The Epistemological Framing of a Discipline: Writing Science in University Oceanography

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Abstract: The purpose of this paper is to examine how instruction in scientific writing in a university oceanography course communicated epistemological positions of this discipline. Drawing from sociological and anthropological studies of scientific communities, this study uses an ethnographic perspective to explore how teachers and students came to define particular views of disciplinary knowledge through the everyday practices associated with teaching and learning oceanography. Writing in a scientific genre was supported by interactive CD-ROM which allowed students to access data representations from geological databases. In our analysis of the spoken and written discourse of the members of this course, we identified epistemological issues such as uses of evidence, role of expertise, relevance of point of view, and limits to the authority of disciplinary inquiry. Implications for college science teaching are drawn.© 2000 John Wiley & Sons, Inc. J Res Sci Teach 37: 691–718, 2000

In the ethnographic study we describe in this paper, we entered as participant-observers; we began by asking ''what's happening here?'' and found that the writing of science by students and the talking about writing by instructors (course professor and teaching assistants) led to a fertile ground for examining how questions of knowledge construction, use, and representation are interactionally communicated in teaching and learning situations. Through an iterative ethnographic research cycle of posing questions; collecting, constructing, and analyzing data; and writing an ethnography; we focused on how the writing of a scientific genre in ''Geology 4: Oceanography'' (an introductory university course) foregrounded questions concerning disciplinary knowledge, thus making visible an epistemology of science. Our treatment of these epistemological issues began by identifying their importance to the participants and continued through the examination of the instructional practices associated with learning to

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write in science. In the discussions of epistemology and writing that follow we develop a rationale for studying epistemological issues associated with writing in science.

As a discipline epistemology has been concerned with the origins, scope, nature, and limitations of knowledge (Boyd, Gasper, & Trout, 1991; Sosa, 1991). In education, epistemology has been influential in the development of educational theories for effective instruction (Duschl, 1990), has been tied to students' conceptual change (Posner, Strike, Hewson, & Gertzog, 1982; Hewson, 1985; Strike & Posner, 1992), and has been investigated as a domain of the nature of science (Ryan & Aikenhead, 1992). To date, few studies have studied epistemology as interactionally accomplished through classroom discourse. Such a naturalistic perspective on epistemological issues raises a number of theoretical concerns and possibilities (Duran, 1998), and has been the subject for two recent reviews of methodological approaches to the study of the nature of science.

In a recent review of methodological approaches for the study of the nature of science (NOS), Kelly, Chen, and Crawford (1998) proposed a framework for the descriptive, empirical study of school science as everyday practice aiming to "understand how what is taken for science is accomplished through the everyday actions of students, teachers, texts, and technologies" (p. 26). In this review the authors found that few studies considered how an epistemology of a discipline was framed, construed, and shaped by actions of actors through everyday practice. Similarly, Lederman, Wade, and Bell (1998) found that research on the nature of science has generally focused on whether students' or teachers' conceptions match researchers' normative views as measured by research instruments and interviews. The authors called for a "move on to questions of classroom practice and lay to rest the continued assessment of teachers' and students' conceptions" (Lederman, et al., 1998, p. 612). These reviews point to research directions that consider how empirical studies of mundane, everyday activities in classrooms can shed light on the epistemological issues relevant to teaching and learning.

Our focus on how instructional practices related to writing in science shape disciplinary knowledge intersects with some recent work on writing to learn in science. Studies of writing to learn in science have begun to examine students' views of the nature of science and how these views change with experiences in writing science. Keys, Hand, Prain, and Collins (1999) proposed a science writing heuristic [SWH] to promote student learning through writing during laboratory experiences. Through a variety of interpretative methods, this study found that students did not experience large changes in their views of the nature of science, but that they did develop more specified understandings of "scientists work, the nature of evidence, and collaboration in science" (p. 1081). The importance of evidence in science writing in this study points to a need to examine the relationship of epistemology and writing in science instruction, an issue cited as needed in further study.

The relationship between epistemology and writing has been identified in recent studies of writing in science. Drawing from writing to learn literature, Keys (1999) noted that the use of scientific genres by teachers to promote scientific thinking has been infrequently documented. Keys endorsed student writing in scientific genres and called for the examination of classroom activities that encourage "integrated inquiry and writing" (p. 128). Prain and Hand (1999) investigated student writing and found that students had a "limited capacity to explain how knowledge claims are established in science in relation to learning through writing, or to understand how writing could act as an epistemological tool" (p. 160). They similarly argued for further research that focuses on student experiences with writing to learn in science. These and other studies have focused on epistemology as manifest in student writing and discussions, in interviews with students, and through questionnaires (Keys, et al., 1999). Following the suggestions of this work (Keys, 1999; Keys, et al., 1999; Prain & Hand, 1999), we present a case of teachers using a scientific genre to enhance students' abilities to formulate arguments and consider the epistemological issues associated with writing in this manner.

The study we present in subsequent sections of this paper differs from previous studies in that we explore the connections of writing and disciplinary knowledge from an anthropological perspective with a central focus on the discourse processes of instruction that frame the academic tasks. Our focus was not on the student written products, but rather on the discourse that framed and produced the writing of science in a particular way. Before turning to our methodological approach and the description of our study, we review research focusing on the production and representation of knowledge in science and in educational settings, as this work was central to our conceptualization of the social discourse manifest in our study.

The Work of Knowledge Production and Representation

Recent studies of scientific communities and practices point to ways knowledge construction, use, and representation can be studied through everyday action (Lynch, 1992; Kelly, Carlsen, & Cunningham, 1993; Roth & McGinn, 1997). One relatively under-examined issue is the study of the epistemology of various disciplines as manifest through the actions of their representatives in educational settings. Therefore, the public presentation of science in educational settings provides a unique opportunity to examine how instructors position the epistemology of a given discipline. This approach develops one line of argument following the "descriptive turn" (Fuller, 1992) in epistemology: the ways educational processes frame disciplinary knowledge through the mundane, everyday activities of accomplishing education in a scientific field.

Empirical studies of science-in-action (e.g., Latour, 1987) show that analysis of the inner workings of the construction of scientific knowledge evinces the importance of the discursive and rhetorical work necessary to establish ideas as counting as science within a particular community (Bazerman, 1988). Similarly, educational studies informed by science studies have identified ways that disciplinary knowledge is constructed interactionally through discourse and interpretative processes (Kelly & Chen, 1999). For example, the evolution and transformation of inscriptions—representations of phenomena typically on computer screens or as printed material—as a cultural practice of scientists has come under study by educators concerned with understanding the public nature of knowledge in science (Roth & McGinn, 1998). These studies examine the social nature of the representation of knowledge and ways in which communities make decisions about knowledge production, circulation, and discrimination.

The study of the mundane and situated activities of scientists offers ways of broadening our understanding of what it means to learn science. By viewing science as culture and practice (e.g., conventionalized ways of knowing, speaking, acting, being), the activities associated with knowledge-in-use of practitioners become relevant for initiating newcomers into a community (Lave & Wenger, 1991). We draw on two studies of oceanographers to illustrate these points; this choice is strategic as oceanography is the discipline under scrutiny in our empirical analysis. Close examination of practitioners' actions has proven fruitful for both the study of the microanalytic work of accomplishing experimental tasks as well as for the study of negotiating ways of making such work possible. For example, in a study of life aboard an oceanographic vessel, Goodwin (1995) explained how becoming a member in the guild of oceanographers involved knowing how to observe and see events in a particular way. Goodwin explained that as an (uninformed) observer (i.e., anthropologist, non-oceanographer) he did not see a "nice feature" noted by the oceanographers:

> The ability to see such an event is embedded within an endogenous community of practitioners, the work of which provides a guide for seeing—interpretative structures that locate particular phenomena as relevant and interesting—and tools and intellectual frameworks that make such phenomena visible in the first place. (p. 263)

