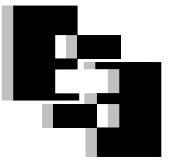
Language and Learning Across the Disciplines

A forum for debates concerning interdisciplinarity, situated discourse communities, and writing across the curriculum programs.



Examination Retakes in Accounting:
Increasing Learning by Writing After the Exam

Gaining Grounds Revisited:
Sustaining Tales of Development

WAC in the 90's:
Changing Contexts and Challenges

Evidence and Interpretation:
Teachers' Reflections on Reading Writing in an Introductory Science Course

August 2000 Vol. 4, No. 2

Language and Learning Across the Disciplines is a forum for issues concerning interdisciplinarity, situated discourse communities, and writing across the curriculum programs.The journal will publish articles dealing with issues in learning theory, discourse analysis, participation in disciplinary discourse, and the social, intellectual and political locations of WAC programs. We welcome articles seeking to make connections among several such areas of inquiry. All manuscripts will be carefully reviewed by members of the editorial board and appropriate outside readers. You may expect to hear from us in two months. When submitting a manuscript please follow the current MLA or APA style sheet; submit three copies (3,000 to 7,000 words); print your name, address, telephone number and affiliation on a cover sheet, not on the manuscripts; and enclose sufficient return postage clipped, not pasted, to a self-addressed envelope. Send manuscripts to Sharon Quiroz and Michael Pemberton, Editors, *Language and Learning Across the Disciplines*, Illinois Institute of Technology, 3301 S. Dearborn, Chicago, IL 60616. Major funding for *LLAD* is provided by the Academic Resource Center of the Illinois Institute of Technology.

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LANGUAGE AND LEARNING ACROSS THE DISCIPLINES

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Letter from the Editor

Sharon Quiroz

Language and Learning Across the Disciplines is pleased to celebrate the debut of our sister journal online, *Academic.Writing*, at http://aw.colostate.edu/index.html . The mission of *Academic.Writing* is to sponsor interdisciplinary perspectives on communication across the curriculum, and to provide the support for faculty that was originally made available on WAC Clearinghouse. According to editor Mike Palmquist, since *Academic.Writing* is designed to take advantage of cyberspace, the journal will not use a volume and number system. Instead, articles will come online as soon as they have been reviewed, and the volumes will be dated by the year, beginning in January.

LLAD and *Academic.Writing* have a loose affiliation, designed to explore the relationship between a traditional print journal and the online version. We plan to develop joint issues from time to time, addressing a specific topic, with material allocated to both kinds of space. Currently we plan that the first of these will be a joint issue focused on writing centers, guest edited at *LLAD* by Lisa Johnson-Stull at Washington State University and at *Academic.Writing* by Carolyn Handa at Southern Illinois University.

The debut website of *Academic.Writing* features a Forum in which Ann Herrington, Donna Lecourt, Susan McLeod, David Russell, Art Young and Mike Palmquist discuss "Principles That Should Guide the Development of WAC/CAC in the Coming Decade." More about that below. Other sections of *Academic.Writing* include a Column on CAC in K-12, Feature Articles, Reviews and Interactions, CAC Connections, Teaching Exchange, Conference Papers, and CAC Research (including CAC research archives). The "WAC Clearinghouse" links designed to support WAC research also appear on the front page: back issues of *LLAD* online, CAC links, CAC Theses, CAC Research (CAC includes WAC here), Introduction to WAC, Join WAC-L.

Subscriptions are free, but *Academic.Writing* needs to document its readership, so readers must subscribe.

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In the spirit of our new venture, *LLAD* in this issue takes up one of the concerns we found in the Forum discussion on *Academic.Writing,* the ongoing tension between Writing Across the Curriculum and Writing-in-the-Disciplines. Several of the speakers in the Forum counseled that in the coming decade WAC/CAC programs should be guided by the pedagogical principles of WAC: the emphasis on pedagogy, and specifically student-centered pedagogy. Art Young's passionate plea is worth reproducing here.

> We need to emphasize writing across the curriculum (WAC) significantly more than writing-in-the-discipline (WID). Many teachers and scholars are calling for a greater emphasis on WID, arguing that knowedge is socially constructed and that academic language is constituted by the written conversation of particular discourse communities (i. e., history or physics). I've sometimes simplified, for my own understanding this concept as: "In order to be a physicist, a student needs to know what a physicist knows, be able to do what a physicist does, be able to read and write the world as a physicist." In some cases, the call for more WID is narrated as a hierarchical advancement over the pioneering but less knowledgeable ways of WAC, with its emphasis on expressivist notions of writing to learn and process notions of learning to write, with its emphasis on authentic voice and negotiating knowledge within the classroom community. For WAC to continue its influence on college campuses and to collaborate more actively with schools and other civic groups, I believe WAC pedagogy needs to be at the philosophical center of WAC/WID programs.
>
> Thus WAC programs need to continue to focus on pedagogical goals associated with expressive writing, reflective writing, writing to learn, conversational discourse, and what I call "the middle ground" of much classroom discourse, a writing space where students develop language and thinking abilities in interplay between what they know and are able to express and the formal language and conventions of academic communities. This is a major way to assist the development of writers in educational settings, kindergarten through graduate school, and this is the way to develop WAC projects that involve students in writing for audiences outside classrooms, and this is the way to develop students who write to make a difference in their own life and the lives of others.

That's great stuff. Now *LLAD* had already put together an issue using articles developed out of the National Writing Across the Curriculum Conference at Cornell, in which all the articles seemed to address writing in the disciplines, if not Writing-in-the-Disciplines. Elsewhere in the Forum, Art wrote that sometimes he thinks WAC isn't about writing at all, but about learning. Perhaps what is attractive in the *LLAD* articles is the way they address learning in the disciplines.

The argument of Lynn Rhodes's article might better be seen as a call for student-centered assessment. Her project is to find a way to tell the story of students' progress through undergraduate education as a seamless tale of individual development, without the little hitch between the gen ed courses and the upper level professional courses, to find a way of valuing what students have to say that does not translate as a set of numbers profiling the professionalization of their language.

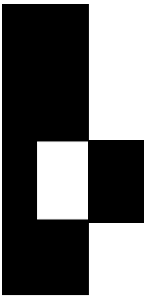
Betty Bamberg's article also deals with evaluating the program at her school Her method of assessment reveals that writing intensive courses in the disciplines (implemented with little input from WAC) appear to be more in harmony with the principles of WAC than do the upper level general education courses that were designed in a more ideally WAC principled process. It suggests that traditional methods of interacting with students in the disciplinary courses at her school already amount to a student-centered pedagogy. Is it enough that teachers in some disciplines ask students to do a lot of writing, say lab reports, and give them a lot of feedback? Is WAC really different from the ideal practice in small liberal arts schools?

The third article, by Cynthia Bolt-Lee and Sheila Foster comes from an accounting department. It documents the value of re-taking essay exams in accounting. Is this WAC pedagogy? Or just good pedagogy? It reminds me of an article that appeared in the last issue of *LLAD*, written by Patty Connor-Greene and Janet Murdoch. They report on research which used writing in ways some WAC specialists would not approve, to teach disciplinary discourse. In the experiment students in a psychology course were required to write short exams in every class meeting, short exams that asked students to work with concepts—with "mid-level Bloom" kinds of questions. At the end of the term students who had participated in these exams were judged better able to read and understand a new but related professional article than students in control groups. The authors admit up front that their methods smack of the lecture/test model. And yet the intervention is on the learning side, not the formal presentation of material.

LLAD editors and *Academic.Writing* editors overlap, so we had read the article by two biologists that is "reprinted" here, from A.W. Like the other two disciplinary examples above, Shahan and Costello offers a

WAC intervention on the learning side of teaching disciplinary discourse. Citing "post-Piagetian" work in cognition that suggests how different is formalized thinking in disciplines from thinking in other life contexts, the authors offer a method for utilizing that work in cognition to design writing assignments and evaluate students' understanding of science.

What these articles have in common is attention to learning processes in the project of teaching disciplines. They do not use expressivist or reflective writing, but they do use writing to learn a discipline. Art speaks of the "middle ground" in which students learn to connect their own lives to the formal and conventional languages of academia. In another sense, writing in the disciplines needs to be the middle ground, used in the service of other interests. Feminists, for example, need lawyers and accountants and historians and biologists to make their cases. WAC needs this WID piece, too.



