of the last before students are introduced to atoms and molecules and the LCM as facts of Nature. Thus, we may understand the shift observed in the teacher's approach at least in part as prefiguring this imminent pedagogical change. Recall that the epistemic organization of the unit hinges on the introduction of atoms and molecules and the LCM as authoritative facts, offered after students' experiments as an explanation for their results, to serve as a foundation for the work they do with molecular models in the last part of the unit. In fact, the lessons immediately following this experiment look decidedly more traditional insofar as they outline these facts about Nature, complete with charts (e.g., the Periodic Table), bold fonts, and other typographical icons of authoritative facts as found in traditional textbooks. Thus, the decontextualizing moves made by Melanie over the course of these 3 days may be understood at least in part by reference to the fact that the class is on the cusp of the narrative and epistemic arc of this unit. At the point we join the story, the gig is almost up, so to speak, and the students will soon find out what decontextualized fact of Nature explains their results; so when this experiment fails, the move to ritualized decontextualized chanting of facts is perhaps an easy one.

Moreover, though CTA takes care to emphasize that students' lab experiences are what ought to authorize the LCM (they have seen it – or should have seen it – with their own eyes), it seems unlikely that the shift in the location of authority that occurs immediately after this experiment goes unnoticed, by the Philips of the class especially. That is, if students flipped ahead in their workbooks at some point during the protracted failure of this experiment, years of institutional acculturation to what facts look like in science textbooks – and to how important mastering them is to getting good grades – would have alerted them to the importance of this Law vis a vis their experiments, and perhaps given away the ending, so to speak. It remains an open question, of course, whether Philip, or anyone else in this class, knew for sure what the results of this experiment ought to have been. It does seem to be the case, however, that the teacher engages in considerable discursive work, with masterful feats of double voicing, for example, in order to finesse this pedagogically, maintaining the fiction of outcome-unknown inquiry as the experiment fails to deliver the right outcome over and over again, and must be repeated.

5.9. Coda

On the third day, Melanie reviews the LCM and seems to encourage students to reason backward from that to the result they should have obtained in the lab.

T: Now it can't be gained or lost. So what does that mean about the weight-the before and after weight in our lab? [. . .]
T: If matter can't be lost or gained what should the before and after weight be?

This is the benchmark concept this whole curriculum unit up to this point has been trying to teach: connecting the students' particular lab results of weight changes with this decontextualized scientific principle about weight. Note that Melanie does not say, "what should the before and after weight *have been*," in which the perfect would have linked the deontic modality to the specific, failed experiment in the past. Instead, she says, "what should the before and after weight *be*?", using the timeless present tense in order to index the general nature of this truth. It is not the case that matter *has been* conserved (in this one instance), but rather that it is (always) conserved.

In this IRE episode, the teacher continues to implicate that the students knew (or correctly predicted, at least) that the weight of the closed system would remain the same after the reaction:

T: How many times did we have to do it to get it to weigh the same?
?: A lot.
P: Like five [or six.]
T: [Like five]-five or six times.
?: Too many.
P: A table.

T: In theory-and we only actually only saw it in experimentation once- what we start with should equal what we end with.

The causative verb phrase, “get it to weigh the same,” implicates that the teacher and students knew what the answer should have been (that they knew the LCM all along, and were trying to get Nature to behave herself, and reveal this truth). Similarly, by contrasting “theory” and (the highly decontextualizing nominalization) “experimentation” suggests that these experiments were designed to illustrate some axiom of Nature. At this point, it seems clear that the fiction of open-ended, outcome-unknown inquiry has been abandoned. In the end, of course, it is not clear how many students actually did know that the before and after weights of the closed system reaction were supposed to be identical (Philip certainly seemed to), but these kinds of utterances seem at least to performatively (and retrospectively) create student-listeners who *did* know this.