Thus, this instance represented just one aspect of what it means to be a scientist, particularly an oceanographer. As described by Kelly et al. (1998):

> becoming a scientist involves coming to see the world in a particular way; coming to understand, use, and draw upon a common body of knowledge; coming to understand how to articulate an appropriate argument given certain contexts; and coming to know how to present oneself and one's data in socially and scientifically appropriate ways. Therefore, education in science can be thought of as contributing to a process in which novices are initiated into a community of practice. (p. 24)

While Goodwin's study examined the everyday practices of scientists on an ocean vessel, Mukerji (1989) considered the relationship of scientists to state interests in their research. Mukerji documented the multiple uses of discourse processes (both written and spoken) and the importance of scientists appropriately mediating their discourse for given audiences, such as recruiting expertise (e.g., postdoctoral scholars) to a particular laboratory, using citations to form alliances, and positioning authors in the rivalries found at the forefront of science. Thus, the communicative system of doing science required a range of competencies. For example, scientists needed to know how to negotiate away some aspects of their intellectual authority, due to the interests of state funding agencies, while maintaining enough intellectual autonomy to maintain credibility in the scientific community. In other interactional contexts, they needed to know how to read and write in the stylized genres of science research journals, or how to demarcate their geographical space from other research groups when competing for the same funding. Thus, scientists in general, and oceanographers in particular, use a range of discourse processes that are employed to accomplish their work as scientists and that come to define the knowledge that counts within their discipline.

One rather unexamined discourse of science is the portrayal of the various disciplines to students, whether they are new initiates to a discipline or outsiders with a need to know about the science in question. In this paper, we examine the instructional practices associated with learning to write in science and how through this process the epistemology of the discipline is portrayed in a university introductory science course.

Educational Context

University oceanography provides a unique and potentially fruitful context for studying science education. Oceanography is an inherently multidisciplinary science, drawing from physics, geology, and chemistry and in interaction with a number of life sciences (Mukerji, 1989; Goodwin, 1995). Because it receives less emphasis than other sciences in the official science curriculum in California's public secondary schools (California Department of Education, 1990), very few students enrolled in this university course had extensive experience with oceanography, even though they did have a considerable amount of secondary school science. Most were first-year university students and the vast majority were not geological sciences majors (oceanography's disciplinary home at the university in question). In addition, unlike other sciences like physics where much educational research has documented students' preconceptions derived from previous experience (Clement, 1982; Halloun & Hestenes, 1985; Dykstra, Boyle, & Monarch, 1992), less is known about students' conceptions in oceanography.

This university oceanography course included unique features. It functioned both as a terminal course for non-scientists as well as a course designed to attract geological science majors. The course focused on how the earth works, covering the formation of the earth and its physical features, the seafloor, ocean composition and currents, the atmosphere, and the climate. The professor's course goals included teaching students to think as scientists, increasing students' scientific literacy, and increasing participation in the earth science major. There were approximately 200 students enrolled in this course. They attended three lectures (offered by the course professor, third author) and one 2-hour laboratory session each week (led by graduate student teaching assistants). The laboratory room had 25 Macintosh power PC computers, CD-ROM drives, and an AppleShare file server, all dedicated to the course. Computers were arranged around the periphery of the room so that non-computer activities could occur at the center tables.

Writing was a key instructional component, allowing the course to be designated a "writing intensive course" at this university. Designation as a "writing intensive course" is based on two premises: "that writing is a central activity in all subjects and majors at the university, and that writing skills can best be developed by repeated practice in a variety of academic contexts" (University of California Santa Barbara general course catalog, 1995–1996). The university required students to enroll in six approved courses, each involving the writing of one or more papers totaling 1800 words. The oceanography course, in particular, required a one page (graded) pre-paper, with peer feedback in the lab sections, and a mid-term "technical paper" typically 6–7 pages in length. The goals for this writing centered on engaging students with key elements of scientific practice including understanding relevant background knowledge (i.e., the theory of plate tectonics), asking researchable scientific questions, selecting data and making observations relevant to the question posed, interpreting data to support a theory or model, presenting an argument, and evaluating the work of others. This mid-term technical paper counted for 30% of a student's final grade for the course.

Writing in science was supported in two central ways. First, the course lectures and laboratory sections were oriented to helping students read and write science. These instructional activities consisted of discussions concerning writing. Topics included how scientists select a problem, how evidence is used to support a theory or model, how observations are separated from interpretations, how these elements are formatted into a scientific paper, and how to generate and use feedback from other writers (see subsequent data analysis sections). The second central support for writing science came from the real earth datasets contained on the CD-ROM, "Our Dynamic Planet" (Prothero, 1995). The CD-ROM provides raw earth data used to solve problems associated with plate tectonics. Students could answer homework questions that were automatically graded. They also had access to game modules that introduced them to the software and ways of identifying geological features. However, the central use of the technology was to provide data representations for reference in student writing. For example, Figure 1 shows an elevation and earthquake cross-section plotted across the Tonga Trench. A similar plot could be generated by students and incorporated in their writing to illustrate the descending pattern of quakes and deep trench feature that indicates a subducting plate, or convergent plate margin. To achieve such representations students select the cross-section endpoints through graphical "point and click" techniques and can choose the plot scales and vertical exaggeration if desired. Between any two locations, students could plot earthquakes and quake cross-sections, seafloor elevation cross-sections, cenozoic volcano locations (on land); determine island ages, measure heat flow; and access movies and still graphics illustrating views or facts about particular

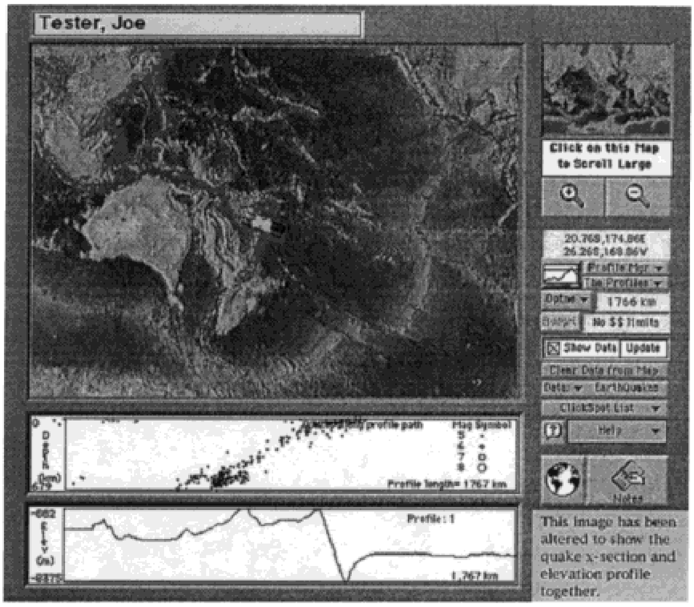

Figure 1. Typical data representation from the CD-ROM "Our Dynamic Planet." This figure shows a typical data screen (with quake and seafloor elevation cross-section plots) from which students were to make observations relevant to their writing task. Both an earthquake and an elevation cross-section are shown plotted across the Tonga Trench. Students select the cross-section endpoints on the map and can choose the plot types (earthquakes, volcanoes, elevations, heat flow, island ages/hot spots) and scales as desired.

locations. The large collection of raw earth data enables students to pose questions about and find support for the theory of plate tectonics, including the identification of plate boundary types (through earthquake, volcano, elevation, and heat flow analyses) and plate motion velocities (island ages/hot spots). With the same databases, more advanced studies could be conducted on variations in slab dip (angle of a subducting lithospheric slab from the horizontal plane), the configurations of more complex plate boundaries, and comparisons of various plate boundaries at different geographical locations. Thus, the CD-ROM technology was designed and used specifically in support of writing science in a particular way that included posing questions and using geological data representations as evidence. More information about the CD-ROM may be found at http://oceanography.geol.ucsb.edu/.