WAC in the 90's: Changing Contexts and Challenges

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Introduction

By1990 the context for WAC programs, which had flourished during the 1980's, was changing in significant ways. Established programs, often begun with external funding, faced challenges such as ensuring continued financial support, identifying new leaders, and keeping faculty involved and engaged (McLeod, 1989). However, new programs faced different contexts and challenges. According to McLeod and Soven (1991), many new programs were being established as top-down, administrative initiatives with unrealistic expectations and little understanding that WAC "involves a comprehensive program of faculty development and curricular change…to improve students' writing and critical thinking skills" rather than a set of requirements that add more writing and focus on grammar problems (26). In addition, most new programs did not have the financial support that earlier programs enjoyed, so release time for a program director or funds for faculty workshops in teaching writing, essential components of early programs, were minimal or nonexistent.

Questions about WAC's theoretical assumptions and future direction also came to the fore as the 1990's began. Although early WAC programs were based on a set of shared principles, different instructional emphases—one focusing on using writing as a tool for learning and one focusing on teaching disciplinary conventions and genres—were present from the outset. Early "landmark" programs such as the ones at Michigan Technical University and Beaver College combined these approaches, but MTU clearly emphasized writing to learn (Young and Fulwiler, 1986; Flynn et. al., 1990), while Beaver College (Maimon, 1979, 1990) focused instruction on disciplinary genres. These approaches, later characterized as "cognitive" and "rhetorical" by McLeod (1989) and as "Formalist" and "American Expressivist" by Mahala (1991), were not initially seen as "mutually exclusive" (McLeod and Soven, 1991, p. 26). However, by the early 90's they were increasingly viewed as representing conflicting rather than complementary instructional approaches. Mahala (1991), for example,

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argued that eclectic programs, which combined strategies from both approaches, were philosophically inconsistent because they overlooked deep differences about the role of writing and the nature of learning in the university curriculum. Around the same time, the accumulating body of rhetorical research on writing in the disciplines led Bazerman (1991) to propose that the "second stage" of WAC focus on introducing students to specialized disciplinary discourse rather than on converting classes into writing workshops. The resulting theoretical dichotomy presented 1990's WAC programs with a further dilemma: whether to construct programs that emphasized one of the two approaches or to try to reconcile differences between them.

Formative Evaluation: A Tool for Program Improvement

Formative evaluation is a preliminary assessment that identifies a program's strengths and weaknesses. Because its purpose is to improve programs rather than to assess student outcomes or render a final judgment on a program's effectiveness, formative evaluation can be a powerful tool for program development and improvement (Scriven, 1996). It is not only a quicker and easier procedure than a comprehensive, summative evaluation, but it can target specific programmatic concerns. The following formative evaluation was conducted at California State University, Los Angeles (CSLA), an urban university with a diverse student body, where two WAC requirements were instituted between 1993-1998, one for a "Writing in the Major" course and the other for writing in upper division general education "theme" courses. The resulting program, established with minimal faculty discussion, was requirement-based and had no clearly articulated goals or overall structure. It consisted, instead, of individual courses developed or modified in response to the requirements. To assess the impact of these two requirements, I designed a formative evaluation that would answer the following questions: (1) To what extent do courses meeting the upper division general education theme requirement and the Writing in the Major courses provide instruction in and an emphasis on writing and critical thinking skills? (2) What instructional approaches (i.e, writing to learn or writing in the disciplines) do the writing assignments and instructional strategies utilize? (3) How well does instruction in one requirement complement and extend the instruction received in the other? Although the account that follows describes a particular program, it illustrates a general methodology that can be used by other institutions to evaluate and improve their WAC programs.

Analyzing the Requirements

CSLA's two writing requirements were instituted at different times and for different reasons. The first, effective in winter 1993, mandated an

upper division "Writing in the Major" course for every undergraduate major. Criteria for these courses were quite specific: writing was to be an integral part of the course, and instruction was to focus on teaching disciplinary genres and ways of developing and articulating ideas consistent with conventions of the discipline. Students were also to write frequently and receive timely feedback on their writing.

The second writing requirement, effective in fall 1998, was added to an existing upper division "theme" requirement during a revision of the university's general education program. To complete their upper division general education theme, CSLA students must take three interrelated courses—one from the Humanities, one from the Social Sciences, and one from the Natural Sciences—on one of nine themes described as "current, enduring, and of significant importance for humanity." Criteria for the writing required in the theme courses were more general than criteria for the Writing in the Major courses and included no statements concerning the goals of the requirement or the function of writing within the course.

Data Collected

I collected assignments from twelve courses, six from each requirement, and interviewed the faculty teaching these courses. For the Writing in the Major requirement, I selected the courses from the Business, Biology, Electrical Engineering, English, History, and Psychology Departments. For the upper division general education theme courses, I selected two of the nine themes—Human Maturity and Aging: Problems and Processes and The Diversity of Human Emotions—and collected data from one course in each of the three areas. The six courses included one each from the Biology and Psychology Departments in the Natural Sciences, one each from the History and Psychology departments in the Social Sciences, and two from the English Department in the Humanities.

Methods of Analysis

To analyze the writing assignments from these diverse courses, I needed a framework that would allow me to compare writing not only across disciplines, but also between major and general education courses. The framework developed by Walvoord and McCarthy (1990) to analyze data in their naturalistic study of writing in four disciplines met these criteria. They found that writing assignments asked student writers to adopt one of three roles: (1) the professional-in-training, (2) the layperson, and (3) the text-processor. In the text processor role, students were asked to summarize, synthesize, or comment on course texts. The layperson role asked students to address problems and issues raised in the course but did not expect them to use disciplinary knowledge or methodology. The professional-in-training role, on the other hand, required students to ana-

lyze a problem or an issue by using both the knowledge and methodology taught in the course. Using these categories, I identified the expected role(s) in each class by analyzing the written instructions, the supporting materials for the writing assignments, and the comments made by faculty during my interviews. Writing assignments were classified as requiring a professional-in-training role if students needed to use disciplinary genres, knowledge, and conventions to complete them. Assignments signaled the text processor role when they directed students to "summarize," "describe," "explain," etc. Assignments requiring the layperson role asked students to use either general academic genres such as the analytic essay or less formal genres (e.g., reflective journals, autobiographical accounts, or personal interviews) and did not require students to use disciplinary conventions, genres, or theoretical frameworks to complete the assignments.

Each of the roles makes different cognitive and rhetorical demands on writers, and these, in turn, imply a need for different levels of instructional support. Therefore, I used a second framework that analyzed the degree of "scaffolding" provided. Scaffolding, an instructional strategy based on the theories of Bruner and Vygotsky, supports the learning of new skills and knowledge through teachers' use of explicit instructional strategies or models. While this scaffolding initially helps learners solve new problems, they subsequently internalize the cognitive and rhetorical strategies and are able to solve similar problems independently (Applebee, 1984). Williams and Colomb (1990, 1993) contend that many students' writing problems can be attributed to their status as "novices" within a disciplinary community and argue that providing explicit instruction (scaffolding) on the strategies and genres used by experts is preferable to the gradual apprenticeship model advocated by Freedman (1993, 1995). To assess the scaffolding provided, I analyzed writing assignment sheets and related instructional materials, class activities, comments on student papers, and instructors' descriptions of their instructional approach. I identified the following types of instructional support in the data: oral feedback through individual conferences or peer response groups, written comments on drafts or completed papers, written instructions that outlined the task expectations and suggested ways to meet those expectations, opportunities to rewrite papers based on feedback and/or to write multiple papers in the same genre, and instructor-led class presentations or activities that explained or modeled expert strategies.

Results

Results from the analysis of the Writing in the Major courses are shown in Table I on the following page:

Department/Course	Expected Role	Level of Scaffolding
Biology: Writing in Biology	Professional-in-Training	High
Business: Business Communication	Professional-in-Training	High
Electrical Engineering: Writing for Elec. Engineers	Professional-in-Training	High
English: Writing the Critical Essay	Professional-in-Training	High
History: Historiography	Professional-in-Training	High
Psychology: Experimental Research	Professional-in-Training	High

Table I: Writing in the Major Requirement

As Table I shows, the six Writing in the Major courses all emphasized the professional-in-training role. Although they used different course designs, each course focused on disciplinary genres and ways of articulating ideas that embodied disciplinary conventions. The English and History courses, for example, both focused on teaching one genre (the literary critical and historiographic essays respectively), and students were expected to apply the analytic and rhetorical skills being taught with increasing expertise as the term progressed. Biology students, on the other hand, wrote papers in several different genres including a biological description, a review article, an experimental article based on an observational study that they had conducted, and a personal statement. Students in Experimental Research, the Psychology course, designed and conducted an original experiment, analyzed the data, and then wrote up the results as an experimental article. Both the Business and Electrical Engineering courses emphasized forms of writing that students would use in the workplace. Business students, for example, wrote memos, letters, short reports, and a ten page, researched analytic report. Students in Electrical Engineering wrote technical reports of varying lengths, including one requiring online research. In addition, the Electrical Engineering course was specifically designed to prepare students for their senior design course, where they would conduct experiments to solve problems similar to those they would encounter as engineers, then present their results in a technical report.

