Teaching/Learning Events in the Workplace: a Comparative Analysis of their Organizational and Interactional Structure

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Abstract

It is widely acknowledged that teaching and learning are organized quite differently in and out of school settings. This paper describes two strips of interaction, selected from a data corpus that documents naturally-occurring work in adult settings often considered to be targets for science and mathematics education. In the first strip (civil engineering), we follow how engineers with different levels of organizational responsibility use an evaluative term, "brutal," in relation to features of a proposed roadway design. In the second strip (field biology), we follow participants' initially conflicting uses of the register terms, "difference" and "distance," as they collaborate across disciplinary specialties. In both cases, disagreements about the use of terms are detected in ongoing interaction, alternative meanings are actively assembled across different types of media, and disagreements are resolved around pre-existing organizational asymmetries. We raise three general questions about teaching/learning in the workplace: (i) What is accessible to participants as teachers/learners under different organizational conditions; (ii) How are disagreements about shared meaning managed, given asymmetries between participants in these events; and (iii) What do these kinds of studies tell us about the acquisition of word meaning as an unproblematic relation between term and referent?

Introduction

It has been widely acknowledged for several decades that teaching and learning are organized quite differently in and out of school settings (Becker, 1986; Collins, Brown & Newman, 1989; Lave & Wenger, 1991; Resnick, 1987; Rogoff, 1990). In addition, most contemporary theories of learning and development claim that learning, as a process, occurs continuously in people's activity (Case, 1992; Newell, 1990). Despite the fact that instructional practices over the past several decades have proceeded as if teaching, learning, and doing were separate activities, it is not the case that people learn exclusively in school and then use what they have learned in other settings (e.g., at home or in the workplace).

It may be obvious that people learn outside of school settings, but we have relatively few studies of how teaching and learning get organized in the ongoing practical activities of workplaces (Hutchins, 1995; Saxe, 1991; Traweek, 1988; Wenger, 1990). This is particularly true of technical or scientific work settings that comprise the proposed "application" of much mathematics and science in secondary and undergraduate education. This paper presents a comparative case study of teaching and learning events in two such places: a civil engineering firm and a field biological research station. In each setting, we use observation, interviewing, collected documents, and video records of naturally occurring workplace activity as our primary data. Observational notes and interviews are used to identify "typical chunks of work" (a term we use with research participants) for recording, and these records then provide a corpus for more detailed interactional analysis of how people work together . For the purposes of this paper, we have selected what we think are representative teaching and learning events, based on our analysis of the entire recorded corpus and our understanding of the broader organizational structure of work in these settings. We use these cases as one approach to documenting and analyzing how teaching and learning happens between people in specific organizational circumstances. (Hall, 1995).

In the first two sections of this paper, we look closely at strips of interaction in which people work out the meanings of seemingly simple, technical terms. Hilary Putnam (1988) argues that reference, as a social phenomena, involves a "linguistic division of labor" where meanings are differentially distributed across a language community. The implication of this view is that meanings in use can come into conflict. This paper documents two such cases and demonstrates how these conflicts are worked through by interactants. In the civil engineering firm, we follow the contested referential scope of an evaluative term, "brutal," as it is used to describe roadway design alternatives. In the field biology research station, we follow how a coordinated, across-discipline meaning of register terms like "difference" and "distance" is developed to analyze potentially different samples from insect populations.

By following these interactions into surrounding organizational conditions, we show that even these simple negotiations are significant teaching and learning events. These interactions are difficult to recognize from a traditional cognitive science perspective as "teaching" or "learning" events. But they are precisely the kinds of interaction that comprise workplace teaching and learning, at least outside of formal training programs in the workplace settings we have studied. In our view, these kinds of events fill in the theoretical landscape that others have called forms of "legitimate peripheral participation" (Lave & Wenger, 1991) or "guided participation." (Rogoff, 1990) Our analysis

of these events works at two, interdependent levels: (1) the routine *organizational structure* of activity in these workplaces, which is available to us through ethnographic observation and interviewing, and (2) the *interactional structure* of participants' work with site- and discipline-specific forms of representation, which is available to us through analysis of video records. Together, these levels of analysis allow us to describe discursive or representational practices in these workplaces, and based on recurrent asymmetries in these practices, the kinds of teaching/learning events through which they are reproduced (i.e., how people learn to participate in practices, and in the process, generate those very practices).