Research Approach and Methods: Oceanography Constructed Through Discourse Processes

Classroom-based ethnographies from various theoretical traditions have incorporated discourse analysis into the theoretical and analytical work of studying cultural practices in school settings (Mehan, 1979; Green & Wallat, 1981; Erickson, 1992). Discourse processes have been identified as central to culturally shaping events in classrooms and other activity systems (Green & Dixon, 1993; Bazerman, 1997). The approach we describe focuses on examining cultural actions, artifacts, and discourse processes through which group members construct social situations and signal to each other ways of being a group member in routine everyday events (Kelly & Chen, 1999). Discourse analysis allows researchers to understand and represent how cultural knowledge (e.g., science) is interactionally accomplished through the moment-to-moment interactions of students, teachers, texts, and technologies. This approach examines how members come to define common constructs and practices through everyday activity.

As a team of ethnographers[1] we analyzed videotapes of lectures and small group sessions, student products (tests, labs, papers) and reflective essays written by the students. Analysis of the data was based on a set of analytic procedures drawn from an ethnographic research framework (Kelly & Crawford, 1997; Kelly & Chen, 1999; Kelly et al., 1998). Through our data collection processes, initial observations, informal interviews, and reviews of the classroom artifacts, we identified the writing of a technical paper as a central cultural practice constructed through ''key speech events'' (Gumperz & Cook-Gumperz, 1982) in the social construction of *Geology 4: Oceanography*. Technical paper is a ''folk term'' (Spradley, 1980) used by the course instructors to refer to the paper written in a scientific genre. The technical paper was the students' midterm assignment in which they were required to use geological data to support an argument for plate tectonics. This writing task was spoken of often by the instructors (course professor and teaching assistants), foregrounded in the ''laboratory manual'' accompanying the course, and was identified by the instructors as a central reason for student use of the interactive CD-ROM database technology. Therefore, as ethnographers of this community, we recognized ''writing of a technical paper'' as important in this community. This served as the basis for our further investigation and methodological decisions.

We reviewed the videotapes for weeks 2–10 of each lecture given by the course professor and of all laboratory sessions offered by two teaching assistants, noting the instances when the participants spoke of, or made reference to, literate practices in science including writing the ''technical paper'' and reading other scientific writing. These videotaped segments were collected on a compilation tape for more thorough analysis (27 episodes totaling approximately 2 h). A catalogue table with a descriptive cover term naming each episode, the date the episodes took place, and a short description was constructed to situate each episode within the broader sequences of events (see Figure 2). The analysis of these videotape episodes consisted of mapping classroom events in increasingly greater detail at various levels of specificity (Green & Wallat, 1981; Erickson, 1992). Instructional conversations have an episodic nature to them, marked interactionally by the members of the classroom (Mehan, 1979; Kelly & Crawford, 1996; 1997; Lemke, 1998). Thus, as researchers, we identified potential boundaries of activity and reviewed the videotaped records to create time-stamped transcripts of the actions and discourse of the participants. This approach utilized the interactional markers to segment a conversation for analysis purposes and, in doing so, defined a set of units for analysis.

Figure 3 shows three levels of discourse analysis (phase units, sequence units, and transcribed talk) used in creating an event map. A *phase* of activity represents concerted and coordinated action among participants, reflects a common focus of the group, and can be identified by the content of the actors' talk in conjunction with relevant contextualization cues (Green & Wallat, 1981; Gumperz, 1992; Kelly & Chen, 1999). For example, the activities depicted in Figure 3 constitute one phase unit. Within each phase, participants structure their conversations and cue each other through their interactions. Cohesive, thematically tied interactions within a phase are labeled as a *sequence unit*. The phase unit in Figure 3 was constructed of six sequence units, each labeled and time-stamped. *Message units* are the smallest

[1] As the third author created and taught the course, he was purposefully not involved in the ethnographic analysis. His contributions to the educational research were made after the completion of the domain analyses and the identification of the cultural themes.

Date	(#) Analytic episode	Short description
		Week 1: Negotiating entry - - no videotaping
		Week 2: Scientific writing and communication
10/12	(1) Students working in groups	Karen (TA_1) explains how to do a peer group evaluation. Uses observation process of scientific method as analogy.
10/12	(2) Qualitative vs. quantitative observations in science writing	Karen explains beach assignment as observation exercise: qualitative data contrasted with "numbers."
10/13	(3) Observation & writing	Karen contrasts "English paper" with science writing. Introduces idea of genres of written discourse. Starts with observations: suggests qualitative vs. quantitative differences, importance of audience.
		Week 3: Maps and profiles
10/17	(4) Observation/Interpretation & writing	Earl (TA_2) starts with student's writing, looks at observation/interpretation distinction.
10/17	(5) Doing science -- Geology	Earl uses real data of ship track lines, makes explicit "what oceanographers do", i.e.. they try to find features.
10/20	(6) Reading and writing lab notebook	Karen stresses need to make outline of the midterm paper before writing, as is recommended in the lab manual.
10/20	(7) Citation & credit: using other's work	Karen discusses sources for the paper. Credit must be given for data source.
		Week 4: Exploring the deep
1023	(8) Technical writing: "What scientists do"	Bill (Prof.) explains importance of writing. Uses examples from personal history as scientist, scientific problems, data, and doing science.
10/25	(9) Writing, using data, role of audience	Bill explains writing process, importance of revision and consideration of audience.
10/25	(10) Power of written language	Bill makes reference to adage concerning writing and power: "pen is mightier than the sword."
10/27	(11) How to make an observation & interpretation	Karen suggests a cause and effect relationship for the observation/interpretation dichotomy. One is needed for the other; "use observation to make interpretation."
10/27	(12) Map as observation	Karen brings up the crucial question of how to find data. Purpose of using "tools" is to find evidence for plate tectonics. Data then become part of the process for making this argument. The necessity of "proof" is invoked here.
10/27	(13) How to display data in the paper	Karen discusses layout of "technical paper." Tries to make explicit how data should be organized to make argument.
10/27	(14) Mechanics of writing science	Karen discusses the "details" of the technical paper: illustrations, references, citation form, footnotes.
10/27	(15) More mechanics of writing science	Karen addresses students' software and documentation questions, how to reference map points and use coordinates.

Date	(#) Analytic episode	Short description
Week 5: Sediments and sediment transport (continued)		
10/31	(16) Nature of the midterm paper	Earl compares technical paper with journal article, magazine and Ph.D. thesis. Here graphics are good, but content is better, according to TA_2.
11/03	(17) What geologists do with rocks	Karen explains sediments and their impact on the coastal environment.
11/03	(18) More reasons for studying rocks	Karen describes that the movement of rocks pertains to oceanography; also the human impact on coastal environment..."that's what geologist's do."
Week 6: Waves and beaches - - no reference to writing or reading science		
Week 7: Earth's heat budget		
11/15	(19) Social/political use of scientific data	Bill takes issue with Rush Limbaugh's use of scientific authority in political discourse.
11/17	(20) Sources of data: Mt. Pinatubo & Rush Limbaugh	Karen makes argument about natural sources of atmospheric gasses and human produced gasses: chlorine in the atmosphere. Limbaugh's data as flawed.
Week 8: No theme identified (shortened week)		
11/20	(21) Writing as a product: grades	Bill talks about Rush Limbaugh and the media in general; wants students to be skeptical of information they hear.
Week 9: World's fisheries		
11/28	(22) Consideration of sources of written knowledge	Earl raises question: source of articles determine their validity? Expresses personal view of persuasion.
11/28	(23) Funding in science	Earl raises issue of data objectivity and bias in science due to funding sources (corp. and gov't.) Modern science is characterized as "not a gentleman's science."
12/01	(24) Responding to grading	Karen discusses writing as a product: used for evaluation. Grade appeals are also discussed.
12/01	(25) Point of view in applied scientific problems	Karen has students work in groups to take positions and to research data to make arguments in environmental application of scientific data.
12/01	(26) Critical evaluation of scientific data	Karen raises questions: How valid is data in the public sphere and political debates? How many studies are needed to make policy?
12/01	(27) Fair grading and model papers	Bill talks about "fair" grading of papers and recommends that students go see their TAs for model/exemplar papers.
Week 10: Coastal marine biology		