Although their methods varied, all instructors also provided a high level of scaffolding to help students learn expert strategies and specific disciplinary genres. In the English Department's Writing the Critical Es-

say, for example, the class was conducted as a workshop where students presented their essays for critique by the entire class and the instructor. In Historiography, the professor provided students with a six page handout of step-by-step instructions for writing the historiographic essay and developed their understanding of these principles during class lectures and discussions by analyzing essays written by professional historians. The Biology instructor modeled disciplinary strategies, and students received extensive feedback on their writing during a weekly, two-hour computer lab where they composed and revised assignments with assistance from the instructor and a Writing Center tutor. Psychology students, who usually took Experimental Design as one of their last major requirements, had been socialized into disciplinary genres and conventions through earlier coursework. Nevertheless, they received extensive oral and written feedback on each section of the experimental article. Both the Business and Electrical Engineering courses were conducted entirely in computer classrooms, and the instructors alternated between modeling and explaining the principles of business and technical writing and providing in-progress feedback as students composed the assigned writing tasks.

Results of the analysis for the general education theme courses are shown in Table II on the following page.

Unlike the Writing in the Major courses, the theme courses show no consistent pattern in terms of expected roles or levels of scaffolding. Three courses—History of Emotions, Psychology of Emotions, and Biology of Aging—expected students to assume the professional-in-training role; however, the emphasis on this role varied. In History of Emotions, for example, only the professional-in-training role was emphasized. One assignment asked students to analyze changing criteria for marriage between the seventeenth and nineteenth centuries by drawing on primary and secondary historical sources while another asked them to critique a recent historical argument on the relationship between courtship, dating, and love. In Psychology of Emotions, the professional-in-training role predominated, as students wrote a scientific review, which used sources from disciplinary journals and followed APA format. However, the paper's conclusion called for the layperson role, as students were asked to write a paragraph that related the topic—a discussion of the relationship between an emotion and a social issue—to their own experience. The Biology of Aging course had less emphasis on the professional-in-training role as the major writing assignment, described as an "analysis paper," asked students to assume all three roles. In the first section of the paper, students summarized the article selected for analysis (text processor role),and in the last they discussed the influence of values on personal evaluations (layperson role). However, in the second and most important

Theme: Human Maturity and Aging: Processes and Problems

Department/Course	Expected Role(s)	Scaffolding
Biology: Biology of Aging	Professional-in-Training	Low
	Text Processor	Low
	Layperson	Low
English: Narratives of Maturity and Aging	Layperson	Low
Psychology:-Psychological/ Psychosocial Development	Layperson	Low

Theme: The Diversity of Human Emotions

Department/Course	Expected Role(s)	Scaffolding
English: Human Emotions in Literature	Layperson	Low
History: History of Emotions	Professional-in-Training	High
Psychology: Psychology of Emotions	Professional-in-Training	Moderate
	Layperson	Low

Table II: General Education Theme Courses

section, they analyzed the relationship between the evidence in sources and the conclusions (professional-in-training role).

The other three upper-division theme courses emphasized the layperson role exclusively. Writing assignments in the courses called for students to consider course topics and/or texts from a personal perspective and de-emphasized disciplinary genres and conventions in favor of general academic or less formal genres. In Human Emotions in Literature, for example, students wrote four emotional "logs," a type of reflective journal, in which they responded to any aspect of the assigned texts (*Hamlet, Ourika, Flowers of Evil,* and *Affliction*) that elicited a personal emotional response. The logs, based on a psychoanalytic approach to reading and responding to literature, were used to deepen students' responses to literature and their understanding of those responses, not to prepare them to write a critical essay. In Psychological/Psychosocial Development, a course in the Human Maturity and Aging theme, students interviewed a person seventy-five years or older (a family member, friend, or neighbor when possible) and evaluated his/her success in coping with older age. Near the end of the term, they wrote their own life story and then imagined what their life would be like as an aging adult. Although students could draw

on theoretical concepts from the course in writing their papers, this was neither required nor explicitly encouraged. In fact, the instructor, who had previously taught a class on aging for psychology majors, clearly distinguished between her expectations for students in the general education course and those for majors, who were required to use psychological theories to analyze topics and issues. The third course, Narratives of Maturity and Aging, was structured so that the literature read dramatized the developmental stages experienced by men and women as they mature and age. One writing assignment gave students an opportunity to analyze their attitudes toward aging by writing an in-depth personal essay or by interviewing someone older and comparing that person's views with their own. The take-home final, which asked students to "explore age-related aspects of crises experienced by characters from three works read," encouraged students to consider aging from their perspective, rather than from a literary or critical point of view.

Levels of scaffolding ranged from low to high with low levels predominating. To help students meet the disciplinary expectations in the History of Emotions, the instructor provided a high level of scaffolding through a detailed handout and extensive feedback on their essays. In the Psychology of Emotions, the instructor provided moderate support to assist students with the scientific review: a page of "do's" and "don'ts" (largely dealing with matters of style), examples of possible and appropriate topics, tips on searching databases for relevant psychology journal articles, and a handout on APA style. The remaining four courses, (Human Emotions in Literature, Narratives of Maturity and Aging, Biology of Aging, and Psychological/Psychosocial Development) had low levels of scaffolding, as instructions for students focused primarily on the topics to be covered and provided few comments regarding the structure or form of the papers.

Discussion

Advocates for a "writing-to-learn" approach have argued that an emphasis on disciplinary writing threatens such WAC goals as shared responsibility for teaching writing, creation of a student-centered pedagogy, and the use of writing as a tool for learning (Mahala & Swilky, 1994). On the other hand, proponents of disciplinary writing instruction point to students' need for instruction in writing more sophisticated arguments on complex subjects and argue that disciplinary approaches can incorporate WAC principles and goals (Williams & Colomb, 1990; Bazerman, 1992; Gottshalk, 1997). Data from the six Writing in the Major courses evaluated in this study lend support for the latter view. In my interviews, faculty who taught the Writing in the Major courses saw teaching students to write within the major as their responsibility and took it seriously. They

also indicated that their writing assignments were designed to teach disciplinary methods of analysis and thinking as well as the discipline's genres and conventions. English majors, for example, not only learned rhetorical strategies for writing critical essays, but also learned ways to analyze and explicate literature. Both Biology and Psychology majors conducted research studies, and this activity required them to carry out scientific procedures and analyses appropriate to their disciplines before writing up their results as an experimental article, a primary disciplinary genre. All six courses also emphasized active learning through a consistently interactive pedagogy that demanded active participation through class or small group discussions and 1:1 conferences with the instructors.

The positive faculty response to the Writing in the Major requirement and the development of generally solid writing courses may seem surprising considering that it was a mandated requirement without university-wide discussion of WAC principles and goals or workshops on teaching writing. However, all six courses were genuinely "writing intensive," and the course titles of four of the six specifically designated them as writing courses. In addition, all departments but one (Business) limited class size to 20 to maximize the individualized attention and feedback that students could receive on their writing. During my interviews, faculty identified several factors that led to the successful implementation of this requirement. Initially, the Writing in the Major requirement stimulated discussions within departments concerning the role of writing within the discipline as well as the function of the required course within the major. These discussions eventually led to a departmental consensus about the goals and content of the course, its placement within the major, and a commitment to the requirement.

By comparison, the emphasis on writing in the upper division theme courses varied considerably. Writing was central to three of the courses—History of Emotions, Human Emotions in Literature, and Narratives of Maturity and Aging—and students' entire grade was based on their written work. In the other three courses (Biology of Aging, Psychology of Emotions, and Psychosocial Development), writing assignments constituted only 10-15% of the course grade, and students were evaluated primarily on the basis of multiple-choice exams. The three courses with a heavy emphasis on writing (the history and the two English courses) were taught by full-time, tenure track faculty in disciplines that traditionally emphasize texts and writing, while those that had a low emphasis on writing (the biology and the two psychology courses) were taught by part-time faculty in disciplines that emphasize empirical research. In addition, class size was also higher in the theme courses that had a low emphasis on writing, ranging from 45 in Psychological/Psychosocial Development to more than 140 in Psychology of Emotions.