Strip 1: Evaluating Roadway Design Alternatives in a Civil Engineering Firm

There is a strong argument to be made that agreements in judgment are particularly indicative of a sense of shared understanding between people (Bourdieu, 1984; Wittgenstein, 1958). Differing judgments about whether something is "good" or "bad," "too much" or "just right," etc. divide people. In this example, we follow how different uses of a single evaluative term, "brutal," divide two engineers working together to design a network of roadways. Furthermore, we analyze how these different uses occasion a situated teaching and learning event, by which we mean an event that is marked as explicitly pedagogical by neither participant and that occurs in the flow of ongoing practical activity. In this event, we find (i) an initial use of the evaluative term "brutal" by the senior engineer, (ii) its re-use by the junior engineer to evaluate a different design feature, (iii) a challenge by the senior engineer to the junior engineer's usage, and (iv) an account of why, in the current design context, the junior engineer's usage is not appropriate.

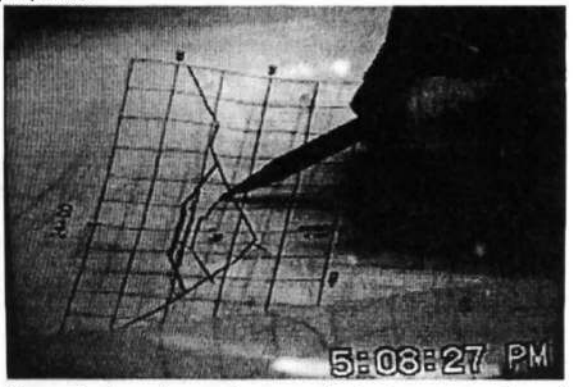

Figure 1. A senior engineer evaluates two alternatives for a proposed roadway using a section view

To understand how their joint activity is structured to produce this teaching and learning moment, we first describe relevant organizational details. With respect to the participants' identities, these details include a pair of potentially relevant (Schegloff, 1992), institutionally-organized asymmetries: Jake is the more experienced practitioner, and he maintains a higher status within the firm and within the project. With higher status comes both a power differential between Jake and Evan and a different responsibility for details of the project's development. These details include a general engineering stricture to "balance the site," which means organizing the removal and replacement of dirt across the entire construction site so that the total amount of dirt "imported" or "exported" is minimized. They also must "meet code" at all governmental levels or develop rationales for code violations that will allow them to argue for "variances" to officials. Finally, with respect to this specific project and its client's needs, Jake and Evan are developing their roadway plan for a hilly and forested site; these features of the land present environmental concerns that require, prior to other considerations, they avoid denuding forested regions of the site.

The ecology of representations (Goodwin, 1995; Hall, 1990; Star, 1995) in these engineers' workspace is densely symbolic and computational. At this meeting, within Jake's partitioned office space, the two engineers gather at a table layered with two-dimensional "paper space" views[1] that model both the site and the proposed design. These views, all partial with respect to the work they must do, are used in coordination to provide for relevant activities, such as, in this example, the production of a design rationale. The paper views are produced from a CAD system, but most of the relevant design is done with and over the paper views; only later are the CAD documents updated. A coordinated reading involves complex temporal and spatial patterns of activity that combine the verbal narration of design features with display and use of deictic, gestural, and graphical spaces (Goodwin, 1994; Hanks, 1990; McNeill, 1992).

After a number of months away from this project, Jake and Evan are refamiliarizing themselves with the design and its overall rationale. Inspecting a set of plans, they notice that Road Four (designed many months prior) has a "grade" that violates city code; the road is about five percent too steep. After Jake coordinates a reading of Road Four's mathematical slope from the vertical and horizontal margin quantities on the profile view, he considers the implications of this slope for the road[2].

Jake: Yeah, (1)this huh road (laughing) is a, is a . . .
STRETCH. You know? (6 sec.) It's gonna be brutal

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1 For a full description of the variety of representations used by these engineers to "see" the site and to "project" potential design features, see (Hall & Stevens, 1995). Generally, these engineers share a set of "views" that resemble those of other design professionals (topographic maps, plan views, section views, and profiles). These two dimensional, metricized representations are used in coordination to plan and design for three dimensional space.

2 Transcript conventions include: turns at talk start with named speakers; embodied action descriptions appear in italics below each turn; the onset of embodied action is indexed by numbers in parentheses within the turn; spoken EMPHASIS is shown by upper case; stretch:::ed words are shown with repeated colons; a question mark precedes ?words that were difficult to hear during transcription; and matching left brackets [show the onset of overlapping talk across turns.

man, (2)twenty percent for . . . for ah . . . fifteen hundred feet. (laughs)

1(R hand points below road in profile view)
2(writes 400, 450, 350, 500 at center of profile view)

"Brutal" is a negative evaluation that refers to the road being excessively steep over a long distance. In this instance, Jake appears to mean the road will be brutal with respect to some human activity, probably driving emergency vehicles. Because this evaluation appears in the natural course of their ongoing work, we interpret Evan's subsequent turn in the conversation as a tacit acceptance of this usage of "brutal" as a negative evaluation.