Figure 2. Sequential catalogue of episodes sampled for more in-depth analysis. Table shows a week-by-week sequence of topics and notes the descriptive cover term naming each episode, the date the episodes took place, and the respective short descriptions.

line #	phase units	time	sequence units	*research notes & comments/* "transcribed talk"
101 102 103 104 105	Goal of midterm paper: Do what scientists do	00:00:05	Reference to lab notebook on how to write a technical paper	*Begins with:* "There's a lot of possible ways you could go on this midterm paper." *Professor describes his balancing act between too much information and too little information; enough information to let students know professor is expecting, but not too much so that it becomes "fill in the blanks."*
106 107		00:00:52	Struggle of scientists	*Scientists go through a progress of struggle:* "trying to make sense out of what seems like chaos a lot of times."
108 109 110 111 112 113 114		00:01:10	Personal experience of not understanding what the data means	"So NSF has given us ah 80 grand or something. We've gone out, done field experiments, measured earthquakes for a couple of months, and we look at it and 'oh boy' and you start looking at it. you start, 'well let's try this.' you start looking at it and plotting things up and trying to make some consistency out of it. Then looking at this." *Professor says for students not to feel alone or dumb if don't understand right away.*
115 116 117		00:01:54	Actions students should take	*Professor mentions need to turn over and struggle with concepts; talk with others; discuss in sections; in the process of "doing science" as scientists do.*
118 119		00:02:20	Earthquake data	*Professor indicates that students will be analyzing current, real data.*
120 121 122 123 124 125 126 127 128 129 130 131		00:02:51	Identifying and explaining a problem	"There's another part of science that you need to know about is you can't explain everything." "Part of doing science is to figure out kinda (winnow) out what can I explain and what can't I explain. What's an interesting problem or what's an interesting thing to explain or what uh you know when when a scientist does research, one of the talents you have or has to be developed is knowing first off what's an interesting problem to study. Second off, whether studying it, and what data you can take can actually solve that problem or get some new information on that problem. So there's a lot of problems in the world uh that that are unsolvable you know, sort of classic problems you might not want to tackle."
	Onset on new phase of activity focused on the waves.			Professor walks back to podium saying, "OK uh waves."

Figure 3. Representation of different levels of discourse analysis. Shown are: line numbers for presentation and discussion, phase unit noted with cover term, time stamps from compilation video dub, sequence units, and research notes and comments.

unit of sociolinguistic meaning (Green & Wallat; 1981; Kelly & Crawford, 1996; Kelly & Chen, 1999), defined by boundaries of utterances or social action that are identified through cues to contextualization, for example, pitch, stress, intonation, pause structures, physical orientation, proxemic distance, and eye gaze (Gumperz, 1992). These units are described in detail in previous studies (Green & Wallat, 1981; Green & Meyer, 1991; Kelly & Crawford, 1996, 1997; Kelly & Chen, 1999) and described for this dataset in detail in Kelly, Chen, & Prothero (1999).

In order to systematize the initial findings and to examine common issues across events, we constructed a set of domain analyses. Spradley (1980) defines a cultural domain as ‘‘a category of cultural meaning that includes other smaller categories’’ (p. 88). This analytic strategy was used to identify the patterns and systems of everyday language as used by members of *Geology 4: Oceanography* (Coffey & Atkinson, 1996). Following Emerson, Fretz, and Shaw (1995), we sought to investigate indigenous meanings of this group of instructors and teachers, not as static categories, but rather by examining ‘‘how members of settings invoke those meanings in specific relations and interactions’’ (p. 28) through these domain analyses.

Through analysis of the event maps (like that portrayed in Figure 3), through multiple viewings of the videotape record, and through analysis of the written ‘‘laboratory manual’’ (cultural artifact), we identified and constructed nine cultural domains. In each instance, we attempted to use folk terms in order to capture as best as possible the indigenous meaning of the participants. For the purposes of cross-referencing and cataloguing, we noted the speaker(s), date, and time on the compilation tape. This allowed us to review the original data and make comparisons across instances. This approach is consistent with critical issues for microanalysis of interaction identified by Erickson (1992): identification of the full range of variation and establishment of the typicality of each instance across the range of diversity.

After completing the domain analyses, we grouped the domains into two broader categories: those focused on constitutive practices associated with writing in science and those concerning contextual and societal dimensions of writing as a scientific practice. Four domains were included as being concerned with writing in science: ways to write in science, ways to distinguish scientific and technical writing (from other forms of writing), reasons for writing as a scientific practice, and ways to distinguish observation and interpretation in science. Five domains were grouped as concerned with contextual and societal dimensions of writing as a scientific practice: kinds of scientific practices identified by the social mediators, characteristics of doing the work of scientists, kinds of scientific norms (and counter norms) identified by the social mediators, kinds of social, political, and economic ramifications of science, and attributes of socially responsible use of science/scientific knowledge. The two broad categories were not entirely mutually exclusive; scientists are members of society and often need to tailor their writing for other than epistemic reasons when interacting with other members of society. The constitutive practices associated with writing in science are influenced by contextual and societal dimensions of writing (e.g., requests for funding are tailored to funders’ needs, but often require substantial evidential support of relevant knowledge). The cultural domains can be summarized as follows:

Domain categorical summary:

Domains concerning practices constitutive of writing in science:

- ways to write in science
- ways to distinguish scientific and technical writing
- reasons for writing as a scientific practice
- ways to distinguish observation and interpretation in science

Domains concerning contextual and societal dimensions of writing as a scientific practice:

kinds of scientific practices identified by the social mediators
characteristics of doing the work of scientists
kinds of scientific norms (and counter norms) identified by the social mediators
kinds of social, political, and economic ramifications of science
attributes of socially responsible use of science/scientific knowledge

Results: Identification and Description of Cultural Themes

As class members participated in common activities and oriented to the task of writing the "technical paper," they came to define sets of beliefs and assumptions about science, scientists, and the work of doing science, including the writing of science. These activities led the course instructors and students to make public a set of assertions about how science was construed in this course. Through their actions, including the spoken and written discourses of science, the participants established patterns in the ways they went about accomplishing the work of defining *Geology 4: Oceanography.* We reviewed these recurrent patterns leading to the identification of two central cultural themes.

Before presenting our cultural themes, we digress to a brief discussion of the nature of claims in cultural inquiry. We present this discussion to illustrate how our cultural themes were identified and how they can be understood as the results of our study. According to Heap (1995) claims of cultural studies (including interactive sociolinguistics and ethnomethodology, disciplines contributing to our perspective) should not be conceived of as empirical generalizations, but rather should be thought of as unfolding the nature of activities and related conceptual phenomena. The task of the analyst in cultural inquiry is "to produce a culturally warranted description of the captured events as the basis for generating claims about the normative organization of the activities that the data are taken to exemplify" (p. 286). Thus, he argues that cultural science inquiries "tell us what we know, but did not know we knew" (p. 284). Geertz (1973) holds a similar perspective about anthropological studies. He argues that theoretical contributions occur through specific studies of particular actors, in a particular time and place. With regards to anthropological inquiry, Geertz states that "Studies do build on other studies, not in the sense that they take up where others leave off, but in the sense that, better informed and conceptualized, they plunge more deeply into the same things" (p. 24). Thus, in our work, we identified cultural themes based on our empirical study and specified the cultural practices framing writing activities in a particular (scientific) context. The empirical examples supporting our two cultural themes provide descriptions of the situated production of talk about structuring text, using inscriptions, making reference, offering interpretations, and demarcating science. These examples provide a specification of the epistemic activities (Lynch, 1992)—descriptions absent from previous research on writing in science education (Rivard, 1994; Keys, et al. 1999; Prain & Hand, 1999).

