21 *Learning to Read Biology: One Student's Rhetorical Development in College*

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At the college level, to become literate is in many ways to learn the patterns of knowing about, and behaving toward, texts within a disciplinary field (Bartholomae, 1985; Berkenkotter, Huckin, and Ackerman, 1988; Bizzell, 1982; Geisler, 1990; Herrington, 1985, 1992). Scholars from a wide variety of subject areas have acknowledged that within their disciplines, texts are best seen not as static, autonomous entities but as forms of dynamic rhetorical action: Authors create texts and readers read texts in a complex of social relationships, motivated by goals sanctioned (or not) by the surrounding culture, to achieve purposes that are always in the broadest sense persuasive. Disciplinary texts, like all texts, are intensely situated, rife with purpose and motive, anchored in myriad ways to the individuals and the cultures that produce them. This is true not only for texts within the humanities and softer social sciences (e.g., see Belsey, 1980; Fish, 1980; Tompkins, 1980, in literary theory; Geertz, 1983, in anthropology; Grice, 1975; Nystrand, 1986, in linguistics; Brown, Collins, and Duguid, 1989; Mishler, 1979, in psychology) but also those within "harder" disciplines such as economics (McCloskey, 1985), physics (Bazerman, 1988), and—more to my purposes here—the life sciences (Gould, 1993; Latour, 1987; Latour and Woolgar, 1979; Myers, 1985, 1991; Selzer, 1993).

Bruno Latour (1987; Latour and Woolgar, 1979), in particular, has been concerned with understanding how scientific facts (codified and reproduced as written texts) come to be seen as freed of the circumstances of their production. His work, along with others' (Bazerman, 1988; Gilbert and Mulkay, 1984; Myers, 1985), has shown scientific activity, and its resultant facts and theory—presented in the form of written texts—to be highly rhetorical and scientists themselves to be motivated and committed agents in this enterprise.[1] A great number of studies of science have focused on discourse—conversations and lab notes as well as conference presentations and formal articles—as both the means of scientific activity and the best way to study the

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scientific enterprise (e.g., Blakeslee, 1992; Gragson and Selzer, 1990; Herndl, Fennell, and Miller, 1991; Winsor, 1989). In short, much of the real work of science is the creation and dissemination of texts, broadly conceived. In addition, other studies of scientific discourse (Fahnestock, 1986; Gilbert and Mulkay, 1984) have suggested that scientists adjust the strength of their claims depending on the audience: Texts meant for scientific insiders hedge and qualify claims, while texts for lay persons and other outsiders strip out such qualifiers, making claims seem more certain and less open to question. Experts within scientific domains, then, draw upon rich representations of discourse as a social and rhetorical act, what Geisler (1991) has called socially configured mental models, as they create and interpret texts and as they judge the validity and usefulness of the information within them.

Learning About Literate Activity in the Sciences

One of the things students of science must become privy to, as part of their disciplinary education, is this rhetorical, contingent nature of written scientific discourse. Science educators at every level have been concerned with fostering students' cognizance of the contexts, conduct, and purposes of science as well as its factual content (Fensham, 1985; Mitman, Mergendoller, Marchman, and Packer, 1987; National Academy of Sciences, 1989). Mitman et al. (1987) have defined the components of "scientific literacy" as not only the mastery of scientific facts and concepts, but an understanding of "the evolving contributions of individual scientists and groups of scientists, . . . the social communities and historical settings in which scientists work" (p. 630) and the place of science within "the broader contexts of human endeavor" (p. 612). In general, these educators have argued that in order to understand, use, and judge scientific content—and, of course, scientific content remains of vital importance to science educators—students need a meta-understanding of the motives of science and scientists and the history of scientific concepts. That is, a rhetorical understanding of the human enterprise of science, as well as the texts that constitute and reflect that enterprise should be bound to the learning of scientific facts.

The educational task of helping students recognize the human nature of scientific activity and rhetorical nature of scientific texts may be part of a larger problem in academic literacy for students: a "myth" of autonomous texts that seems to operate in academic settings at every level. This myth has been well described—and well critiqued—in other contexts by Nystrand (1987), Cazden (1989), Brandt (1990), and Farr (1993). In general, the belief in autonomous texts views written academic texts as discrete, highly explicit, even "timeless" entities functioning without contextual support from author, reader, or culture. Research studies by Applebee (1984), Geisler (1990), Haas and Flower (1988), Hynds (1989), Nelson (1990), and Vipond and Hunt (1984), among others, have suggested that beginning college students approach academic tasks as if they believe that texts are autonomous and context free. Treating texts as if they are autonomous may be facilitated both by

features of academic discourse itself (see Farr, 1993, for a review of linguistic research on academic discourse) and by a culture of schooling that encourages students to see texts primarily as repositories of factual information (Goodlad, 1984). Certainly a number of school reading and writing tasks—in college as well as high school—seem to be predicated on the doctrine of the autonomous text: strict new critical readings of literary works; tests that ask students to recall and reiterate informational content only; textbooks that always seem to be written by nobody and everybody, as if the information embodied in them was beyond human composition, and beyond human question.[2] The educational problem, then, is this: Entering college students may hold an arhetorical or asituational theory of written discourse, a representation or model of discourse that precludes seeing text as motivated activity and authors as purposeful agents, when in fact discourse theorists and scientific educators agree that students would benefit from a more rhetorical model.