The theme courses also exhibited more varied instructional patterns. Three courses (History of Emotions, Psychology of Emotions, and Biology of Aging) asked students to complete writing assignments that required them to use disciplinary expertise and to assume the professional-in-training role. However, only one (History of Emotions) provided a high level of scaffolding to help non-majors use disciplinary genres and conventions despite the fact that all Writing in the Major courses included such scaffolding. The three remaining courses (Narratives of Maturity and Aging, Human Emotions in Literature, and Psychological/Psychosocial Development) gave writing assignments that asked students to adopt the layperson role, and assignments in these courses focused on relating the theme to students' present concerns, deepening their understanding of topics within the theme, and applying the thematic issues to their future lives. This de-emphasis on disciplinary genres and analytic methods undoubtedly contributed to low levels of scaffolding.

Writing instruction in the upper division theme courses, therefore, had neither the coherence nor the consistent approach that I found in the Writing in the Major courses. Only three of the six theme courses could be considered "writing intensive," and only one—History of Emotions—provided sustained instruction in writing. In addition, the courses were almost evenly divided between an emphasis on disciplinary and writing-to-learn approaches. These inconsistencies may be attributed to several factors. First, the criteria for the general education writing requirement were far less specific than the criteria for Writing in the Major courses, encouraging an "additive" response to the requirement. In addition, part-time faculty taught three of the courses. Although all three had heard "something" about a writing requirement, none of them knew exactly what it was. However, the full-time faculty, who were more familiar with the requirement, did not indicate they had modified their approach in response to the requirement. Rather, writing was integral to their courses because it is central to teaching and learning in their disciplines—history and English.

To what extent might student writers find the contrasting instructional approaches used by their three courses within one of the upper division themes confusing or conflicting? With the exception of their general education theme courses, upper division students at CSLA take courses primarily in their major. Stockton (1995) found that as students develop expertise in writing for their major courses, that expertise can conflict with disciplinary conventions in other courses. For example, English majors in her study had difficulty writing the kinds of narrative accounts expected in upper division history courses because they seemed like plot summaries, a rhetorical strategy they had been taught to avoid when writing literary analyses. By the time students have reached uppe-

division status, they will have experienced a range of approaches to and expectations for writing in courses across the curriculum. Although they may well find the diverse rhetorical tasks and expectations encountered within a single theme to be confusing, these differences are most likely to cause them difficulties when writing assignments ask them to adopt the professional-in-training role and, therefore, to use disciplinary conventions and genres that are likely to be unfamiliar. They would therefore benefit from a high level of scaffolding, but this was provided in only one of the CSLA theme courses with a disciplinary emphasis.

Implications and Future Directions

Despite the oppositional stances sometimes taken by advocates for writing-to-learn and writing in the disciplines, viewing them as dichotomous approaches oversimplifies a complex relationship. Given the structure of the baccalaureate degree, most upper division coursework will be in students' major departments, and successful completion of writing assignments in their majors will require students to use disciplinary genres and conventions. The Writing in the Major courses in this study demonstrate that an emphasis on disciplinary writing instruction does not necessarily conflict with such WAC principles as active learning, shared responsibility for writing, and a student-centered pedagogy. Even though the courses evaluated did not use assignments generally classified as "writing-to-learn," the disciplinary assignments served as tools for deepening students' understanding of concepts and topics in their majors. Despite being a mandated requirement, Writing in the Major courses were taught by committed faculty and shared a coherent approach to writing instruction. Although the explicit criteria for the Writing in the Major course may have contributed to its successful implementation, university faculty will be more receptive to assuming responsibility for developing disciplinary writing skills than for "general" writing skills. Most faculty are strongly committed to their disciplines, and they are able to see disciplinary writing instruction as one step in the process of inducting new members into the discipline.

Despite their many positive features, the Writing in the Major courses could benefit from incorporating ideas and assignments developed primarily by programs emphasizing a writing-to-learn approach. For example, none of the courses included the informal, ungraded writing assignments that are generally associated with writing-to-learn approaches, and students' understanding of disciplinary concepts might have been enhanced by a broader range of assignments (see Klein and Aller, 1998, and Kastman and Booker, 1998, for examples of courses that use writing-to-learn assignments to complement disciplinary writing tasks). However, incorporating writing-to-learn into disciplinary writing courses may prove difficult. CSLA

faculty may not have used such assignments because they were unfamiliar with them, but Russell (1991) points out that there is a long history of disciplinary resistance to cross-disciplinary approaches, and opposition to writing-to-learn assignments has been noted even in programs that included extensive faculty training (Slevin, et. al., 1990).

Although mandated disciplinary writing courses may be reasonably successful without the structure of an overall WAC program and faculty workshops on teaching writing, mandated general education requirements are likely to be problematic and unevenly implemented. In "WAC and General Education Courses," Thais (1992) observes that successful strategies for teaching writing in major classes must be adapted for general education classes because of differences between them. Although his analysis focuses on lower division general education classes, some of the differences he points out are applicable to CSLA's upper division theme classes. At the upper-division level, students are also likely to enroll in general education courses with little intrinsic interest and motivation and to lack familiarity not only with the subject of the courses but with their discourse forms, style, and methods. Other similarities between upper- and lower-division general education classes include their broad, general goals, a reliance on part-time faculty, and larger classes. Thaiss recommends using a writing-to-learn approach in general education courses and introducing faculty to WAC principles and strategies through faculty workshops. In developing an overall approach, he stresses the need for "programmatic thinking" to help faculty plan a "diverse, complementary writing program across the curriculum (p. 104)."

In her closing address at the 3rd National Writing Across the Curriculum Conference, Herrington (1997) attempted to integrate WAC and WID approaches by recommending that future WAC efforts aim toward instructional practices that promote active learning, draw on students' authoritative knowledge when appropriate, encourage their pursuit of personal interests through disciplinary methods, and foster a dialogue between students and teachers (89). These goals might serve as a starting point for reconciling differences between WAC and WID approaches and bringing coherence to problematic 1990's WAC programs. However, creating a university-wide commitment to a WAC program that incorporates such principles "after the fact" represents a considerable challenge for requirement-based programs. It is difficult to backtrack and initiate faculty dialogue on WAC and or provide workshops for previously established, requirement-based programs. At CSLA, efforts to develop a plan for assessing general education outcomes may offer a forum for pointing out problems with the general education writing requirement. I am hopeful that these discussions will help faculty clarify the purpose and function of writing in general education courses as well as lead to faculty workshops

on teaching writing across the curriculum. Programs at other institutions may discover that linking WAC to local priorities and initiatives will be the most effective strategy for beginning conversations about mandated WAC requirements and arguing for additional resources to implement an effective program.

In his history of writing across the curriculum, Russell (1991) claims that "Cross-curricular writing programs were almost always a response to a perceived need for greater access, greater equity" (p. 271). The perceived literacy crisis of the 1970's combined with open admissions policies created conditions conducive to the widespread adoption of WAC in the decade that followed. Today, an increasing number of first generation college students, many of whom speak English as a second language, are seeking access to higher education at the same time as remedial programs are being attacked and dismantled. The need for WAC programs is as strong today as when the movement began because WAC's underlying principles will support these students' efforts to succeed academically. As WAC moves into the 21st century, we need to direct our efforts not only toward maintaining long-term, successful programs, but also toward transforming the requirement-based programs of the 1990's into ones that are genuine sites for writing and learning across the curriculum.

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Gaining Grounds Revisited: Sustaining Tales of Development

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Sustainable development is a popular phrase often associated with environmental studies, but the phrase can serve as ecological metaphor through which to view environments associated with writing assessment and writing program development. Sustainable environments depend on symbiotic relationships. Writing assessment and writing program development constantly rely on the classroom environment as the essential site for understanding student growth in writing. Applying a metaphor of sustainable development to student development in writing presumes that novice writers will first acclimate to academic writing across the curriculum, and that more experienced students will acculturate to writing within their chosen disciplines. But each student and each classroom teacher, in turn, affects the environment of generalized assimilation and acculturation since each student, at any given time, has unique and different needs. Thus, institutional diagnostics and assessments are - by their very nature - a sampling of water flowing by in the stream.[1]

Ideally, institutional writing assessment should always strive for more follow-up to quantitative generalizations, for more discussion about particular students who tend to complicate institutional writing assessments, for more balance between institutional reporting of data, which tends to go out to a larger public, and institutional feedback to the students themselves. Institutional writing assessment that claims to measure general student development should privilege and encourage more reflection from individual students as well as from individual classroom teachers.