Our two cultural themes center on the mediational role (Kelly & Green, 1998) the instructors played in portraying the practices of science and writing to the students. The first cultural theme can be stated as: *Writing in science is shaped by a community's procedures, practices, and norms. Communication concerning these procedures, practices, and norms defines what counts as writing in science and thus constitutes a situated view of disciplinary knowledge*. Across events of the course and as represented in the cultural domains, there was evidence of the discursive work necessary to construct the writing of science in particular ways. Some of these discussions explicitly referenced ways of writing in science and related these writing practices to community norms.

The first example of how written knowledge is shaped by a community's procedures, practices, and norms concerns the specifics of text construction. Analysis of the students' laboratory manual written by the course professor identified how the students were given a template with various sections, each with an accompanying description about what would count as an instance of ''introduction,'' or ''observation,'' etc. The format of a technical paper was presented in the course laboratory manual and was to include sections labeled: abstract, introduction, methods, observations, interpretations, conclusions, figures and captions, references.[2] This text structure was suggested not only in the written instructions to students, but also in class discussions concerning writing. Karen,[3] one of the teaching assistants, compared science writing to ''English major type style'' (Figure 2, analytic episode #3, Oct. 13) and in another segment asked the students to ''compare what is the differences between say an English paper writing you know or a like you're making short story (or something) between scientific writing. What are the differences'' (Figure 2, analytic episode #1, Oct. 12). Later in the transcript, Karen explained her view that scientific writing required adherence to a specific format, prepared for a specific audience. The format of the students' ''technical paper'' was the subject of a class discussion for Karen and her students on Oct. 27 (Figure 2, analytic episode 14, Oct. 27). Throughout the discussions of text structure, the use of data representations were noted as important.

Students were instructed to use diagrams, figures, and other data representations (i.e., inscriptions, Roth & McGinn, 1998) as evidence for their scientific argument. In addition to the textual information about text structure and how the uses of inscriptions should be incorporated, each of the instructors (course professor, Bill P., and teaching assistants, Karen and Earl) spoke of ways of using inscriptions in scientific writing. Consider the following example (Figure 2, analytic episode #5, Oct. 17). In this episode Earl was answering students' questions during a laboratory session. He was showing the class a 2 by 3 foot inscription (seafloor depth chart) on white paper, pinned to the blackboard on the wall in front of the class. He began by explaining that ''this is what geologists do'' and how the students will be asked to carry out similar task in their writing assignment.

Speaker	Transcribed talk in message units[4]	Some relevant gestures
Earl:	this is what geologists do	*pointing to inscription*
	these are ship track lines	
	where a ship has gone along	*still pointing to inscription, faces*
	the sea floor with a sonar beam behind it	*audience*
	and if	*facing inscription*
	you think the colors	

[2] An alert reader will notice that the general structure of this educational research paper, following the conventions of the American Psychological Association (APA) publication manual, varies only slightly from the scientific technical paper described to the students in their laboratory manual. For a review of the epistemological orientation of the APA manual, see Bazerman (1988).

[3] Pseudonyms (Karen, Earl) were used for the graduate student teaching assistants.

[4] Classroom discourse was transcribed at the level of message units (Green & Wallat, 1981; Kelly & Crawford, 1996), defined by boundaries of utterances or social action, and identified *post hoc* by cues to contextualization (Gumperz, 1992). We used = to show conversational overlap, () to show words for which we are uncertain, and x to show each unintelligible syllable in a series. The dialogue of Earl with his students is transcribed with one message unit per line. For brevity sake, all subsequent transcripts separate message units by a slash (/).

Speaker	Transcribed talk in message units[4]	Some relevant gestures
	represent elevations	*facing audience*
	like you're plotting out	
	blue is dark	*pointing to specific feature of*
	there's deep	*inscription*
	the red is a	
	is higher	
	the ship went along a track here	*picking up chalk*
	kind of went from low	*drawing sketch (profile matching*
	a little bit higher	*talk) on blackboard*
	back down	
	and lower	
	and that happened	*facing audience*
	all along these tracks	*pointing back to inscription*
	this a track along a mid-ocean ridge	*facing audience, gesturing with*
	where you go high	*hands on front of body*
	and you go low	
	where there's	*putting hands together in "V" shape*
	what they call a rift-valley	
	in the middle	
Student:	purple really deep?	
Earl	the purple is really really deep	*pointing to specific feature of*
	what might the purple be?	*inscription*
Student:	[inaudible]	
Earl:	a transform fault	*facing audience*
	so (pause)	
	that's a good observation	*placing hand on inscription, facing*
	but this is really	*audience*
	what	
	the oceanographers do	
	they try and find the features	*facing audience*
	by just doing it	
	and you're	
	doing a very simplified version of that	
	so it's a good exercise	
	to get an idea of	
	of how these things	*looking down to papers on table*
	are done	

Earl gave some general background about the inscription (ship track lines), how it was made (from sonar tracking) and then began to discuss the representational features of the inscription (specifically, the use of lines and colors to represent various ocean depths). As he discussed the lines on the inscription, he drew with chalk a representation of his interpretation of the inscribed lines (profile plot), and then offered a geological interpretation of the feature (rift-valley). A student queried about the purple color, suggesting it was "really deep" and subsequently answered Earl's questions about what feature was depicted by the purple lines. Although the student's response was inaudible for our camera microphone, Earl responded as if the student answered in an appropriate way. Earl then noted that this was a ‘‘good observation’’ and related the specifics of the geological work to the students’ writing assignment as the students will be doing a ‘‘simplified version’’ of ‘‘what oceanographers do.’’ Thus, in this example, Earl drew from his experience as a scientist to explain scientific practices (interpreting inscriptions) and identified how such practices are central to the students’ writing assignment.

The second illustrative example of the first theme concerns issues of norms for justifying and referencing knowledge in science. Scientific writing was presented as requiring justification and citation. These conventions were portrayed as essential elements to writing science. In the following episode (Figure 2, analytic episode #7, Oct. 20) Karen explained to the students the importance of using citations in their writing:

Speaker	Transcribed talk in message units
Karen	if you’re citing works/you’re citing/a book/journal/a videotape/computers/you wanna/you wanna cite that work/meaning/giving credit/cause you need to give credit to/somebody/for/who’d compiled this information/or wrote this paper/or book/kay?/uh/it’s very important for you to do that/and I hope it’s/in the section/on writing your/midterm paper

Karen proceeded to note the types of sources students were expected to cite: computer CD-ROM database, course textbook, plate tectonics video viewed in class, and library books. The following week (Figure 2, analytic episode #15, Oct. 27) the issue of citation came up again in response to a student question concerning the MLA (Modern Language Association) handbook. Karen explained to her students, ‘‘make sure you do cite all your references. If you take information from your oceanography text, or these [holds up nearby books] . . . Make sure you cite them in the appropriate form.’’ In this case the ‘‘appropriate form’’ was not the MLA handbook, but the conventions described in the course laboratory manual. The use of citation to document evidence and give credit to other sources came up often in the discussions about writing illustrating that the course instructors expected the students’ written work to conform to community practices and norms.

As a final example illustrating this cultural theme, we turn to the instructors’ distinctions between observation and interpretation. In the description of technical writing presented in the laboratory manual and in eight different videotaped episodes sampled for analysis, the course instructors drew distinctions between observation and interpretation. Observations were portrayed as the ‘‘raw input’’ and ‘‘just the facts’’ in the laboratory manual. Observations were explained as being generally quantitative in nature; including details such as lengths, directions and geological features; and what ‘‘everyone would agree on’’ (cf. Quine, 1969). Interpretations were portrayed as more personal, as derivative of observations, as explaining observations, and as supported by observations. The distinction between observations and interpretations was central to the task of writing of technical papers. The data representations such as the elevation and earthquake cross-section plots depicted in Figure 1 were to be used by students to make relevant observations, given their research questions. To introduce the practice of writing observations, the first class assignment involved recording observations at a local beach.