Evan: Other(1)wise you'd be up here and (2)you'd have to cut way across [sho::oo

1(R hand to upper left of the profile view)
2(R hand sweeps right then left above the proposed road)

Jake: [Ri::ght.

Within the materials jointly at hand, Evan begins to assemble a rationale for this brutal grade that contrasts their design choice with an even less desirable alternative ("Otherwise [...] you'd have to cut way across"). Jake's collaborative completion ("[Ri::ght") indicates they both judge this design feature to be "brutal." Over the next several conversational turns, Jake leads a coordinated narrative and gestural tour through multiple paper views of the region surrounding Road Four. When he reaches a particular section view (see Figure 1) in this developing rationale for an overly steep road, Evan points to the section and again uses the evaluative term, "brutal." But in this instance, Evan refers to what he projects as an excessive amount of dirt needed to fill under this part of the proposed road.

Evan: (laughs) (1)That's brutal, huh? Well, I don't know. . . [maybe not.

1(L hand points below roadbed in section view)

Jake: [Yeah . . . well, but ... look at it THIS way . . .

Evan's use of "brutal" is tentatively offered ("Well, I don't know"), and as Jake begins to disagree[3] ("Yeah... well"), Evan retreats even further from the evaluation ("maybe not"). Both participants orient to a contended usage of the evaluative term: Jake because he challenges Evan's evaluation, and Evan because he retreats when Jake begins to disagree. At an interactional level, these are the dynamics of asymmetry at the organizational level (see Rogoff, 1990, pp. 204–205), and they are central in determining whose terms are appropriated and how those terms are used to refer. We understand Evan to be appropriating a term and improvising its use in participation with a differently-knowledgeable other; a commonplace type of learning in practice (Cole, 1985; Lave & Wenger, 1991; Rogoff, 1990).

We take this to be a teaching/learning event that emerges in the ongoing work of a civil engineering project. As they continue, Jake does more than simply reject Evan's evaluation; he again explains, using a coordinated assembly of narrative, drawing, and deictic pointing why the amount of fill required in this section is better than the existing alternatives. By sketching one of these alternatives (Figure 1) he shows that it would save little and require "ripping down the whole side of the hillside." In this implicit moment of situated teaching, Jake assembles a broader rationale of this feature for Evan, but he also strengthens his own conviction ("it's perfect") that a twenty percent grade on Road Four is necessary to save a hillside full of trees. As their project moves towards municipal approval, this argument may support a request for a variance.

Strip 2: Analyzing Chemical Differences Between Insects in a Field Biology Research Station

Our second strip comes from a regularly scheduled meeting among an interdisciplinary team of scientists in a field biology research station . Their work on this project concerns what they call the "chemical ecology of forest insects." In this meeting, two entomologists (Mark and Gary), a chemist (Leah), and a visiting biostatistician (Bill) discuss how to analyze differences in the chemical makeup of a waxy residue stripped off of termites' exoskeletons. They use these chemical differences to classify termite species and to map the geographic boundaries of termite colonies (insects in a colony are all of the same species). This kind of information is helpful for developing and assessing the effects of new, "environmentally softer" pesticides, but it is also central to basic research questions about the distribution and ecological role of a variety of insects.

Figure 2. A biostatistician illustrates a possible distance measure using two CGs.

Two organizational features of this setting are important for our analysis of teaching and learning. First, there are asymmetries in the hierarchical position of participants within the project and across disciplines. Mark is a senior

[3]This form of challenge is described by conversation analysts as disagreement expressed with a dispreferred form. It is offered with hesitation and with an affiliative "Yeah... but " rather than a bald "no" (Goodwin & Heritage, 1990; Pomerantz, 1984).