Do students' views of academic discourse change over the course of their college careers? Studies of development in the college years such as those by Perry (1970) and by Belenky, Clinchy, Goldberger, and Tarule (1986) have not specifically addressed issues of reading and writing, although I will return in my discussion to their relevance for the case I present here. In an ambitious and extensive set of studies, Haswell (1988a, 1988b, 1991) looked at growth in writing competence through college but did not explicitly address how students view texts or how disciplinary training and literacy instruction interact. This article, then, provides an initial exploration of one student's developing rhetorical understanding of texts. It details a longitudinal study, an extended four-year examination of one student as she progressed during college, focusing primarily on how the student's views of, and interactions with, disciplinary texts changed through her postsecondary education. Although Eliza (a pseudonym) may have tacitly subscribed to the doctrine of autonomous texts early in her college career, by the time she left college she had come to a greater awareness of the rhetorical, contingent nature of both the activities and discourses she participated in within her chosen field, biology.

In order to track Eliza's developing notions of text, I focused primarily on her reading processes and practices, and on the various texts she read, rather than on her writing processes and products. This was done for several reasons. First, studying Eliza's reading allowed me to examine her interactions with a greater number of texts, since she read many more texts than she wrote through the four years. She also read many more types of texts—textbooks, research reports, articles, proposals, lab notes, data sheets—than she wrote, especially in her biology and chemistry courses. In addition, I hypothesized that in her reading practices, Eliza might demonstrate more rhetorical sophistication than she would in her writing, where many more production skills must be managed (Scardamalia, Bereiter, and Goelman, 1982). Indeed, in discussions of her reading, Eliza showed a level of awareness of the activity and agents of discourse that seldom was obvious in the texts she wrote. Finally, while a great number of recent studies (Berkenkotter et al., 1988; Her-

rington, 1985, 1992; McCarthy, 1987; McCarthy and Fishman, 1991; Nelson, 1990) have examined students' writing in academic disciplines, few have expressly looked at how students read specialized texts within the disciplines. . . .

The Subject/Participant

Eliza was one of a group of six randomly selected case study participants that I began to track in their freshman year at a private research university. Eliza grew up in a middle-class family in a large eastern city and attended a large parochial high school near her home. She was the youngest of four children and had a large extended family, with aunts, uncles, and cousins living nearby. Her parents' education ended with high school, as did her two older sisters', while Eliza and her brother completed college. Eliza reported that her parents were "very proud, very supportive" of her during college,[3] both financially and emotionally. Her postsecondary education was partially financed by federal grants and through work-study awards.

Eliza graduated fourteenth out of a class of 450 from her high school, where she was in the upper tracks in English, math, and science. Eliza said she was "brainy" in high school, but "not a bookworm—more like the class nerd." She felt her high-school education was "as good as any," and she was especially full of praise for the math program there—"Sister Elise could teach anyone mathematics." The math club won citywide competitions for three straight years while Eliza was in high school. The curriculum for science classes—one-year-long course for each of four years—consisted mostly of lectures and textbook reading, with a minimal amount of lab work. Students were evaluated almost exclusively through objective tests in these science courses.

Eliza came to college interested in biology and later considered the possibility of pursuing a double major in biology and chemistry before finally deciding (late in her sophomore year) to focus exclusively on biology. As a freshman, she said she was majoring in biology "because I'm pretty good at it," but by the time she graduated, her interest in the subject was much deeper and more committed. During her senior year, she made comments like, "I'm learning to be a scientist," or "I'm going to be a scientist," or even, "I am a scientist." College-level reading and writing were time-consuming for Eliza, as for many of her classmates, but she worked hard at both and was determined to do well. Her final college grade point average was about 3.0.

Setting

The study took place from August 1986, one week after Eliza arrived at college, to April 1990, a few weeks before she graduated with a BS in biology. The setting was a private research university in a medium-sized eastern city. About 6,500 students, one third of whom are graduate students, attend the

university, which is predominantly White. Males outnumber females by a ratio of about three to one among undergraduates.

Interviews took place in my office in a computer development center where I was a part-time consultant. Because Eliza did not identify me with any department from which she was taking classes, I believe she felt free to give honest and detailed descriptions of her teachers, assignments, and course work, and her feelings about them. At the same time, as Patton (1980) has suggested, I wanted Eliza to see me as someone who "spoke her language," that is, as someone who had at least a passing knowledge of the subjects in which she was interested. For the first three semesters, I could use course notes and background knowledge from my own upper-division undergraduate courses in biology to keep informed. Later, I relied on a colleague in chemistry (who had an undergraduate degree in biology) and on some outside reading to help me attain a cursory knowledge of some of the topics Eliza was addressing in reading, writing, and lab work assigned in biology.