In framing this observation exercise in the laboratory manual, the course professor made comparisons with a courtroom trial. The comparisons served to show how, much like in a courtroom, the students were to ‘‘paint a big picture’’ and support this with the presentation of evidence. These comparisons framed writing observations in science as an activity of persuasion, rather than a telling of indubitable facts. Karen described the same assignment of observations at the beach as the ‘‘different way’’ her students would need to look in order to engage in a scientific observation (Figure 2, analytic episode #2, Oct. 12).

Speaker	Transcribed talk in message units
Karen	getting down/to the beach/and/looking/at the beach/in a different way/than you usually look/at the beach/usually you/go on the beach/ you're going down to/you know/surf or/swim/or lay on the beach/or (xx)/whatever else/you do (xxx)/you know you just go down there/to do other things (*emphasis on the word, ''other'')*/you don't actually go down/to look at the kelp/and (xxx)/the shape of the beach/and the wave/I mean you don't/usually/go down/to look at those things/specifically

In this case, Karen framed the pedagogical activity as one involving ‘‘looking at the beach in a different way’’ and contrasted this form of observation with other activities that they might typically do at the beach. She signaled to the students that observation in oceanography meant looking at things they typically see differently and specifically. Discussions about ways of observing and what counts as an ‘‘observation’’ became a patterned practice of the students and instructors, and its distinction from ‘‘interpretation’’ an important element constitutive of scientific writing from their point of view. Consider the following example of an exchange between Earl and a student regarding use of observations and interpretations (Figure 2, analytic episode #4, Oct. 17). In this case, students were instructed to get into groups of 3–4 and to read each other's features, and to identify ‘‘descriptions’’ and ‘‘interpretations’’ for approximately 10 min. Earl circulated around the room, reading some of these features, and choosing a few to read aloud.

Speaker	Transcribed talk in message units
Earl	''it is a/small round island/surrounded by a/flat plane'/'it is possibly/a em/volc/a volcano'/what's different fr/with that one/from everybody else's?
Student	[inaudible]
Earl	what?
Student	[inaudible]
Earl	I didn't/interpret/the water/at all
Student	you're saying what/you're ki/you're making a suggestion/of (water)
Earl	yeah/I'm making an/interpretation/I said an islands/right?/I/it's a very short thing/I could've said/more details/about why/when you say 'island'/you imagine what?
Student	water surrounded
Earl	wa/surrounded by water/and then I made an interpretation of possibly a volcano

In this case, the naming of the land mass as a volcano was considered an ‘‘interpretation;’’ however, it is hard to know from the classroom discourse how such distinctions were being made. Furthermore, whether the ‘‘round island’’ was considered a description, or an interpretation, remained ambiguous. As was often the case, Earl invoked the laboratory manual as a reference for the students.

Speaker	Transcribed talk in message units
Earl	remember/when you're doing this/part of your/midterm project/was/is listed on page 35 of your lab manuals/is/to do some interpretation/doesn't always have to be/perfect and correct/but you have to/present data/and interpret it

The cited page (35) of laboratory manual described the students' assignment. However, six pages before the issue of interpretation was discussed:

> *Interpretation:*
> Here is where you take your individual observations and use your experience, insight, and knowledge to explain them. The physical mechanisms that are responsible for the observations should be discussed. The interpretation is often called a "model" of the process. It is yours, and is not necessary [necessarily] representative of reality. *Each interpretation must be backed up by observations*. (emphasis in original, p. 29)

These examples demonstrate how teaching practices (e.g., invoking and describing ways of writing) reflect epistemological positions (e.g., evidence is constituted by use of inscriptions). While this theme focused primarily on issues specific to writing, the second theme expands to include relevant contextual information for writing in science.

The second cultural theme constructed through social mediators' portrayals of science can be stated as: *Writing in science is a situated practice that requires an understanding of the reasons, uses, and limitations of written knowledge*. In order to present ways of writing science, the instructors needed to talk about writing in science through recounting personal experiences, exemplars of scientific practice, and descriptions of community practices not directly related to writing. We present three examples of spoken and written discourse that support the identification of this theme.

The first example concerns the broader contextual information used by the instructors to introduce, motivate, and describe writing in science. In this case, like the others that follow, the conversation was not narrowly focused on writing, but rather on ways that writing was part of science and ways that science interacted with other parts of society. In describing the scientific paper assignment, the professor presented certain literacy practices of oceanography as a discipline including question-posing and its relationship to explanation. This description is presented as an event map in Figure 3 (cross-referenced in Figure 2, analytic episode #8, Oct. 23). He explained that science is a struggle (lines 106–107), the difficulties he has faced doing fieldwork (lines 108–112), and that students should not feel alone or dumb if they do not understand right away (lines 113–114). At time 00:02:51 he began describing the importance of identifying and explaining a (scientific) problem. He suggested that "Part of doing science is to figure out kinda (winnow) out what can I explain and what can't I explain" (lines 121–123). In this case the professor offered insight into the practices that constitute doing science from his perspective. He continued, "What's an interesting problem or what's an interesting thing to explain or what uh you know when when a scientist does research, one of the talents you have or has to be developed is knowing first off what's an interesting problem to study" (lines 123–126). Thus, in order to write science in the ways suggested, students needed to understand how inquiry begins with properly posed questions (i.e., those that can be explained).

In addition to offering views about common practices of explanation, students were offered reasons why writing is important in science and why learning to write scientifically is useful. For example, in the lecture of October 25 the course professor noted how writing was central in efforts to persuade agencies and individuals of the importance of one's scientific research, suggesting that "You know you really think a lot of how to communicate your ideas when you're asking for money." In these examples, the professor helped shape an epistemology of his discipline by drawing from his personal experience as a scientist and offering suggestions about how to think about doing science. Thus, the negotiations with state funding agencies described by Mukerji's (1989) study of the field of oceanography were evident in the ways the discipline of oceanography was portrayed to students.

The second illustrative example comes from the course laboratory manual. The ethnographic analysis revealed that the laboratory manual was an important text for the students as it was referenced often in the instructors' discourse. Much like the analysis of the spoken discourse, this written document served as a basis for analysis of community practices (Spradley, 1980). We took note of emergent topics and discourse patterns in the manual that concerned writing in science. One example of this is the first assignment, entitled, "Lab section #1: Scientific writing and communication" (this is the beach observation assignment in which students made observations at a local beach and were subsequently asked to review each other's writing before making changes to their own writing). A sample of the text from this section of the manual is presented in Figure 4. For analytical purposes, line numbers, underlining, and annotations were added to the instructor's text. Jottings and short phrases in the "researchers' comments" column served to identify issues across texts. For example, the sentence beginning on line 303 "Real science involves dealing with messy, inconsistent data, figuring out the best explanation from a choice of competing and sometimes conflicting possibilities, and arguing with other researchers who may prefer completely different interpretations of the same data" was noted as an explanation about "doing science" and as the identification of a scientific practice. This description of "real science" is consistent with the pattern of situating science in broader societal issues, including global warming and the "conflicting opinions among respected climate scientists" (lines 311–312). The agonistic struggles of scientific argumentation are noted as well: "Researchers present their best data and interpretations at professional meetings and in publications, then let their colleagues offer their rebuttals or critical evaluations" (lines 316–318).

Thus while the ostensive lesson was oriented to writing in science (i.e., understanding how to write an observation), issues concerning the inquiry processes, conflicts, and critique were introduced as central to the writing processes. These issues point to the need for authors to consider the views and position of possible readers and how their texts can be shaped by community practices. This analysis of the language of the laboratory manual contributed to the analytic inferences about the positioning of the discipline of oceanography. As in the other cases, this example demonstrates how what counts as the disciplinary knowledge was framed through the presentation of disciplinary practices and interactionally accomplished through discourse (i.e., writer–text–reader).