research entomologist and this projects' leader, Gary is also an entomologist (he and Mark hold Ph.D.'s), and Leah is a staff biologist with specialized post-baccalaureate training in chemistry. Bill, on the other hand, attends the meeting as a consulting biostatistician (he also holds a Ph.D.), but he works on a variety of projects across the surrounding field research station. So we find relevant asymmetries both in what people are expected to contribute across disciplinary specialties (e.g., entomology, chemistry, and biostatistics), and because participants in this meeting have quite different responsibilities for different aspects the project's ongoing activities. The second relevant organizational feature concerns the routine structure of work on this project. This meeting is one type of activity within a broader structure which the entomologists call a "biogeographic study." These studies regularly take project participants through distinct types of activity: (i) from field sites where they subdivide the forest floor into rectilinear "plots" and then systematically collect insects from a grid-like structure of "traps," (ii) to a chemistry laboratory in the research station where they extract and identify hydrocarbons from these insects' bodies using a gas-chromatography/mass-spectroscopy (GC/MS) device, and finally (iii) into project meetings like this one, where the resulting chromatograms[4] (CG's, see Figure 2) can be used to identify termite species and to follow the moving boundary of termite colonies.

The strip we examine in this section comes at the end of a biogeographical study of termites, and the consulting biostatistician is helping the project develop a statistical measure that can compare two CG's and support judgments about different species or colonies. The second organizational feature is important because activity and talk in this meeting (e.g., choosing pairs of CG's and announcing a "difference" between them) needs to be held accountable to the broader chain of activities in a biogeographic study. The CG's shown in Figure 1 are the final point in a process that converts bugs into graphs that the entomologists call "hydrocarbon phenotypes." Since there are marked asymmetries between participants in their disciplinary backgrounds, their responsibilities within the project, and their actual work across different aspects of the biogeographical study, each participant can take on the role of a "teacher" or a "learner" during this meeting.

At the outset of the meeting, Gary and Bill (the biostatistician) disagree over whether to use a standardized statistical clustering algorithm to aggregate termite samples, but Mark interrupts, enlisting Leah (the chemist) to help arrange a column of four CG's that they place in front of Bill to demonstrate what Mark calls "a good comparing." Mark shows that two of the CG's are "radically different" and so probably come from different species, another pair "don't look that different" and so may come from the same colony, but a final pair (shown in Figure 2) have the same types of hydrocarbons in slightly different relative proportions and so probably come from different termite colonies. Each of Mark's pairwise judgments is accomplished using deictic points to specific peaks being compared across CG's, then Gary and Mark collaboratively summarize the final comparison as having "no QUALitative difference between here, just quantitative difference" (i.e. same species but different colony). Across multiple occasions in which we have observed project members using CG's, this is a typical discursive practice: narrative judgments of qualitative and quantitative difference are made as the entomologists use their hands to select specific peaks that, as they put it, "JUMP out at you."

In our analysis, this collaborative summary marks the end of a teaching event staged for the benefit of Bill (the biostatistician), who is a newcomer (i.e., asymmetrically located) both in these entomologists' discursive practices for comparing CG graphs and in the routine organization of their project work. In this sense, he needs to learn enough about their activities to be able to give advice about constructing a statistical measure that will behave sensibly. So as Bill takes the next turn in this conversation, he has been positioned by members of the project team as a learner who needs to display his understanding of "a good comparing" of CG's, but he simultaneously takes the role of a consultant who needs to teach these project members about a statistical approach to their differences. At the first turn boundary of Bill's carefully worded opening, Mark emphatically disagrees with Bill's usage of the term "distance."

Bill: You know the (1)part, part of the thing is, is how you define, again how will we go about defining a distance ?up here. (2)You're trying to use your eyes to, to, to (3)match these two up and see where there are differences and where there aren't?
1(R point circles over two CG's)
2(R point traces up vertical, across horizontal of a CG)
3(open R hand, taps thumb on bottom display, middle finger on top display)

Mark: DIFFERENCES, not distances, differences.

Bill repairs in his next turn, reiterating that what "we're trying to get" is a way to combine all the "differences" used by these entomologists into "one number," something that Mark then says he would "LOVE." Bill goes on to describe various approaches to combining these differences, sweeping his hands over a pair of CG's to show how they would be aggregated, but he continues to use what appears to be a specific, statistical meaning for "distance." As Bill finishes narrating and manually illustrating this set of statistical possibilities, Mark again challenges this use of the term "distance," referring to a drawing of a field sampling plot to show Bill what he means by "distance."

Mark: What I'd like to do is, sort of... (1)get rid of the distance. I don't know what you're talking about. When I'm talking about distance, (2)I'm talking about geography, [j:: ?linear ?measure

[4]Chromatograms are graphs that show GC/MS retention time along the horizontal axis (i.e., hydrocarbons pass through the device at specific times) and relative abundance along the vertical axis (i.e., the height of a peak shows how much of a specific hydrocarbon is present).