Data Sources

Qualitative case study methods were used to track Eliza through her four years of college, and attempts were made to triangulate data sources. Interviews (several each year) were supplemented with the examination of artifacts (texts written and read for classes), reading/writing logs kept by Eliza (freshman and sophomore years), observations by the researcher of classes and reading sessions, and the collection of several read-and-think-aloud protocols (junior and senior years). As is often the case with qualitative research, data sources and methods evolved as the study progressed (see Goetz and LeCompte, 1984, especially chapter 5, Data Collection Strategies). For example, reading/writing logs were discontinued after the sophomore year because Eliza indicated that they were taking an inordinate amount of her study time to complete. At this point, read-and-think-aloud protocols were added (they were used in the junior and senior years only) as an alternative data source that could furnish some of the same kinds of information as the logs. In addition, I terminated my concurrent interviews with Eliza's teachers when she indicated that my talking to her teachers made her uncomfortable. (I did talk with some of these teachers later.) . . .

Longitudinal Narrative

In order to examine—and do justice to—the richness of Eliza's undergraduate educational experience, I constructed a longitudinal narrative drawing on qualitative analysis of data from the sources described above. . . .

The following narrative traces Eliza's interactions with and learning about texts through four years of college. For each of her four college years, I discuss first the kinds of reading tasks in which Eliza engages, drawing primarily on interviews and reading/writing logs. Next I describe Eliza's read-

ing processes and practices, drawing from the read-and-think-aloud protocols, my observations of reading sessions, reading/writing logs, and interviews. The narratives for each year conclude with a longer section, which examines how Eliza's conceptions of the rhetorical nature of discourse and the contingent nature of scientific facts developed. Interviews (particularly the segments identified as revealing views of discourse) were the primary data source for these sections, and they were supplemented with data from reading/writing logs, read-and-think-aloud protocols, and teacher interviews.

Eliza as a Freshman: "The Book Says." As a freshman, Eliza's academic work focused almost exclusively on preparing for tests in her biology, chemistry, and math courses. She also wrote a fairly extensive synthesis of various authors' positions papers in her English class. Her processes consisted of mostly linear reading of textbooks and, for the English class, essays. If she had trouble comprehending, her strategy was usually to reread, and she made extensive use of a highlighter, sometimes marking whole paragraphs with it. She also often took notes, usually verbatim, from her reading. According to statements made in interviews or entries in her reading/writing logs, Eliza's goals for most of her reading were "to learn it," "to understand it," or even "to memorize it." Understanding the book or what "the book says" was paramount at this point in Eliza's college career. Eliza viewed her role as a reader as one of extracting and retaining information, a not unsavvy approach, given the ways that she was held accountable for the reading.

In the reading for her English class, Eliza's goal was slightly different, stated most frequently as "to figure out what they're saying." The curriculum in her English class was built upon a recognition of authors and their claims and positions. Students in the class worked from a common corpus of texts on a single topic—animal experimentation—and produced progressively more difficult written texts based on readings: summary, synthesis, analysis, and original contribution. In addition, the instructor asked students to create visual representations—a path of argumentation, a synthesis tree—to help them visualize the conversation going on among the several authors. (This curriculum is illustrated in Kaufer, Geisler, and Neuwirth, 1989.) Possibly due to the emphasis in this class on authorial conversations, Eliza seemed to view the texts she read for her English class less as a source of information to extract and more of a place in which someone says something. That someone did not usually have an identity (beyond author) nor a motive, although "he" did have a gender: All references to authors used the masculine pronoun, even though some of the texts were written by women. In interviews and reading/writing logs, she stressed the importance of understanding the authors, as she often repeated statements like, "I'm trying to understand what he's saying" and "trying to figure out what he's *really* saying." "Trying to figure out what they're saying" was also stated as a goal in reading/writing logs. Whether due to the different kinds of texts she was reading for this class or to the instructor's emphasis on authorial claims, Eliza seemed to have a clearer sense that the essays were connected to human agents, and she

even had some cognizance that the texts were connected: "He [the teacher] says it's like they're [the authors] having a conversation." However, the authors Eliza discussed often seemed synonymous with the book she described in her reading for other classes, with "the author says" equaling, in effect, "the book says." Nor during this year did she mention authors' motives or intentions, the multiple contexts surrounding the texts she read, or intended readers and their reactions.

As a freshman, then Eliza seemed to have a bifurcated view about texts and authors: On the one hand, she talked as if both the texts for her biology and chemistry class and the information contained in them was unconnected to human agents—"understanding what the book says" or "understanding what it says" were frequently cited goals in the reading/writing logs. In the reading for her subject matter courses, she seemed to operate without a rhetorical frame, accepting the texts she read as autonomous. On the other hand, the curriculum in her English class seemed to be nudging her toward a more sophisticated conception of discourse, with at least some mention of authors and their relationship: Authors "have a conversation" (as in the example above) and "they were bothered by the same things that bothered me."

Two pairs of concepts developed by Belenky et al. (1986) are useful in further examining Eliza's developing theories of knowledge. The notions of received knowledge and procedural knowledge and of separate knowing and connected knowing emerged at various points as Eliza's education progressed. As a freshman, Eliza's epistemological theory seemed to be one of received knowledge, and her role was receiver of that knowledge. Her goals were to learn or understand or memorize what "the book says," or "figure out what he [the author] is really saying." Tellingly, she described how her English teacher would have to accept the claims of her paper if "I can prove it in writing from the book." The book here was the ultimate authority—through which one received knowledge and by which one's own contributions were judged.