The final example of the contextual and societal influences on uses of science concerned citizen responsibility for reading, understanding, and using scientific knowledge in responsible ways. This was manifest in discussions of the issues of expertise, point of view, audience, and limits to knowledge. Although the oceanography instructors described science as grounded in evidence as opposed to unsupported beliefs, they were careful not to canonize science and scientists. The students were asked to consider multiple points of view, to be suspicious of unsupported arguments from any source, to identify sources of information and authors' points of view, and to be skeptical of any one person's position, including the course professor. This was evident across the instructors.

Text from Laboratory manual	researchers' comments
This lab starts you on a sequence of lab and class exercises that are designed to give you a realistic research experience. I want you to have the experience of thinking like a scientist. To the student, science seems like a lot of textbook explanation. Real science involves dealing with messy, inconsistent data, figuring out the best explanation from a	doing science
choice of competing and sometimes conflicting possibilities, and arguing with other researchers who may prefer completely different interpretations of the same data. There are many examples of long accepted interpretations that are revised after many years. The theory of plate tectonics is a good example. Wegener first proposed that the continents were once together in the 1930's. Yet, it took 30 more years before earth scientists became convinced he was right. The theory of evolution is a good example of	scientific practices
a subject where science and politics collide. More recently, there have been conflicting opinions among respected climate scientists about whether global warming has actually occurred during this century. Popular talk show hosts have even gotten into the act, using the fact that scientists disagree, to argue that scientists don't know what they're talking about. Unfortunately, this kind of reaction displays a fundamental ignorance of	social responsibility and science
how science works. Researchers present their best data and interpretations at professional meetings and in publications, then let their colleagues offer their rebuttals or critical evaluations. It is through this process that we hope to ultimately arrive at the best possible understanding of the earth and its processes. Yet, we always realize that new data or new viewpoints may cause us to revise our ideas.	scientific practices
You must learn to tell the difference between good and bad science. This is not easy. It is important to listen to alternative views. In many instances, a particular point of view is	social responsibility
represented by someone with a "Dr." before his/her name, yet he/she has not done actual research within the field he/she is discussing and has not published in peer-reviewed publications. Those who are familiar with the research process become very skeptical of claims that astonishing or controversial results are being "suppressed" by a science	norms in science communities
establishment. Scientists LOVE to poke holes in each other' work!	scientific practice

Figure 4. Artifact analysis of text from "Lab section #1: Scientific Writing and Communication." Shown is the actual text excerpt from the laboratory manual in the middle column. The line numbers were added for presentation purposes. The researchers' comments are the product of multiple iterations and reformulations of analytic terms that became markers for the domain analyses.

In the following example the course professor, Bill, was comparing the status of claims made by research scientists and a famous radio talk show host concerning scientific evidence for global warming, in particular as related to the Mount Pinatubo volcanic eruption (Figure 2, analytic episode #19, Nov. 15). After reading excerpts from *The Way Things Ought to Be* (Limbaugh, 1992)—complete with the insinuative language and strength of conviction indicative of its author—Bill stated that the scientific community had multiple voices and differences of opinion, citing an article published in the journal *Science* (Minnis, et al., 1993). The contrast was not to show differences in the inherent validity of the respective assertions (i.e., scientists got it correct, Limbaugh got it wrong), rather, the example demonstrated the differences in the critical stance of the observers: scientists consider evidence in light of a multitude of factors recognizing the limitations of their interpretations, radio talk show hosts less so. These differences were suggested to be evidenced in the writing of scientific texts. While scientists were portrayed as having some evidence for global warming, it was suggested that other scientists had different interpretations. Bill suggested further that his position should similarly be taken as just one on many possible:

Speaker	Transcribed talk in message units
Bill (prof.)	and that's why I say/there's too much information/in the world/wer-we're information overloaded/and so/what we do/is we come to people/to condense information/just like you're doing it right now/in class/I'm giving you/a certain viewpoint/of information/and/what I'd like to teach you/uh/if you come away with anything/from this class/is/recognize/that I have a viewpoint/and/don't trust it/find other people

Karen similarly suggested that students be skeptical about what they read in science. In this case, Karen and her students were reviewing an article about global warming (Figure 2, analytic episode #20, Nov. 17).

Speaker	Transcribed talk in message units
Karen	remember when we were/dealing with /both natural/and then/artificial/sources/of/ gases/whether they be/greenhouse gases/or/particles in aerosols/which can/you know/reflect/um solar radiation/you have to be careful/when/you/read about these things/it makes you/really understand/what's going on with these particles/most natural gases and particles/have very short residence time/in the atmosphere/as opposed to what we're putting out now/in our factories/et cetera/which can be/in atmosphere/on the order of/centuries we believe/okay/so/um/you really have to pay attention/when you're reading about/things/and you have to be careful with what people say/like Rush Limbaugh/if you're at all curious/um/if you look up on like/volcanoes and stuff/you can find what he talked about Mount (Pinatubo)/it was really retarded/um/a lot of misinformation

Karen pointed to reading for specific information (i.e., both natural and artificial sources of gases), noting the relevant properties (i.e., reflecting solar radiation, residence time) and how these properties speak to the issue in question. As was often the case, contrast was used to show how scientific argument varies from other forms of argument.

Earl provided a final example illustrative of how point of view was to be considered by students when reading science (Figure 2, analytic episode #22, Nov. 28). In this case, Earl and his students are reviewing claims made in an article concerning overfishing and fishing rights [“Fishing Down the Food Chain” in *The Amicus Journal* (Russell, 1995)]. They were discussing industrial and governmental interests in exploiting and protecting fish populations. Earl began by posing a question leading to a discussion of point of view:

Speaker	Transcribed talk in message units
Earl	first question/where is this paper from?
Student	National Resources Defense Council
Earl	I like that/National Resources Defense Council/who are they?/anybody got any idea?
Student	*inaudible response*
Earl	yeah/that’s the/Amicus Journal/but the people who publish it/is the National Resources Defense Council/so
Student	*Student asks question off-microphone*
Earl	well/what’s COLAB/in this area?/colational/coalition of agriculture and labor/it’s the/business entity/it sounds nice/but
Student:	Is it just a bureaucracy?
Earl	I’m not sure who they are/but I/I fi/I/I think/you kinda have to know/who writes your articles/before you read them/so you can kinda/extract the information/out of/the article/that you think is/relevant/and/you know/cause part of the thing is/is/how do you feel/about the article/after you’ve/read it

Earl emphasized that the students needed to consider the authors and their political alliances when reading their scientific reports—a point often missed by textbook authors who present the canonical science content, independent of authors’ points of view. Thus, in sum, the picture painted of scientists and the ways they practice their craft was a complex one without clear cut answers. The teaching of scientific writing included ways of reading science and explicit discussion of limitations of knowledge.

Discussion

Our ethnography provided a means for us to document how the epistemology of oceanography was constructed, portrayed, and construed through spoken and written discourse in an introductory university course. The details of the mundane everyday activities of teaching and learning about writing in science provided many examples of how epistemological issues run through many educational events. This course may have been unique in its explicit emphasis on knowledge use and display by students and teachers, rather than display by teachers and assumed appropriation by students. Nevertheless, the emphasis on writing as a scientific practice and its relation to values in science provided fertile ground for exploration of education and epistemology. Three issues concerning epistemology and science emerge from the analyses of these classes: the situationally specific uses of discourse related to learning disciplinary practices, the positioning of science as disciplinary knowledge, and the distinction of science from other ways of knowing. Drawing from this discussion of epistemology and disciplinary knowledge, we draw implications for college science teaching.