1(hands up, pushing away towards Bill)
2(R point to white board, then traces and shifts gaze to Bill)

Bill: [And I'm, but I'm talking about (1)some sort of measure, to say... how di::fferent these, [two... uh:::
1(hands flat over two CG's, then R hand rockers between them)

Mark: [Yeh, ok. And that's what you're calling a distance?

Following this relatively direct disagreement, Bill repeats his offer to produce "one number" that can be used to judge whether CG's are from the same colony. Mark nods in agreement, then begins using Bill's statistical meaning for "distance" as a "statistic" for comparing CG's. As the meeting continues, both of these participants manage a coordinated use, across disciplines, of "differences" (i.e., entomological judgments) and "distance" (i.e., a statistical aggregate over those judgments). As this strip ends, Mark jokingly suggests that this new distance measure might be named after him. We take this to be end of a mutual teaching/learning event, in which Bill and Mark each appropriate aspects of the other's meanings for register terms.

Discussion

This paper gives a close description of two strips of interaction, selected from a data corpus that documents naturally-occurring work in settings often considered to be targets for education in science and mathematics. Our aim has been to give sufficient ethnographic background about the organizational conditions of people's work to support a detailed analysis of the interactional structure of teaching/learning events. The interactional details of how these events emerge and are carried out need to be held accountable (in our analysis, as in their work) to the very conditions that bring the events about. We take a narrow focus on learning, asking how people outside of school or laboratory conditions learn the meaning of terms that are important in their work (i.e., evaluative and register terms). In both cases, disagreements about the use of terms are detected in ongoing interaction, alternative meanings are actively assembled across different types of media, and disagreements are resolved around pre-existing organizational asymmetries.

We close by raising three general questions about teaching/learning in the workplace: (i) What is accessible to participants as teachers/learners under different organizational conditions; (ii) How are disagreements about shared meaning managed, given asymmetries between participants in these events; and (iii) What do these kinds of studies tell us about the acquisition of word meaning as an unproblematic relation between term and referent?

In the events we have analyzed, people learn by participating in the activities that establish meanings for words, so they must have access to these activities. Similar to Hutchins (1995) analysis of observational "horizons" in the work of navigation, we find that access to discursive practices occurs at two levels. First, the organizational structure of work in large measure determines who will be present when critical activities are undertaken. The civil engineers we studied work together on most phases of a design project, but in the biology research station, the biostatistician (Bill) did not work in field collection sites or the chemistry lab where an articulated chain of activities produce the CG's he is asked to compare. As a result, the project team needs to make parts of this chain of work visible to Bill, and the meaning of register terms within this chain of activity is hotly contested. Second, the types of representational media being used in the context of teaching/learning events (Hutchins calls these "open tools") greatly influences the visibility of meaning, as an accomplishment, within ongoing discursive practices. This is particularly vivid in our analysis of civil engineers, who must work together to "see" specific regions in their ongoing design (i.e., two hands and one pair of eyes cannot manage some aspects of their work in "paper space").

On the issue of differences of meaning and how they are recognized and managed, it may be that teaching/learning events outside of schools and psychological laboratories are densely clustered around breakdowns (de la Rocha, 1986), some of which are marked in conversation as disagreements about otherwise shared meanings. Following disagreements at an interactional level of analysis then provides a window onto potential teaching/learning events. In our comparative analysis, we identify disagreements and then follow their consequences for evidence that someone has "taught" and someone else has "learned" (e.g., Mark's appropriation of Bill's usage of "distance"). Conversational forms (see Engle & Greeno, 1994, on "intellectual conversations") and their entailments for learning will likely change under different conditions of asymmetry (e.g., project hierarchies, levels of schooling, gender, or disciplinary specialization).

Finally, when following people's activities out of school or laboratory situations that 'freeze' the organization and intended meaning of "tasks" (see Newman, Griffin & Cole, 1989 for a similar critique), traditional notions about word meaning as a relation between term and referent need to be reconsidered and empirically grounded in people's situated activities. Here, we find terms (evaluative and register) being deployed in situations where their referents are actively assembled and frequently contested. Having a "meaning" at any given point requires the ability to participate in a coordinated set of representational practices across narration (e.g., "a good comparing"), inscriptions (e.g., an ordered column of CG's), and embodied action (e.g., deictic points selecting CG peaks that "jump out at you"). If, in representing human action, we delete these interactional resources and their coordinated assembly, we likewise delete central phenomena in the creation and circulation of meaning.

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