Reading as a Sophomore: Eliza Encounters the Research Paper. During her sophomore year, Eliza's reading tasks and reading practices, and the means by which she was evaluated, remained essentially the same. The one major change in her reading, from her point of view at least, was that there was simply a lot more of it. It was Eliza's and her classmates' impression that the department and the college attempted to "scare people away" with the amount of work that was required in the courses that Eliza took during this year. She continued to have hundreds of pages of textbook reading every week, frequent exams, and little discussion in her classes. Eliza did have more lab courses during this year than during the previous one, but these labs required little reading.

Eliza's reading practices showed an increased attention to the procedures of knowing. According to Belenky et al. (1986), procedural knowers are "absorbed in the business of acquiring and applying procedures of obtain-

ing . . . knowledge" (p. 95). As a sophomore, Eliza seemed to view learning as the application of certain procedures: Reading was always done with highlighter in hand, for instance, and her notes (usually almost verbatim) were labeled and organized.

One interesting development during Eliza's sophomore year was the research paper assigned in her cell biology course. The instructor gave the students little direction on the project, assigning a research paper that was to be five or six pages long. In Eliza's words, "We're supposed to pick a topic that interests us, and then just go more in depth with it, go in research books and just write about it." The topic was selected from a list of cell structures provided by the instructor. The paper was also to include a section on experimental methods, but this section involved little reading and Eliza seemed to spend little time on it. According to Eliza, the goal was to write "a paper that tells what's known about our topic," and she did not attempt to develop a thesis or controlling idea, nor did she even see a need for one (cf. Stotsky, 1991).

Eliza located articles by using a reference list provided in the back of her cell biology textbook, and she ended up reading three of these articles and taking notes on them. Although the three articles varied in their relevance and usefulness for Eliza's paper, she noted in her log that the reading and note taking was easy. In her log she said, "My goal is to prepare a general knowledge of my topic, using papers listed in the book." Activities noted in her log included "reading, taking notes," "writing down some relevant facts," and "pulling out" information. For Eliza, writing the research paper seemed a matter of applying the appropriate procedure (Belenky et al., 1986): If one finds the relevant articles and pulls out the appropriate facts, then one "can make a research paper [oneself]." Eliza talked as if a research paper was a simple task, and in fact, for her it was: She and many of her classmates wrote their papers together in the library the night before the papers were due. The following excerpt shows the almost casual way that Eliza treated this assignment:

> I just took brief little notes, like types of drugs, or something about the experiment. And basically just sat down later on and just wrote the paper from there. I figure it was the next night. [Consults reading/writing log in front of her.] Yeah. Basically that's what everybody did, they waited—they just went and read the articles the night before, and got in groups or something and wrote it, you know, to help each other out.

Eliza's strategy for the research paper resembled what Nelson (1990) identified as a "low investment" strategy in students performing similar tasks: She waited until the last minute and then relied on a minimum number of sources, sources selected mainly because they were easy to locate and convenient. But my knowledge of Eliza even at this early point in her college career led me to believe that she was in fact quite committed and "invested" in her education, her field of study, and her future as a biologist. She approached classes with a real seriousness, and she spent a great deal of time

and effort preparing for tests in her chemistry and cell biology and genetics courses. I believe Eliza's limited, even cavalier, approach to the research paper assignment was due to the fact that it simply did not occur to her that reading articles and writing a research paper had much at all to do with her goal of becoming a biologist. Tasks like her chemistry lab or genetics exams, or even her math homework, were obviously tied in her mind to the work of biologists, and for these kinds of tasks Eliza had a very high investment approach. Writing a research paper may have seemed to her an exercise that was quite unconnected to the real work of science.

Eliza seemed to view her own research paper and the articles she read as unconnected to the field of biology as she construed it: autonomous information embodied in textbooks, which she was required to learn. This notion is supported by the almost complete lack of reference in her interviews and logs to rhetorical or contextual elements surrounding the texts she read. The attention to authors, which surfaced during her reading for her English class in her freshman year, had disappeared. There was no evidence that she viewed any of the texts she read as the product of an individual author's motives or actions. Nor did she exhibit any cognizance of the texts she read as historically or culturally situated. Even the citation lists in the articles she read were used primarily as a convenient way to find other articles, not as an intertextual system tying separate texts together.

During her sophomore year, Eliza still seemed happy with her rhetorical, asituational approach to reading texts that she viewed primarily as autonomous. Certainly, it was an approach that was well rewarded. She got a good grade on her research paper, and she did well on exams in all of her classes. If Eliza operated without a rhetorical frame for much of her reading and writing during her sophomore year, there was nothing in her school environment to signal weakness or problems with that approach.

Eliza's Junior Year: Seeing Authors as Scientists. One important change in Eliza's life this year was her new work-study job. Beginning this year, Eliza took a work-study job growing protein mutants in a lab run by one of her professors. Eliza's direct supervisor in this work, a graduate student named Shelly, became an important mentor for her during the junior year and on into the senior year. She described the work this way:

> It [the lab job] gives me a lot of individual attention because I work side by side with Shelly, who's a graduate student in the lab, and like she's—well they gave me a project and when I need help or have problems, she guides me through it. Like an apprentice, I guess. . . . I like it better [than classes] because it's more difficult. Well, not more difficult, exactly, but the nobody knows the end result, like [they would] in my bio lab.