Typically, students are discussed through narrative, in teacher lore. "Without a question, an academic reflex to hold lore in low regard represents a serious problem… and Practitioners need to defend themselves, to argue for the value of what they know and how they come to know it" (North 55). In contrast, statistical differences in freshmen's writing abilities contrasted to upper level students' writing abilities are often seen as

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more reliable bases for decisions made about writing programs. Certainly quantitative research – used sensitively - is useful because legislators and administrators do need to make judgments. However, those "numbers" determined through quantitative assessments must also point teachers back to those individual students who demonstrate personal growth or the lack of it in their writing. Classroom and institutional writing assessment should first benefit students, individually, with care. This principle should become the primary ethic for assessors of student writing. Writing assessment thus seems compromised when its primary purpose is to report results as average scores while ignoring students' unique needs and voices. While conducting institutional assessment, writing program administrators might be more aware of particular students as unique, not just representatively a "figure" in the "landscape." This would be a more humane use of writing assessment, to benefit these individual teachers and students, for many teachers do need help in recognizing when growth is present, and many students do need very personal attention with academic writing.

Writing teachers who regularly examine the differences between freshmen writings and junior / senior writers know that - in general - most students mature as individuals and acculturate as a group. Teachers also know that while some students pass individual courses, any skills "unused thereafter is learning that is not developmental" (Haswell 5). Teachers and administrators are both particularly alarmed by any "legend of deterioration." Personally, I despair that any individual student in our writing classes might actually worsen as a writer after the freshman composition sequence. Most teachers naturally seek to create environments that will presumably help more students in various stages of development through general education and into their disciplinary majors and schools. Most assessments do not fully appreciate those unique environments.

Researchers of WAC and WID have naturally sought out predictable evolutions. These researchers, who often serve as institutional assessors, have sought to characterize transformations that can be articulated as practices which, in turn, can be used to help students to become successful writers in academic setting and beyond. But how helpful have institutional assessments been to most teachers of writing? Within a broader campus environment, with each assessment of student writing, writing assessors look for evidence of continued growth and maturation, or in other words, sustained development. Often, however, the numbers aren't very impressive, especially to external audiences who might not understand that insignificant gains or even statistical losses could mask qualitative gains in individual students' writing abilities.

Teachers of writing (and teachers who use writing in inter-disciplinary ways) realize that students must become more adept and rhetorically

flexible, to become "rhetorical chameleons" (Russell). Teachers and assessors of student writing continue to look for ways to characterize most of the students who enter and exit writing programs, and they continue to seek models for integrated and sequenced curriculums that will enable all students to mature and sustain abilities in writing (Haswell). Certainly teachers must rely on broader, institutional assessments, as indicators of general trends, while assessors must rely on teachers in individual classrooms to help most students make the transitions expected during their course of study from general education classes into disciplinary discourses. The challenge that most teachers and assessors face is how, when, and where to share their respective understandings so as to create an environment that will sustain student growth in writing.

Many writing administrators assume that through careful assessment, we can find ways to solve the problems that all students bring to academic writing, especially the problem of sustaining development. We also share a presumption that good teachers can take control of students and their life processes as they move through our classrooms and assignments. Assessments based on a broad sample often lead the classroom teacher to believe that if one could just find the right process, and coordinate the right activities, and introduce the appropriate technologies, one could then manage all of the students' assets and resources.[2] But honestly, how much can the individual classroom teacher manage? Longitudinal studies (Walvoord; Sternglass) remind us that there is a good deal of complexity that is permanently beyond our knowledge.

Time presents the first formidable barrier. Across a student's academic writing career with all the starts and stops, and changes in majors, and distractions from life itself (particularly at non-residential campuses), the likelihood of maintaining and sustaining development in writing abilities does not appear to be very high. Given this complexity, some teachers choose to "live more poorly" by ignoring or refusing to deal with the dilemmas of student writing at all (as some also ignore or refuse to confront environmental dilemmas). Many choose to use well-worn formulas to respond to student writing; for instance, some of my colleagues tell any student who has any kind of problem with writing to go to our writing lab where they expect the student to be fixed and repaired. Some avoid having to deal with student writing altogether. We sense that we cannot even manage our own colleagues in the institution. Anyone who has attempted to spread the doctrine of writing across the curriculum knows that salient fact firsthand. Composition teachers and researchers must begin to think of their institutional and academic transition of students as writers within a larger environment, including the broader, more politically charged ecology.[3]

The Struggle to Hold to an Interpretative Tale

As the Director of Writing Assessment at my institution, I oversee a junior portfolio requirement that has generally been recognized as a successful institutional writing assessment. But I struggle to make this institutional assessment meaningful to individual students, advisers, and teachers. As a classroom writing teacher myself, I continuously confront the complexities of fostering each student's unique development. Obviously neither one assessment nor one classroom can fully appreciate the fullness of any one student's development as a writer. But this is a sampling of the water in the stream, an analysis of one sample's development in writing, and the potential for using that assessment to improve the teaching of composition skills to particular students. It's not particularly hard to generalize about a particular sample of students, but it is much more difficult to translate those generalities into useful pedagogical practices.

A "Rising Junior Writing Proficiency Portfolio" is currently our primary tool for institutional writing assessment and writing across the curriculum. I will provide a quick timeline as background for the current environmental climate at my institution (which is constantly changing, to be sure). In 1992, our English Department's developmental writing program received commendation from our state Commission on Higher Education for our use of placement testing to develop a strong freshman composition program. In 1995 we were mandated by our state legislature to eliminate all developmental programs. Thus we were forced to abandon the very program that had just been commended.

In place of the developmental program, the English department decided that the time was ripe to develop a "writing across the curriculum" program. Through a campus-wide Writing Inventory in Fall 1995, we proved that sufficient writing was expected throughout the general education curriculum to support WAC. We chose to ignore a problematic drop in sophomore writing. Since we have articulation agreements with community colleges, we have tended to number courses that might actually be sophomore level as 300+ because we are enrollment driven. Ultimately, we determined that sufficient writing took place in general education (courses numbered as 100/200 which I have labeled as WAC courses) as well as in the disciplines (courses numbered as 300/400 which I have labeled as WID courses). Labeling these courses as WAC or WID assures me that both native and transfer students can reasonably expect to have sufficient writing to complete the portfolio requirement in a timely manner (defined as 60-75 hours of course work for native students, or within thirty hours of entering as transfer students).

The English Department thus mandated the "rising junior" proficiency requirement, modeled indirectly after Washington State's portfolio

assessment (Condon), in Fall 1996. I became Director of this assessment while carrying a full load as a teacher in the English Department. Each student submits four papers and a cover essay (for a total of five submissions per portfolio). Because we have a substantial transfer population, we have been flexible about the types of papers being submitted. We also allow for students who expressed dismay about not having enough papers to submit well past the "expected" submission at 60 to 75 credit hours, and many transfer students do indeed delay submission until their final semester.

By Spring of 1998, after we piloted and gathered enough portfolios to begin noticing trends, three types of portfolios could be defined. About one third of the portfolios are "true WAC portfolios," submitted at 60 hours and characterized by four submissions across general education. These portfolios typically contain papers from English, history, sociology, and a humanities elective (religion, music, drama), thus the WAC designation. Cover essays for WAC portfolios often include rationales for choosing papers from this scattering of courses. In contrast, about one third of the portfolios are submitted after 90 hours. These are characterized by submissions that are related to a discipline, thus the WID designation. Discipline-based portfolios typically come from transfer students who are nursing majors or business majors. Their cover essays often describe a sequence through these students' upper level course work. Finally, about one third of the portfolios contain a mix of general education and introductions to a discipline. These students typically stress in their cover essays that their most significant work is not seen through the bulk of their portfolios. These students characterize their general education papers as weaker submissions and stress that "real" work is demonstrated by one "best paper," typically one inclusion from a 300 or 400 level class in their discipline.

Realizing that we had three types of portfolios, we thus began to question could we characterize and distinguish any common traits or peculiarities of students who were negotiating general education from students acclimating to disciplinary identities? Examining individual students' reflective cover essays (in which they justified four academic writings as demonstration of academic writing competency), we hoped to find overlays of thought about process and products. Could we tease out the students' development as college writers and "measure the progress" of a predictable evolution or transformation from WAC (writing across the curriculum in the general education curriculum) to WID (writing in the disciplines) through this institutional writing assessment? If so, these understandings could be used in faculty development workshops. Information given in these workshops would be used as "tools" by departments and schools to help individual students explicitly to reflect on the

writing expectations of the disciplines as well as the larger academic community. Ecologically, we surmised that workshop information would "trickle down" to improve the entire environment; those of us with the power of knowledge would share that knowledge with colleagues who would share that knowledge with students. Driven by stewardship and inter-disciplinary motives, institutional writing assessment could thus contribute to the betterment of the commons.