This comment recalls others that the teacher makes referring to the curriculum unit and its developers’ intentions as separate from her own. Not always happily, Melanie says things such as, “what *they’re* getting at here is. . .,” where the referent of the third person pronoun is the unit or its developers, or occasionally those in the district who are working with this research project and coordinating the implementation of this curriculum unit (see her comment above, “what *they* gave *us* instead is denture cleaner”). Melanie divorces herself from the curriculum unit – to which she has pledged “fidelity” – at precisely those moments when she seems to think that the unit is failing (her, as a teacher) in some way. In the earlier example, Melanie aligns herself with other teachers (“what they gave *us*”), using pronominal indexes to construct and inhabit a participant role for herself as just one of many beleaguered teachers in the district who have found that this lab does not work, and to whom *they* (district officials of some sort) gave sub-standard materials. In this stretch of talk, however, Melanie aligns herself with the students, saying “how many times did *we* have to do it to get it to weigh the same?”. The first person plural pronoun does not index Melanie and the other teachers in the district as her earlier comment does, but instead indexes her and her students, positioning Melanie as fellow inquirer, alongside the students at their lab tables doing the experiment, trying to “get it to weigh the same.” So even when the cat is out of the bag, so to speak, this kind of pronominal usage still functions to preserve the ideology of experimentation in school science, where the teacher is just another interrogator of Nature.

Melanie then returns to talking about *why* the lab failed, and implies that it is tied to the materials used, and vows to “go searching for it [a better jar] this summer so it actually does work next time.” She is not happy with the failure of this lab, and perhaps feels (as other teachers told us they definitely did) hamstrung by the project’s insistence that the unit be implemented faithfully. So she tells students that she will use her personal resources – she’s a good teacher, darn it! – in order to make the unit, and this lab in particular, work more effectively. Nature failed to reveal her conserved self, but only because the unit/district failed to provide adequate materials, leaving teachers in these embarrassing situations (that are caught on videotape no less). These sorts of moments reveal not only the pre-determined nature of scientific inquiry, then, but also to some degree the bureaucracy of a large suburban school district as seen through the eyes of a frustrated teacher.

She next says, “In theory if we catch everything, everything you start with equals everything you end up with.” The last part of the teacher’s utterance is a prosodically marked ritual couplet that appears increasingly frequently as this lab progresses (and indeed as the curriculum unit progresses): “everything you start with equals everything you end up with.” This kind of equational utterance, characterized by the verb “equal” in the simple present tense, implicates that the predicated state-of-affairs (that “everything you start with equals everything you end up with”) is as timelessly true as a mathematical formula or axiom. Scientific facts appear in the simple present tense, for example, in order to index that they are true for all time. The pronoun shifts and ritual chanting described in this class are perhaps not as uncommon as one would think. In analyzing the process by which teachers build common understandings in lab-based classes, Edwards and Mercer (1987) describe a class in which the many of these same linguistic features are observed.

Melanie's reference to the particulars of the lab seems to serve as an opening for Philip who raises his hand to tell Melanie about a procedural change they might consider making in order to get the lab to work out in the future. Rather than putting the baking soda into a flask and then putting a stopper on top, Philip recounts an experiment whereby the baking soda is in a balloon, which is attached to the top of the flask.

T: Question?
P: Oh one thing, I re-I remember somewhere else the-the-someone did-did an experiment almost just like this, but they put baking powder in a balloon, and had-had that way, then-then dumped it with the balloon still on top.
T: Mhmm.
T: [So], that, [created no=, loss?]
P: [X]. [So the balloon-it made sure nothing] got out.
T: Right. We did that [in first period. Still didn't work.]
P: [There's no possible to get out. The balloon probably] fell out anyways.
T: It did?
P: From that. No what you're saying-it probably fell off when you did it, but it didn't fall off whenever XX.
T: When we did baking soda and vinegar with the balloon we put baking soda into the balloon first period and then dropped the baking soda into the vinegar, and the balloon was still around the flask.
P: Mhmm.
T: We still lost or gained weight. There was no consistency.
P: Oh.
T: I don't know. Maybe this classroom is cursed.

Philip attempts to revisit the particulars of the experiment, and suggests changes in the procedure so that the right results obtain. However, the class has moved on from a highly contextualized laboratory endeavor to the more traditional pedagogical read/write/recite ritual, and the teacher does not seem keen on returning with Philip to critique the particulars of the lab set-up. Thus, a long interactional conflict emerges when Philip attempts to step outside this process of decontextualization, and Melanie shuts him down (using decontextualizing phrases involving nominalizations, note, such as, "there was no consistency" and "created no loss"). This lab is done (thankfully), and maybe the best interpretation they have is that "maybe this classroom is cursed."