As a reader, Eliza this year seemed much more sophisticated. In contrast to the methodical, linear reading she engaged in earlier, Eliza now exhibited a range of reading strategies—skimming, reading selectively, moving back and forth through texts, reading for different purposes at different times. In

this way, she was beginning to look like the practicing scientists whose reading Bazerman (1985) and Charney (1993) have studied. She also read some texts not solely to glean information but to learn about conventions and structures: "I'm reading this to get an idea of how to set up my own report." She also made a distinction now between "just textbook reading" and reading journal articles, and she predicted (probably accurately) that "in grad school, all I'll read will be journal articles."

The academic tasks that Eliza faced still included a number of exams, although her classes tended to be smaller and some of these exams were what she called "essay exams," which meant that students answered questions in short paragraphs rather than through one word responses or multiple choice. Eliza also had a research paper to do this year in her virology class. But the assignment itself, or Eliza's representation of it, was more specific and complex and connected the research paper to the larger situational and cultural context of virology research. Rather than a goal of "prepar[ing] a general knowledge" of her topic, as in the sophomore year, Eliza's goal was now to "find out what people are doing" with a particular virus, look at "where the technology is going in the future," and to "think up some experiments" to do with the vaccinia (cowpox) virus. Implicit here was the notion that her work on the vaccinia virus would be tied to the work of others, via her text.

In both her reading for this particular research paper and her reading more generally, Eliza exhibited a much greater awareness of the contexts surrounding the texts she read. This was reflected in the greater number of interview segments that dealt with rhetorical concerns. Her first-year attention to authors reemerged in the interviews during the junior year, but in a much more complex way. Whereas the authors she talked about as a freshman were writers only, the authors she talked about now were writers, certainly, but also scientists. She attributed motives to these authors, seeing them as making choices as researchers—"so they're using this as a prototype for the manipulation"—or as agents in an uncertain enterprise—"they're saying they're not sure if this is how it replicates" and "they don't know too much about the actual microbiology of the virus." She showed a cognizance of the activity of the field of virology, claiming that a particularly well-investigated virus is "like a beaten horse—they've studied it so much." When she encountered an article reporting what was to her a particularly esoteric and specialized kind of research, she asked somewhat sardonically, "What kind of people *do* research on this?" Now, texts were not autonomous objects, but manifestations of scientific action and human choices.

At this point, Eliza was also beginning to recognize a historical, situational context surrounding and supporting the texts she read. In one interview, she went on at great length about how she selected articles to read: "First, of course, I see if the titles are relevant . . . but some of them, like from 1979, well, 1979 isn't that far back, but they weren't sure then if what they were seeing was true." Later, she claimed that "some of them were really old, like in the '70s," and were "getting me nowhere," so "I set a limit of like, maybe, 1980 to the present." In general, by her junior year, Eliza had a much

more fleshed-out representation of authors—authors as writers and as scientists, authors with motives and within circumstances—than she did earlier. And texts, the claims they make, and their truth value, were now seen as the product of a particular, historical time.

Reading Contingent Science as a Senior: Increasing Sensitivity to Context. The academic tasks she was required to complete had changed somewhat by Eliza's senior year. She had exams now in only two of her courses, and other assignments included critical presentations of research articles and critiques of others' interpretations of similar articles. She had extensive writing assignments based on reading in two of her classes, but now she did not call these research papers; rather, they were a review article and a model proposal.

Eliza's reading processes and practices also continued to grow in complexity. She now spent a great deal of time and effort going over figures and tables in texts she read, offering by way of explanation: "This is important. Most professors can read just by looking at figures and their legends." She also exhibited a greater awareness of the intertextual nature of discourse; texts were not isolated, but linked. She still used citations to uncover relevant articles, but rather than skimming the citation lists as she did the year before, she now examined how particular sets of articles used and represented the claims of their sources (cf. Latour, 1987), and she claimed that one can often "tell by the title if they build on one another." The claims of another set of articles "are all related, indirectly," she said.

Eliza's attention to the rhetorical elements of discourse—authors, readers, motives, contexts—also exhibited increased sophistication in her senior year. For Eliza, as a senior, not all of an author's claims were equal. While the results section may have been solid, the claims of a discussion may have been more contingent, as illustrated in the following example, where Eliza demonstrated her understanding of scientists' uncertainty and their commitment to theory despite insufficient data and where she used a metaphorical term (handwaving) for how this uncertainty is manifest in written discourse:

> ELIZA: There's a lot of handwaving in the discussion.
>
> CH: What's that?
>
> ELIZA: Handwaving? They're not sure of theory. They sort of have data which suggest it. But they can't come out and say that. . . . You don't know what's happening first. Is it binding here first? Is it binding to an active enzyme? You're not sure.
>
> CH: Do you think they're not sure?
>
> ELIZA: Yes. I'm sure they're not sure.

Eliza also had specific representations of different kinds of authors. Authors who write journal articles were active scientists, "the people who actually did the study," while authors of textbooks tended to be more senior with a great deal of experience: "even older than my boss [an associate professor who runs the lab where she works], because he's been around a long time

but he's not qualified to do a textbook yet." Textbooks and journal articles were also seen in a certain historical context. Eliza recognized that one reads these texts with an eye toward this temporal aspect of their composition. She said, "By the time a textbook is written it's out of date. To really learn the stuff, you have to read the journals." This was a far different approach to text than the one she demonstrated as a freshman, when one simply memorized as best one could "what the book says."