Our first discussion point concerns the situationally specific uses of discourse in science. As with the members aboard the oceanographic vessel studied by Goodwin (1995), these scientists (acting as instructors of oceanography) used meanings defined by an endogenous community of practitioners. For example, as ethnographers, the case of observation/interpretation distinctions represents an example of how insider knowledge (of scientists) can be obscure for newcomers (students) and how it is often learned through practice rather than stipulative definitions (Lave & Wenger, 1991). At first pass, from an outsider's point of view, a clear separation of observation and interpretation may seem difficult to make in any definitive manner, especially given arguments from philosophy of language about meaning in use and its connections to different purposes and ''forms of life'' (Wittgenstein, 1958). All observations are (at least) somewhat interpretative. Yet, from our ethnographic point of view, the scientists used ''observation'' in particular ways to count as a particular discourse practice. Thus, in order to do science as our participating scientists sought to do science, students needed to understand the indigenous meaning of observation and know how to use it appropriately. Similarly, the scientists portrayed interpretation as differing from observation and marked this difference as socially significant. Therefore, part of the process of coming to know how to think like an oceanographer (in this case) was to understand how scientists made such distinctions and subsequently how to write these into a technical paper with scientific data. In this way, the disciplinary practice of writing a scientific argument depended on situationally specific uses of discourse that came to define ''observation'' in particular ways. The centrality of this distinction to the writing assignment left the students with the task of choosing just what features of the CD-ROM data representations could count as a valid observation. They then needed to use these observations rhetorically to construct an argument.

Our second discussion point concerns how the discourse processes of this university oceanography course positioned science and thus provided the students with particular views about science. Through discussions centered on writing in science, the course participants framed an epistemology of their discipline as one that considered the contextual nature of science (e.g., issues of funding, audience, economic and political ramifications), expertise (e.g., considering speakers' roles in framing arguments), evidence (e.g., supporting conclusions with an evidential base), and responsibility (e.g., citizens' role in the use and understanding of scientific knowledge). This is an important dimension for university (and other) science teaching: The discourse processes, both spoken and written, provide a means for communicating the substantive content of science as well as communicating messages about science (Carlsen, 1991; Kelly & Crawford, 1997; Cunningham & Helms, 1998). The importance of this dimension of science teaching can be illustrated through comparisons with other discourse analytic studies showing science to be portrayed as unassailable facts and laws of nature (Cochran, 1997; Moje, 1997). For example, through ethnographic analysis of a university organic chemistry course, Cochran (1997) found that reliance on lectures and texts as sources of information led to a kind of school science that promoted ways of succeeding in the course over ways of understanding the principled knowledge of the discipline. Science, in this case organic chemistry, was positioned as a discipline comprising content and product, with verifiable, objective answers. In contrast to this study by Cochran, the students in this university science course were required to engage in a central scientific practice: formulating an argument based on datasets. The data provided by the CD-ROM was not limited to a prescribed body of information (i.e., that relevant to a particular curricular goal). Rather, students were given the opportunity to face the same sort of struggles facing scientists in constructing a scientific text.

The third discussion point concerns differentiating science from other ways of knowing. The instructors made use of contrast (technical writing vs. fiction, scientists vs. radio personalities) to communicate their views of scientific writing and of science more generally. This poses a potential problem. The instructors specifically spoke of the importance of evidence and of grounding science in facts, yet they were careful to note the importance of reasonable skepticism. They sought to teach science as grounded, but not absolute. To err in one direction might suggest a scientistic view (Duschl, 1988), whereas to err in the other direction may cause students to inappropriately dismiss science as just another biased view. A grounded, but not absolute, view of science is consistent with (certain) science studies and worthy of elaboration.

Science is not easily separated from other systematic ways of knowing. For example, identification of definitive demarcation criteria for science eluded the positivists—science could not be shown to be based exclusively on empirical content absent of metaphysics (in the positivist pejorative sense). Developments in science studies, particularly the strong theory-dependence of scientific methods identified in philosophy (e.g., Boyd, 1985; Kuhn, 1996;), the problems of experimentation identified in sociology of science (e.g., Collins, 1985), and the embedded nature measurement identified in anthropology of science (Knorr-Cetina, 1999), make clear distinctions between science and other ways of knowing difficult and potentially ideological (Toulmin, 1982; Watson-Verran, and Turnbull, 1995). Yet, taken across multiple instances, scientific communities produce knowledge that is more instrumentally reliable (i.e., yielding accurate predictions about observable phenomena, see Boyd, 1991) than just anyone's personal opinion. Science teachers are thus faced with the task of socializing students to particular practices, of enforcing certain criteria for uses of evidence, and of identifying and acknowledging the limits to scientific knowledge. All this is to be accomplished while considering students' ideas, valuing their point of view, and respecting them as persons (Strike & Soltis, 1992). To teach anything that might reasonably count as science, that is, to provide opportunities for students to understand the communal knowledge and cultural practices necessary to act in socially appropriate ways, educators need to make certain epistemic distinctions, lest students view just any idea from a popular charlatan as epistemologically secure and as relatively well-confirmed scientific theories. Our argument is that the epistemological position of science in the discourse of education can be better understood through naturalistic studies that document the ways science is portrayed in school and provide examples from which normative goals can be set and reframed. Thus, to have faith in the instrumental reliability of scientific knowledge is not to adhere necessarily to a discourse of hegemony; rather it is to assess the relative contribution science can make to the pragmatic needs of members of society given varied purposes (Rorty, 1991).

Our discussion of epistemological issues associated with the teaching of writing in science points to implications for college science teaching. We present three implications consistent with recent reform initiatives in science education (American Association for the Advancement of Science, 1993; National Research Council, 1996). Our first implication concerns the use of technology in support of educational goals (i.e., the geological datasets in the "Our dynamic planet" CD-ROM). Computer technology was used to give students access to real datasets so that they could frame arguments in support of scientific theory. The particular teaching approach demonstrated that, carefully arranged, technology can be used to serve multiple goals of college science teaching including helping students understand the nature of scientific investigation and argument, the processes of constructing an argument, and the use of scientific theory and constructs. In this way, the content of science was not merely theory, laws, or facts, but rather issues of content of science included understanding of scientific knowledge through its use.

Engaging students in rhetorical aspects of science in this manner points to our second implication for college science teaching. The focus on using real but ambiguous datasets to formulate arguments and the discussions of scientific practices related to science writing, demonstrate how multiple goals of learning of and about science can be understood as mutually supportive. In a study of argumentation in science education, Duschl, Ellenbogen, & Erduran (1999) noted how the use of argumentation can serve three central educational goals: conceptual goals, epistemic goals, and communication and representation goals. In this university course, geological knowledge was centrally important, but this knowledge was not to be merely absorbed, rather it was to be put to use rhetorically by the students. Communication about scientific knowledge similarly required understandings about the nature of evidence. Thus, conceptual, epistemic, and communication goals were integrated into the instruction.

Third, the teaching of plate tectonics through the use of argument formation presents students with both the scientific knowledge and the ways this knowledge was developed, and thus represents pedagogies advocated by philosophically based educational perspectives (Duschl, 1990). This contrasts significantly with the ‘‘final form’’ presentation of current scientific theory, where the supportive arguments are both separated from content and often relegated to minor roles in the teaching of science. Further study needs to examine the students' use of this technology, in particular how they constructed their arguments with the earth data. An analysis of student's arguments and use of data would provide evidence of the benefits of teaching in this way, particularly through a consideration of the scientific merit of the students' arguments from a normative point of view.

Conclusion

In this paper we have provided examples of how through the study of everyday activities epistemological positions of science are constructed through discourse processes. The presentation of writing in science by instructors of a university oceanography course provided a means to examine how issues of evidence, point of view, expertise, and skepticism, among others, shaped disciplinary knowledge. Our investigation of the epistemological framing of a discipline through the study of the production of a scientific paper follows recent calls for examining teaching and learning practices as related to the nature of science (Lederman, et al., 1998). Studying the situated, mundane activities that come to define disciplinary practices represents one dimension of an empirical study of epistemology (Kelly, Cunningham, & Carlsen, 1998). Studies across educational settings, grade levels, and activities can further specify ways that disciplinary knowledge is invoked, articulated, represented, and communicated to students through teaching practices.

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