Idealism soon met with problems. Many students definitely had difficulties with self-reflection (Yancey). The rhetorical situation of analyzing themselves as academic writers in a proficiency review required each student to negotiate with audience in problematic and challenging ways (Young). Quickly, and long before these realizations, however, the task of examining the portfolios had become institutionalized, and primarily quantitative.

Our assessment relies on the judgments of a departmental committee of four full time professors (who rotate on and off every three years in a small department). These professors conduct the review of the 300+ portfolios that have come in each of the three years to date. We have no masters' or Ph.D. program, so we have no graduate students. We each have, on average, 20-25 years of classroom teaching experience in all levels of composition. We all teach freshmen. We all teach upper classmen. For classroom assessments, each of us relies on personal expectations, judgments and reflections.

For our departmental and institutional assessments of student writing, we rely on a holistic rubric, first developed during the 1980's when we still conducted placement testing for developmental assessments, which we first modified for a Freshman Folder (pre/post) assessment. We further modified and now use this rubric for the Rising Junior Assessment. Our English Department has even wrapped its departmental goal statements around this rubric. We have thus used this scale for departmental assessments (see appendix 3) for many years.

As readers and classroom assessors, this group of professors has read placement tests, freshman folders, and (most recently) rising junior portfolios together for over a decade. Our inter-reader reliability always hits right at 90%. We talk about student papers, we share assignments and concerns, and we deliberate on our goals and objectives in a regular assessment loop. Our students have benefited. This collegial departmental group has obviously had some success with individual students' transformational tales of sustainable development because of our dual roles as assessors and teachers.

The rub of this institutional assessment is that when the assessment reporting moves away from this group of professors, who know the students firsthand through classroom experiences, to those who do not,

this is when we become victims to the interpretative tale of alienation and deterioration. When communicating our conclusions beyond our first hand experiences with a set of student texts, the tendency to generalize takes precedent over individual needs. We must generalize at some point in order to evaluate. But we must also resist the tendency to generalize, especially when examining the larger community, such as when generalizing about the entire Sample. Within the environment of categorization and numbers, what individual features and students can be highlighted in this assessment? Can the institutional assessor fully realize an ethic of caring when looking at numbers instead of individual students?

Fostering An Evolutionary Tale of Growth

In order to test a "defining characteristics" of WAC, Transitional, or WID portfolios, a sample of 60 students who submitted portfolios in Spring 1999 seemed to serve as a valid and reliable group for analysis. This Sample submitted 60 portfolios containing 300 papers: 60 reflective essays, and 240 papers composed across the curriculum and in the disciplines. Three categories were set up to determine whether or not reading a WAC, WID, or transitional portfolio made any difference in the readers' judgments. No student should be misjudged in this competency review, and this classification seemed to be the first place to take unique student characteristics into account. While we have worked primarily from this first question of how much impact the categories have on the readers, additional questions have evolved that have led us into a much fuller appreciation of the complexities involved in sustaining individual development within the larger environment.

Our first question concerned the categories that we had begun to realize characterized the submissions. How much impact did reading a "WAC" or "WID" portfolio have? Our Sample entered as freshmen in Fall 1996, yet submitted as "rising juniors" in Spring 1999. Some of the students were indeed "true" juniors; some were "about to graduate seniors" (several had accumulated enough credit hours to have graduated twice, but had transferred, changed majors, or otherwise built up a substantial number of non-degree related credit hours).

A colleague, who directs our institutional writing lab, and I independently categorized these portfolios as WAC, transitional, or WID. Our inter-rater reliability was close to 95% agreement, and we disagreed and debated the differences between WAC and Transitional more than we disagreed about Transitional and WID. After our independent readings and our collaborative debate, we determined that the Sample of 60 students was quantitatively categorized as follows:

- twenty-three (38%) were "WAC";
- fifteen (25%) were more Transitional (with portfolios that con-

tained primarily WAC papers but demonstrating a definite major focus in at least one paper and in the cover essay); and

- twenty-two (37%) were "WID."

Admittedly, the categories could not be clearly defined for at least a dozen of the portfolios, particularly since most of the WAC portfolios contain one "transitional" paper in the student's chosen discipline. On the basis of both the level of the course and the student's major, a student declaring any major who did not include a paper specifically written for the declared major would be classified as WAC. For instance, a business major who included English, history, sociology, and religion papers would be classified as WAC. In contrast, an English major who included two freshman or sophomore level papers in English or history (200 level) along with two senior level English papers (400 level) would be classified as WID. A nursing major who chose to include two freshman or sophomore level papers in English or history along with two senior level nursing papers would be classified as Transitional. The transitional portfolios typically "house" at least two papers in the discipline. Furthermore, the transitional portfolios tend to explicitly "straddle"; the students seem to be more deliberate in choosing "representative" pieces to demonstrate how their writing is changing as they enter their chosen disciplines. Truthfully, the distinction between WAC and transitional is often not very clear. Enrollment tracking indicates that in fact many juniors and seniors are taking "freshman level" coursework; additionally, some of the choices that freshmen and sophomores make often include upper level courses.

The committee of professors had already met, read, and scored at the time of classification. Each student's portfolio had been read as part of the Spring submissions for proficiency without any discussion of differing types that might be found. After classification, each group displayed a range of scores on the rubric's scale of 1 to 5 (weak to strong). Low scores were defined as 2.8 – 3.3; mid range scores were 3.4 – 3.9; high scores were 4.0 – 4.9 (no student scored a perfect 5).

Even though the committee did not realize the categorizations of WAC, Transitional, or WID, on the average, the categories did, in fact, receive differing scores; in fact, there are inverse proportions of low and high scores between the WAC and WID groups.

8% of the WAC group had "low" scores;
47% of the Transitional group also tended to score "low";
23% of the WID group scored "low."

17% of the WAC group had "high" scores;
27% of the Transitional group had "high" scores;
32% of the WID group had "high" scores.

A second question arose. In the earlier "Inventory" of faculty across the campus, faculty reported that various genres and writing purposes were being assigned and gathered. Were the actual submissions reflective of the "Inventory"?[4] We found the obvious; different departments and schools used writing for discipline-based purposes and expected discipline-based formats. Still, most faculty in every discipline and school noted that they relied on a variety of writing activities. For instance, instructors in math and computer science had identified 39 separate classes in which they assigned writing. However, no graphs, tables, email conversations, web pages, or computer programs have appeared in math and computer science students' junior writing portfolios (see appendix 2).

Additionally, the Inventory survey indicated that instructors in most disciplines were requiring students to submit proposals, outlines, journals, and presentation notes, but none of these have appeared in the portfolio submissions. Generally, many types of writing assignments that seem to foster "writing to learn" are "embedded" or lost in the more formal paper submissions of the portfolio. Students in their cover essays sometimes tell the evaluators that they are deliberately inserting a part of a larger assignment, particularly if the assignment was done collaboratively. Students who detail the processes of assignments also hint at having gone through activities such as note taking and annotations, outlines or abstracts, proposals and presentations, but they only present the finished report or research product for our evaluation. The emphasis on finished product is all too obvious in the portfolio submissions. Thus the portfolio assessment has not provided quantitative evidence that a classroom teacher and proponent of "writing to learn" activities can use to assert that these activities should be used more deliberately across the curriculum and in the disciplines.

Interesting differences do arise when the actual submissions are contrasted to the kinds of writing assignments that instructors reported they gave. The curriculum that we say we offer is different from the curriculum that we see actualized in the submissions. The fact is that students feel that they must submit finished writing, particularly reports and research papers. Furthermore, portfolio submissions do not represent the variety of assignments across the disciplines that the Inventory survey promised, since humanities assignments make up the bulk of the actual submissions (see appendix 1).

To further complicate the Inventory results, some portfolio submissions seem to be hybrids, crosses between the categories assumed by the survey. For instance, an assignment that has regularly appeared in the portfolios submitted by education or nursing majors is a hybrid assignment, a "literature review" that masquerades as a self-reflective piece, typically entitled "My Philosophy of Teaching" or "My Philosophy of Nursing." This paper is appropriately seen by the student who submitted

it as a report of theorists in the field. Typically this paper is poorly written, lacking structure or development of thought. Yet the professors who assign these papers definitely have some expectations; in general, the nursing faculty want a real literature review, while the education faculty desire a personal narrative in response to the call for "philosophy."