Eliza's independent work with the graduate student Shelly continued in the senior year. Although it is clear that Eliza's relationship with Shelly was not perfect—when asked if Shelly was easy to work with, Eliza hesitated, then said with a laugh, "Sometimes!"—she was proud of work she had done in the lab. Eliza observed, "I'm working for her, but I've created two mutants in a protein, on my own." Eliza said she had learned a lot from the experience: "Like when I started I was clueless. I really never could understand totally what they were talking about." However, she stressed that "Now when Shelly says something to me, I understand what she's talking about." And later: "I understand what they're [other professors and grad students on the project] talking about."

Eliza's work with Shelly in the lab may also have contributed to her awareness of the social and rhetorical dimensions of discourse. This is suggested by the way she discussed her writing in conjunction with this work. She was concerned that readers of her lab journal be able to use the information there: "It [her writing] is important because somebody who comes when I leave is going to want to work with my mutants and they are going to want to understand how it works, how it grows." She was also beginning to understand how discourse fits into the larger culture of scientific research, recognizing how her own writing will help her make a place for herself within that culture. Regardless of her skill as an immunologist, she believed, without writing, "I'd never get my point across. I'd never get a grant. I'd never have any money, so forget it. I'd be out of luck." A text was now seen as a storehouse of information but as a way to pursue one's scientific agenda; without it, the scientist is isolated, unable to do her work, "out of luck."

Despite her obviously greater sophistication, Eliza, as a senior, still exhibited a certain tension in the way she talked about texts and the way she talked about facts and knowledge. Like the scientists studied by Gilbert and Mulkay (1984), Eliza seemed to move back and forth between two repertoires, the first a foundationalist view of texts, demonstrated by comments like the following from a senior-year interview: "The teacher will nail us if we're not perfectly factual," an example that suggests as well that Eliza's professor was concerned with students factual understanding of course material. At other times, Eliza voiced a more contingent view of the texts she read, noting "handwaving" in the discussion of an article of mentioning that researchers may have been confused or mistaken in plotting their results. It seems unlikely, however, that Eliza was in control of these repertoires in quite the same way that the biochemists studied by Gilbert and Mulkay were. Further, this bifurcation in the way she viewed texts may have

reflected her continuing dual roles, functioning both as a budding scientist taking her place in a research community and as a student, still responsible for learning course content and demonstrating her competence to her teachers and other authorities. Similarly, Eliza by turns exhibited characteristics of both "separate" knowing and "connected" knowing (Belenky et al., 1986). She sometimes separated herself from the knowledge or claims of a text, positioning herself above it, as when she described how "I started by just looking at the figures and legends to see what's wrong with them" or predicted that in grad school she will "just look at articles and tear them apart, say what's wrong with them." But she had also become somewhat more of a connected knower, seeing connections between her own uncertainty about scientific methods and findings and the uncertainty of the researcher/authors whose research she read. Eliza also described her connections to the mutants that were the object of her research, connections that Harding (1986) identified as one of the traits of feminist science. Eliza said she knows "what it [the mutant] likes to grow on, what it hates to grow on. . . . It really is like the baby that you have to watch out for." Eliza here echoed the now-famous anecdote of geneticist Barbara McClintock, describing herself as "part of the system . . . right down there with [the chromosomes]," and the chromosomes themselves as her "friends" (cited in Keller, 1983).

Discussion of the Narrative

Through her four years of college, Eliza's theory of discourse changed in important ways. Early in her college career, the bulk of the texts she read for school were seen as sources of information, and her job as a reader was primarily to extract this information for use in tests or reports. For the most part, both texts and the information they contain seemed unconnected to the authors or the circumstances that produced them. Not that Eliza was unable to understand the concept of author or authorial claims: in the reading of essays for her English class, she became somewhat conversant with these notions. An English curriculum which stressed authorial conversations and encouraged students' graphic representations of authors' interactions may have contributed to Eliza's understanding of discourse during the freshman year. But, in the sophomore year, when the "scaffolding" (Applebee, 1984) provided by Eliza's English class and instructor were withdrawn, she again seemed content to view texts as autonomous. As evidenced by her approach to the research paper in her sophomore year, Eliza seemed to view reading and writing as unconnected to the scientific work for which she was preparing herself. Rather, at this point, reading and writing were seen as the work of school, not the work of science.

Beginning in her junior year, we begin to see important changes in Eliza's views of discourse: She exhibited a growing cognizance of texts (and the science they report) as the result of human agency. Similarly, her representations of discourse seem to have expanded to include a notion of texts as accomplishing scientific and rhetorical action, fulfilling purposes and mo-

tives, as well as presenting facts and information. Her recognition of the rhetorical nature of discourse was somewhat uneven, of course: Sometimes she talked as if science and scientific texts were purely factual, set in stone; other times, she saw them as more contingent. By her senior year she often viewed texts as multiply connected—to authors and scientists, to other readers, and to historical circumstances—and even demonstrated some understanding of her own connections both to scientific texts (and, by implication, to their authors) and to the objects of her own research. . . .