6. Indonesian ritual speech events: an unlikely connection

The strategies employed by students and teacher to safeguard the authority of the LCM when the experiment fails are remarkably similar to those we see in a context quite far removed from this American middle school science class. In western Sumba, in Indonesia, Weyewa ceremonies to address calamities of various kinds are marked by elaborate sacred orations that share many of the features we have been discussing. When the order of nature is disrupted by calamity – a flood, sudden death, or pestilence – the Weyewa begin a ritual speaking process of trying to restore equilibrium by recovering the "words of the ancestors;" these speeches are a way to uncover these neglected truths. Beginning with a relatively informal "conversation" with the spirits to determine its cause or "source" of the misfortune the orators' speech gradually becomes less connected to the particular sociocultural setting, and by the end of the rite, the orators chant ritual couplets that are understood as decontextualized, authoritative truths that reaffirm their sense of social order. Over time, the orators' speech becomes less indexical and dialogic over time, is marked by fewer deictics and personal pronouns, and is increasingly characterized by poetic patterning, especially syntactic and prosodic parallelism (Kuipers, 1990). What is striking for this paper, of course, is that many of the same sorts of features that decontextualize (i.e., "entextualize" and make authoritative) the discourse of these ritual speech events, are those by which the truth of the LCM is made real in this science classroom.

For example, students and teacher address the first failure of the lab by questioning the ritual aspects of their performance of the procedures. "Think about speed," the teacher says as she tells them to redo the closed system experiment. When the placation rites of the Weyewa fail to produce the anticipated results, what comes into question is the *way* in which those rites were performed (Kuipers, 1990). In this context, however, the teacher does not blame particular students' methodological performance, but rather uses a term that depersonalizes the failure: it is not "*your* speed" or "how quickly *Philip* added the baking soda." Philip, of course, blames his co-experimenters' performance directly ("It looks like *she* was putting it a little slow in there"), as well as blaming the procedural script ("it's hard-hard to get this on right before any X gets out"), and the materials themselves ("Oh I don't think there's enough bake-baking powder to get really good results" and "this thing's fickle"). In the end, though, he colludes with Melanie to invoke a more depersonalized (and hence authoritative) explanation of their failure to achieve the right results, blaming "human error," and seeking confirmation from the teacher that their results might be bracketed as "insignificant."

The syntactic and prosodic parallelism that characterizes several of the teacher's utterances also recalls the ritual couplets at the end of the Weyewa rites. When Melanie says repeatedly, with rising and falling equational intonation, "what I started with was the same as what I ended up with," this indexes as authoritative the (in fact quite unruly) results of the experiment. "What they started with" was *not* the same was "what they ended up with" for the first four times the students did or watched the closed experiment reaction!

Finally, that the teacher has the students recite the LCM in unison recalls the intoning of the Weyewa "words of the ancestors." When the lab's results call the LCM into question, its authority is preserved by means of a traditional pedagogical strategy not so unlike the ritual chanting of Weyewa truths. Of course, this "decontextualized" chanting is in both cases wholly situated within its own rich context, a fact made painfully clear to Philip when he recites the LCM to Gloria as directed by the teacher, and she tells him to "shut up."

7. Preliminary conclusions

Our analysis of this lesson and its failure most strikingly revealed that the students do not question the authority of the conclusion they are supposed to reach based on the lab, that is, the LCM. Although efforts to demonstrate it repeatedly failed, the law itself never comes up for questioning by either the students or the teacher. Instead, teacher and students engage in a dialectic process, collaboratively challenging some of the evidential warrants that structure the argument of the lab when the expected results are not forthcoming. For example, in addition to negotiating which inscriptions count as results, the students' performance of the procedures is questioned, as are the procedures themselves, and their ability to produce valid results. (Maybe there is not enough baking soda. It is "hard" to get the lid on the beaker. Maybe this whole lab is "faulty.") But students never question the epistemic warrant that allows them to conclude that matter is conserved: the results still point to the conservation of matter, in other words, even when they do not. The linguistic features that mark this process were found to include syntactic and prosodic parallelism, tense (past/nonpast) and aspect (progressive/nonprogressive) shifts, pronoun shifts and reported speech, register shifts, and nominalizations.