Some individual students were making obviously poor choices in their submissions. So a third question arose: why did particular students deliberately chose WAC, WID, or transitional submissions? In conferences with each failed student during an appeals process, some have admitted that they had "better" papers in their disciplinary writing than in their general education courses, but they were deliberately passing over their WID papers when submitting their portfolios. Some students seem to deliberately submit WAC papers (particularly English papers) to accommodate English Department readers. Some students in business, nursing, and the sciences do not trust scorers from an English background to read non-humanities papers. Within this institutional assessment requirement, we obviously need to realize and examine some students' expectations about submitting particular kinds of essays.

Realizing that the portfolios were a treasure trove of information led me next to read through the reflective essays of each of the 60 students in the Sample more closely. During this return to the cover essays, I hypothesized that descriptive traits would be realized (mildly, moderately, or strongly) in each category of portfolio, and I employed the following matrix:

WAC cover essays are characterized by:
- *Expressions of concerns about choice of "topics";*
- *Expressions of personal interest in individual subjects;*
- *Use of grades to determine value of papers;*
- *Justification of paper by "self engagement" instead of "critical review."*

Transitional cover essays are characterized by:
- *Expressions of concerns about "process";*
- *Deliberate use of rhetorical terms;*
- *Expressions of concerns with research elements;*
- *Some display of rhetorical awareness of approaches and modes.*

WID cover essays are characterized by:
- *Justification of topics as "real world applications"*
- *Deliberate use of more audience awareness;*
- *Reliance on jargon appropriate to the discipline;*
- *Expressions of concerns about boundaries or restraints based on instructors' expectations.*

The Director of our Writing Center and I both read again through each cover essay and made separate notes about the students' reflections about their choices and their abilities as academic writers. We read independently and then compared our notes. We were amazed, truthfully, at how consistent our notes were. We had independently noted almost the same kinds of comments, except that I was more interested in students' reflections about purpose, and he was more perceptive about their reflections on grades. Looking closely at the students' rationales while matching their comments to their scores, we realized that cover essays also demonstrated specific and categorical differences.

The WAC group was especially emphatic about personally justifying and connecting to topics.

- 83% of this group either noted or strongly emphasized topic concerns.
- 50% of the WAC group noted (but none emphasized strongly) any concerns with process, research, or use of rhetorical terminology (and those who were "most concerned about research" tended to be the "low" WAC scorers).
- 25% of the WAC group noted (but none emphasized strongly) any "real world" applications, or used any "jargon" that might be related to a particular discipline, or addressed specific audiences deliberately (instructors or the readers of the portfolios).
- A small group of WAC students at the "low" end (all scoring 3.0) used grades to justify their submissions.

The Transitional group was less emphatic about personally justifying or connecting to topics.

- 73% of this group did note their choices of topics, but only 47% noted their personal involvement with the topics.
- 50% noted concerns with process. This group did express more concern about research elements (60%).
- 40% noted "real world" applications; only 25% addressed audience deliberately.
- 50% seemed to be using "jargon" more deliberately.
- Most significantly, Transitional students seemed more "bound" by the models that we provide in a portfolio kit, especially to students at the "low" end who consistently stressed a desire "to reflect a variety" of choices. Their reflective essays seemed to be more redundant and less

distinctive because of this refrain. Our own directions to the students had been constraining to this group of borderline Transitional students.

The WID group was more sophisticated about process, rhetorical terms, and research.

- 82% of the WID group did mention personally connecting to their topics; only 50% of the group emphasized this connection as their justification for choosing the papers.
- 80% of this group noted or strongly emphasized these points in their reflective cover.
- 80% of this group also emphasized "real world" applications and tended to use "disciplinary jargon" more deliberately.
- More surprisingly, this WID group did not tend to "push against" the boundaries set by instructors or assignments; only a few at the "low" end deliberately rebelled or tested their disciplinary expectations.
- The WID portfolios were additionally, as a group, more likely to use metaphors to describe their choices or their processes.
- WID students were also more likely as a group to express "regret" for having a limited number of suitable papers from which to choose, especially noticing if they had no English papers to submit.
- A group of WID students scoring at 3.3 simply listed choices without any real discussion of personal involvement, process awareness, or discipline specific awareness.

This analysis again forces one to confront the particular limitations of institutional assessment, to query generalizations, and to rethink the problems of realizing conclusions to which only a small group of assessors have access. Ultimately, the numbers, once reported, are less significant than the realities about individual students that one can take back to classrooms and conversations with any other teachers across the curriculum and in the disciplines. But the institutional assessment does have power. "Regardless of context, the kind of assessment … changes the game. What you design changes what you can learn. And not least, bringing contexts together creates more than the sum of the component parts" (Yancey). Ultimately, the sample taken from the stream becomes factual data to be used to project and predict.

The individuals who made up the Sample could easily be lost. But their voices must be shared. Writing assessment must not lose the student. These students are not just containers of words without an author. They are real students with real frustrations as student writers who would

benefit from individual and sympathetic assessments, whose individual developments must be sustained.

Following are excerpts from six students' cover essays. The first three students represent the lower scores in all three categories of WAC, Transitional, or WID. These students either failed or were judged to be borderline in their writing competency. Regardless of category, all three students still demonstrate that they have sustained some sense of development as writers. Changes are subtle. But the transformations are real. They each demonstrate evolving maturity in their comments about the process of writing and awareness of their audiences and purposes. They could be sustained in this development as academic writers through effective use of assessment and careful teaching.

- An accounting major states: "Each paper (in general education) has a specific reason for being written and chosen" and "each has been a learning experience."
- A second accounting major adds that the portfolio reflects "the wide variety" of courses taken (in the transition from WAC to WID) and concludes: "the assignments were challenging" but the "effect was satisfactory once completed."
- A communications major concludes, "As a student in journalism, I find it very hard to relate to the standards of an excellent 'English' paper,' (after) being trained in journalism to write in a different way as a mediator… absolutely forbidden to express my own thoughts."

A second group of three students, who represent the high end of scores in all three categories of WAC, Transitional, and WID, also demonstrate awareness of a learning process, as well as consideration of differing writing expectations across disciplines. In contrast to the previous students' comments, the increased development displayed by these students is subtle, but real. Their development as writers could also be sustained.

- An education major concludes that she was "apprehensive" about the portfolio at first, but realized "why it is so important": "the learning process does not stop (because she) worked for months to correct these papers" to her own "high standards."
- A political science major emphasized that "most of (his) assignments are research based" so he chose deliberately to "illustrate the four types of research (he's) done so far (in political science): literary, interview, survey, and self discovery."

- An English major (who started with a simple listing of "a variety of writing assignments" never noted that she is a graduating senior in English, but all the papers come from upper level English classes. After a sophisticated review of her submissions, which included literary analysis and research, she concluded simply: "I know how to plan, research, draft, write, and revise my writing."

Simply, we know these students. We have taught them. We have seen them in our offices, our classrooms. Specifically, I have worked with the first three students after they failed their reviews. The most important contrast that I found in my contacts with all of these students was that these three were defensive. In many respects they set the stage for their readers to react as "others" and to judge them more harshly. They were victims of the rhetorical situation.

And because of teacher "lore," I also know that the sixth student, the English major who scored so highly on her review, suddenly switched her major to psychology two weeks before she was to graduate. She currently has 240 credit hours (having switched from secondary education to English some time ago), but she stopped out of her senior seminar and without speaking to her advisor or her seminar teacher, she redrew her candidacy for graduation and jumped into psychology. Why? The reflective comments suggest why she made this decision, and in hindsight, I see her lack of commitment and her use of the writing process in a very formulaic fashion.

Another significant difference between the lowest and the highest scorer in the WAC category is the fact that the high scorer sought out assistance in our Writing Room since she realized her weaknesses early in her academic career. Yet many of the students who would benefit from Writing Room interventions do not take advantage of this institutional resource. Of course, more questions are now evolving about the role of peer consultants and Writing Room interventions.

Coding and analysis of the Sample have led to additional questions that reach out beyond the classroom into the broader administrative environment as well. In this ecological perspective, this is good and necessary. For instance, if WID portfolios are being submitted substantially "later" in the college career, what effect will reading later submissions have on the scoring of all portfolios? Can we reasonably track enrollment records for students who submit portfolios early and for students who submit portfolios late? More numbers should lead to another need for narratives with implications for retention, another politically charged administrative issue.

One practical question is whether to spend precious research time, while carrying a full teaching load in composition, on examining how "writing to learn" activities can transform individual students between general education courses and writing in their disciplines and sharing those results with my colleagues across my campus. Or is it better to give attention to how students in specific areas – nursing, business – are being asked to address writing assignments that ask them to address conflicting goals such as to report and to reflect? Or is it more efficient to reach out to the administrative and legislative bodies that control funding?