General Discussion

We have seen how Eliza developed as a reader in a number of ways through her four years of college. Her reading practices became more sophisticated as she moved away from the linear reading and verbatim-note taking strategies of her freshman year to the skimming, selective reading, and in-depth attention to tables and legends in the senior year. Her goals for reading changed as well. In the freshman year she was primarily concerned with "figuring out what the book says"—understanding and memorizing scientific concepts. As a senior, Eliza was trying to find or make a place for herself within an academic community, and she used reading to help her reach that goal—although reading continued to function, as it had throughout her college career, as a way to become conversant with scientific concepts. Arguably, the most important change in Eliza's reading of texts, however, was in her growing awareness of the rhetorical frame supporting written discourse—including a representation of authors as active, motivated agents and a cognizance of the historical, situational, and intertextual contexts supporting both readers and writers. As a senior reading the texts of her major field, Eliza resembled expert readers in her attention to rhetorical concerns. To my mind, this change constituted the beginnings of a new theory of discourse for Eliza. She began to see texts as accomplishing scientific action as well as embodying scientific knowledge: She recognized that behind scientific texts are human authors with motives, authors who are also interested, but sometimes uncertain, scientists; she started to see that scientific facts are contingent and historically bound. The changes in Eliza's use of verbs to talk about texts and authors and the growing presence of human agents in her interview discourse suggest, as well, that important changes were going on in Eliza's view of the scientific enterprise. Possibly most importantly, Eliza began to see her own role as not simply learning the facts but of negotiating meaning—that is, doing her work—amidst the many voices of her discipline.

What kinds of factors and events may have led to Eliza's growth and development as a reader? Of course, a longitudinal case study does not allow strong causal arguments, but I would like to suggest four somewhat interrelated explanations. Teasing out how the factors described below, and others, influenced Eliza's rhetorical growth is beyond the scope of this study. Further qualitative and quantitative studies, as well as meta-analyses of existing research, will be necessary in order to begin to understand the complex of

factors contributing to the rhetorical development, in reading and in writing, of students like Eliza.

Increased Domain Knowledge. A strong knowledge explanation for Eliza's development would maintain that her increased facility with the terms and concepts of biology (and its subfields of immunology and molecular biology) led to her increased rhetorical sophistication. In this view, the "world of domain content" precedes and supports the "world of rhetorical process" (cf. Bereiter and Scardamalia, 1987; Geisler, 1994). Research in areas as diverse as the cognition of chess playing, in which Chase and Simon (1973) found expert players to have huge numbers of domain-specific patterns in memory, and sociolinguistic studies of literacy by Scribner and Cole (1981), which showed Vai villagers able to perform logical operations in known but not unknown domains, support the strong knowledge explanation. In fact, this explanation was one that Eliza herself offered for her increased facility with reading academic articles. In her junior year, she noted that "it [the article] was really technical, but I understood a lot more than if I had been a sophomore reading it, [because] I've been exposed to a lot of terms." One possible drawback to the knowledge explanation is that it rests on a conception of domain knowledge as static, fixed, and necessary prior to rhetorical knowledge, a conception that has been questioned by recent advances in the philosophy of knowledge (e.g., Rorty, 1979).

Instructional Support. A second explanation would hold that, as Eliza's education proceeded, she was exposed to different kinds of classes and assignments, and that this instructional support, provided by her teachers and by the curricula within the biology department, was responsible for Eliza's rhetorical development. Indeed, as we have seen, there were vast differences in class structure, assigned texts, and reading and writing assignments as Eliza's college education progressed. Some credence is added to this explanation by the fact that when Eliza was given explicit support for thinking about authorial claims and other rhetorical elements—through the texts, assignments, and interactive framework of her freshman English class—she seemed able to invoke and use at least some rhetorical knowledge.

A variant of the instructional support explanation would hold that it was the different kinds of texts that Eliza read that invited or required different strategies, goals, and views of discourse from her. Eliza certainly did read different kinds of texts later in her college years, as primarily textbook reading gave way to research reports and published articles. Analyses like those of Fahnestock (1986) and Gilbert and Mulkay (1984) have demonstrated that the texts scientists write for "outsiders" (like entry-level textbooks) are quite different than those they produce for "insiders" (like theoretical and experimental journal articles). And in some ways, Eliza was a different reader—with different goals, strategies, knowledge, and rhetorical sophistication—when she read these different kinds of texts.

"Natural" Development. To students of life-span studies or developmental psychology, Eliza's growth in rhetorical sophistication echoes other studies of college-age adults, most notably that of Perry (1970) and of Belenky et al. (1986). We have already seen some of the ways that the changes in Eliza's views about facts and discourse in science illustrate various positions in the Belenky et al. scheme: As a freshman she seemed to view knowledge as something to be received—therefore her almost overriding attention to "what the book says." Later, she exhibited characteristics of the procedural knower, and as a senior she looked, at times, like a separate knower and at other times like a connected knower. While Belenky et al. were careful to caution that the positions of knowing that they described are not stages or part of a developmental progression, at least in Eliza's case, one way of knowing did seem to give way to others.