Interestingly, the parts of the lab that the students *do* challenge are much the same as the vulnerable points at which scientists can critique each other's arguments; the students question the same sorts of epistemic warrants that structure scientific arguments more generally (Viechnicki, 2002; Toulmin, 1958). This suggests that the whole lab can be seen as a sort of "lived argument." Whereas scientists criticize the methods of competing studies, we observe the students negotiating the authority of the procedures – *as they perform them* – in order to make them demonstrate a right thing. Since they do not question the conclusion, they work backward, trying to get the lab to demonstrate the right thing in whatever way they can. Thus, whether or not individual students knew what the results were supposed to be, they and the teacher *act* and *talk* in ways that presuppose that the outcome of the lab is known.

The 3-day sequence of entextualization that we describe, furthermore, in which the class moves from a highly contextualized lab to a highly decontextualized law of Nature, is seen to be parallel to more general processes of meaning creation. We argued that the process by which the students and teacher make sense of this failure, together preserving the authority of the lab (its results and the conclusion to be drawn from them), recalls and refracts the discursive process of entextualization by which certain inscriptions in science come to be known as facts (Viechnicki, 2002). Likewise, in Weyewa placation rites, a similar move is made from thoroughly contextualized discourse to decontextualized ritual chanting. The process of coherence-building in a middle-school science classroom, and in a ritual event in Indonesia, look remarkably similar: the prosodic parallelism of the chant, for example, and the syntactic parallelism of the teacher's equational utterances (Kuipers, 1990).

By documenting the failure of this social constructivist, inquiry-based lab, and the teacher's return to more traditional pedagogical techniques involving the transferal of decontextualized information, no value judgment is intended. Our description of how the teacher and students together created coherence out of the failure shows instead that even after the teacher has abandoned the constructivist curriculum plans, the entextualization process by which coherence is created is social, and richly contextualized nonetheless. For example, as we discussed above, the students actually are instructed to recite the monologic and decontextualized law of nature *to each other*. Moreover, despite the failure of the lab, the students in fact experience at least one version of the ideological path from knowledge claim to decontextualized fact, apprentices to the epistemological trajectory of knowledge claims. Thus, it is hoped that this study helps to erase, or at least to call into question, the stark evaluative boundary between "good" constructivist curricula and "bad" traditional pedagogy, for our data suggest it is social "all the way down." Of course, that students move from a contextualized claim about the world to a decontextualized understanding of laws of Nature (eventually to be able to apply those laws to new contexts), is certainly well understood in science education. The focus of this paper certainly was not on how this cycle is intended to happen, or how it should have happened, but rather what actually happened: the fine-grained linguistic and rhetorical moves by which this process occurred in this particular classroom.

Finally, this paper also demonstrates the enormous amount of discursive work, so to speak, which goes into preserving the ideal of open-ended inquiry in science, and thus may offer a contribution to the field of science studies. Whereas the highly scripted nature of scientific research articles preserves the appearance of open-endedness in scientific research (a scientist-writer asks a question in a research article to which he apparently did not have the answer before doing the experiment), the highly scripted nature of the curriculum unit likewise helps the teacher to discursively construct the event as being "real" scientific open-ended inquiry, where perhaps the answer might not be known even to the teacher. The teacher prompts the students to ask questions that the lab experiment can help to answer, but she then must pretend not to know the answers, that is, what that lab is going to reveal. In sketching the linguistic and rhetorical infrastructure by which the appearance of open-ended (answer-unknown) scientific inquiry is maintained, we showed how some of the teacher's utterances are masterful feats of double voicing as she constructs and inhabits multiple participant roles for herself (as teacher on the one hand, and as fellow observer of Nature, erasing her knowledge of the outcome, on the other hand). Various scientific terminologies are recontextualized in interesting ways when the outcome is known, revealing students' different participatory stances during this performance, that is, how invested, perhaps, they were in the shared fiction of an open-ended lab.

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Further reading

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