Perry's (1970) study of Harvard undergraduate males (to which Belenky et al. [1986] provided something of a corrective) more explicitly chronicled a movement by undergraduates in how they view knowledge and authority, especially in terms of their schoolwork. According to Perry, there are nine positions in the developmental scheme, as students move from dualism to multiplism to relativism and finally to commitment. Like the current study, Perry was especially interested in the outlook which "perceives man's [*sic*] knowledge and values as relative, contingent, and contextual" (p. 57). Early in her college career, Eliza, like Perry's dualist, viewed knowledge as information, correct and incorrect information, with authorities (in Eliza's case, textbooks) embodying correct or true information. As a multiplist, she began to see that authors hold various positions on values (in the English class) and later, that different biologists hold different views of nature. As a senior, Eliza exhibited characteristics of the contextual relativist (who understands that truth depends on context) and even of commitment, as she more closely identified herself with a field of study and indirectly with the values of that field. Interestingly, I saw little evidence that Eliza ever held the extreme relativist position Perry described (in which no truth or values exist) or the extreme subjective position Belenky et al. described (in which all knowledge is personal and private). Possibly, as a member of a culture that highly esteems science and as an individual who never really questioned the value and contributions of science, Eliza found these positions simply untenable.

It is possible, then, to see Eliza moving through various positions in the Perry (1970) and Belenky et al. (1986) schemes. However, as Bizzell (1984) has forcefully argued, Perry's scheme (and, I would argue, the scheme of Belenky et al. as well) does not in fact describe strictly "developmental," that is, natural or inevitable, stages. Rather, Perry's work described the results of a certain kind of education or enculturation—and the philosophical assumptions that Perry's subjects acquired were often ones they chose, not ones that were genetically preprogrammed. Similarly, while I would not claim that Eliza set out with the goal of viewing science rhetorically, she clearly did want to emulate the graduate students and professors with whom she worked—recall the statements that "I'm learning to be a scientist," "I'm

becoming a scientist," and "I am a scientist." Interestingly, Perry attributed his subjects' development to the classics-based liberal-arts education at Harvard. Although Eliza, as a senior, ended up resembling subjects at the upper ends of the Perry scheme, her education was quite different, a classically scientific one, with minimal exposure to humanities or liberal-arts courses.

Mentoring in a Sociocultural Setting. Seeing education as the process of becoming an insider leads to the fourth possible explanation, namely, that the context of Eliza's work experience directly supported her education in biology. Beginning in the summer between her sophomore and junior years, Eliza began to work as an assistant performing routine tasks in the lab of one of her professors, under the direct supervision of one of the professor's graduate students. As the linguistic analysis of human agents mentioned in the interviews revealed, Shelly became quite important to Eliza, making up a full 10 percent of the mentions of human agents in the interviews from Eliza's senior year. Other studies have suggested that the mentoring that Shelly provided for Eliza may be very important for students entering academic disciplines. Theorists of education like Brown et al. (1989) have postulated that "cognitive apprenticeship" is one mechanism by which students acquire complex skills, while feminist theorists have suggested that a strong (female) mentor can help women achieve in university settings (Belenky et al., 1986; Rich, 1979). The National Academy of Sciences (1989), in a document for students called *On Being a Scientist,* has stressed the importance of the mentor-student relationship, and a recent study by Blakeslee (1992) has shown this scientific mentoring in action in one physics research lab.

Eliza also worked within a larger team of scientists as she participated in the day-to-day work of the lab. Some of her responsibilities were tedious and mundane—keeping records and cleaning equipment—but she was also responsible for other, more complex tasks, such as creating and monitoring the growth of several protein mutants in the lab and attending staff meetings of lab personnel, including the professor. By late in her senior year, she was able to say that "When I go to lab meetings now, I understand what they're talking about. And it's not just Shelly's work either. It's other people who are working on the same project. I *understand what they're saying* [emphasis hers]. It's great because I never understood before."

Eliza's experiences in the real world setting of a lab, where students, professors, and other technicians worked together in the conduct of research, probably taught her a great deal about the actual, contingent nature of much scientific activity. Indeed, in one sense Eliza was much like Gilbert and Mulkay (1984) or Latour and Woolgar (1979): These researchers, like Eliza, were "students" of scientific activity, and they learned a great deal about the very human enterprise of science, and its social and discourse-based nature, by watching the day-to-day operation of a research lab. Eliza may have learned the same lessons about the rhetorical nature of science in her observations of and work in the cell biology lab.

A biologist and a chemist with whom I consulted on the project both believed that, for many science students, extended experience working in a lab (beyond class labs) is of paramount importance in facilitating a growing understanding of the scientific enterprise, describing the experience as "like a light bulb going on" for students (J. P. Lowe, personal communication, 23 January, 1993; A. G. Stephenson, personal communication, 21 January, 1993). . . .

Concluding Comments

This study offers a detailed, fine-grained look at one student's development over time, something we could not see in a study designed to address similar questions with groups of students of different ages. Another of the real benefits of this kind of research—longitudinal, in-depth case study—is that it allows a richer picture of an individual. Multiple data sources enrich our view of Eliza and her learning, and observing her over time cautions us against making generalizations about her abilities or her thinking. Because many of Eliza's teachers knew her for only a semester or possibly a year, they may have had limited knowledge of her long-term educational and career goals and of her history as a learner. Indeed, it is interesting to contemplate how different our views of students might be, and how our teaching might differ as well, if we were able to learn about our students over a period of years rather than weeks.