Or is time better spent on individual students? Both classroom and program experiences can support students as they become more rhetorically aware and increasingly confident as writers, even though they struggle when confronted with each new writing situation, as do we all.

Essential questions still nag: what are the connections between our freshman composition courses, between expository and argumentative assignments and the analysis of literature? We even find ourselves as an English department now beginning to grapple with sequencing in our composition program, and questioning what writing in the English major should encompass. I have also begun to walk, gingerly, into the business school with growing awareness about differences between writing in the management track contrasted to writing in accounting. I have had insightful conversations with nursing faculty about their expectations for critical thinking and their attempts to professionalize their discipline by grounding their students in theory. I have begun to explore, with the biologists as well as with the historians, the considerable differences between writing factually or writing interpretively.

Those of us who evaluate especially need to listen to other disciplinary evaluators concerning students' audience awareness, the quality of their thoughts, uses of sources, organizational strategies, stylistic strategies, and – yes - control of grammar and conventions. English instructors are not the only institutional evaluators of student writing (Yancey). It happens all of the time across this campus, and we need to understand each others' motives and expectations in more complex and ecological ways.

These are just a sample of what this evolving analysis of a Sample has initiated. What to make of these in terms of a larger discussion, as a program developer, is the next challenge. Significantly, I firmly believe that the metaphors of sustainable development, including stewardship across a common inter-disciplinary environment should prevail. Ecologically, balance should be struck between the generalities of reporting institutional assessments with the specific, often implicit and embedded idiosyncratic character of the teaching individual students.

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Notes

1 Haswell's 1991 analysis of a sample of students in *Gaining Ground* serves as the basis for this analysis.

2 David Orr's *Ecological Literacy* was the catalyst for extending the ecological metaphor.

3 In South Carolina, because higher education is now funded entirely by Performance Indicators that emphasize graduation rates, all funding for developmental programs has been completely eliminated for all four-year and post-graduate institutions. While assessment legislation has not deliberately set out to ignore individual student needs, the program review process and the emphasis on "closing the assessment loop" does lead assessors to use efficient assessments which basically lump and number students. Mandated formats have resulted in closer examination of goal statements and more expectation for demonstrative results. However, results are easily averaged into single numbers, and thus the individual student's needs are easily lost. I have to ask just what does it mean that any student, as a freshman, averages a 3.3 on a scale of 5 while any other student, as a junior, averages a 3.5. I also have to consider that without more demonstrable "profit," the powers that control the purse strings may condemn and seize these grounds where student writing takes place, particularly if these grounds are seen as sites to be mined or taxed.

4 Results of the Fall 1996 Inventory are available at http:www.usca.sc.edu/uscaonlinewr.wacsurveys.

Appendix 1: Student submissions by levels

(100 / 200 indicate general education courses; 300 / 400 indicate discipline based courses)

Courses that might be WAC at lower levels or WID (in majors like English): 240 papers total:

Humanities		WAC	Transition	WID	total
(Anthropology/					
Communications/	100	37	32	6	75
English/History/	200	18	6	10	34
Music/Philosophy,	300	1	4	9	14
Political science/	400	3	3	9	15
Religion/Sociology/					
Spanish/Theater)					138

Sciences					
(Biology/Chemistry/	100	6	6	5	17
Geology/	200	-	2	1	3
Psychology)	300	2	5	4	11
	400	-	-	-	-
					3

Courses that could be seen as "WID" specific (of 240 papers total):

Business		WAC	Transition	WID	total
Accounting/	200	4	-	-	4
Management/	300	3	8	15	26
Economics/	400	-	-	3	3
Finance					
					33

Education					
(early childhood/	300	2	4	8	14
elementary/	400/	-	2	8	10
secondary/	500				
exercise science)					24

Nursing					
(associate/	100	-	-	2	2
BSN)	200	-	-	4	4
	300/400	-	-	8	8
					14

Appendix 2: The students' portfolios contained the following kinds of submissions:

Information gathering: 10 total
notes from text (0); lectures (1); observations (7); interviews (2)
(Interviews were not addressed in the "Inventory"; nobody turned in class notes.)
Testing comprehension: 14 total
identifications (1); narratives (1); short essays (12)
(Most acknowledged as "take home finals," one was revised as a "diagnostic.")
Application: 16 total
outlines (0); abstracts (16); graphs (0)
(Yet outlines and charts often appeared as part of finished papers.)
Analysis: 2 total
presentation notes (0); surveys (2); computer programs (0)
(Presentation notes were mentioned in some cover essays associated with communication classes, but finished papers were also required).
Focusing research: 10 total
proposals (0); hypotheses (0); critical review of texts (10)
(Some papers were specifically book reports, especially in history).
Organizing research: 2 total
lab journals (0); case studies (2); annotated bibliographies (0)
(Again, these are mentioned in cover essays as part of the process associated with finished products but these "writing to learn" assignments are embedded and "lost" with the emphasis on finished papers.)
Finished products: 163 total
reports (62); essays (41); research/term papers (60)
Self assessment: 18 total
self critique (4); journals (3); creative writing (5); personal philosophies (6)
(Personal philosophies were not part of the "Inventory" but seem to cross over a line between writing to learn and essays or reports.)
Correspondence: 5 total
(All of these come from the same class, business writing.)
memos and letters (5); email (0); web pages (0)

	Excellent		Average		Weak
Rhetorical sophistication	**5**	**4**	**3**	**2**	**1**
audience awareness, purpose, voice	Positions are clear; complexities and various viewpoints are addressed.		Positions are evident, and some attempt is made to accommodate various viewpoints.		Lacks position on topics; superficial; little to no addressing of various viewpoints.
Quality of thought	**5**	**4**	**3**	**2**	**1**
logic, evidence and support	Unified, and strong control of content; opinions and claims are well-supported with ample evidence.		Generally unified; ideas are balanced, opinions and claims are adequately supported.		Little evidence of control of ideas; ideas are not supported, or support is cliché / sloganeering.
Use of sources	**5**	**4**	**3**	**2**	**1**
attribution and documentation	Sources are clearly identified /synthesized; textual citations and works cited are correct.		Mixed use of sources; some synthesis and evidence of citations in text and works cited.		Obvious plagiarism; little to no citation of obvious source material in text or works cited; no synthesis of sources.

Structure	**5**	**4**	**3**	**2**	**1**
unity, coherence, transitions	Ideas are well connected through structural and linguistic transitions; structure complements and completes content.		Some evidence of structural and linguistic transitions; structure is generally adequate for the content.		Overall unity and coherence are flawed; parts are poorly connected, and there is little evidence of planning or organization.
Language	**5**	**4**	**3**	**2**	**1**
clarity, expression, eloquence	Diction and syntax are well-chosen to express ideas; no redundancies.		Acceptable language, although somewhat limited in vocabulary and syntactic fluency		Language errors and limited choices in syntactical forms. Language limits and distracts from expression of ideas.
Mechanics and usage	**5**	**4**	**3**	**2**	**1**
grammar, agreement, punctuation, spelling, other _____	Grammatical structures are well-chosen; no errors distract from meaning.		Grammatical structures carry the meaning forward, although readers notice an occasional error.		Grammar errors are so obtrusive that readers are seriously distracted by them.

Appendix 3
Portfolio Rubric

Examination Retakes in Accounting: Increasing Learning by Writing After the Exam

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The Citadel

Realizing the increased importance of good communication skills to success in the profession, how can today's curriculum help students gain vital skills? One method of combining the need to learn from errors, to increase retention, and to improve writing skills is the *examination retake*.

The examination retake is a learning strategy that can be used on any exam or assignment in any discipline where the professor determines that such an assignment would be beneficial to the class. This procedure involves allowing the student to redo some or all questions missed on his/her graded examination. On the retake the student gives details of the correct formula for problem-type questions or written explanations for non-problem type questions. Retakes are optional and available to all students regardless of their original grade.

Many students freely admit that they never review returned exams. Consequently, they do not utilize, or even recognize, the returned exam as an opportunity to learn from their mistakes. This can result in a failure to retain much of what has been studied previously, or to the retention of incorrect material. This practice is especially detrimental in a discipline such as accounting where content is cumulative.

The accounting discipline requires students to keep current in their work. Given the sequential progression of courses, the accounting curriculum, by its very nature, should provide an incentive for students to learn and retain as much as possible from each course. However, students typically are not aware of the importance of each segment of the accounting curriculum as a building block until it is too late.

The primary goal of teaching is to increase student knowledge. Although there are a number of ways to measure the resultant learning, undoubtedly the most frequently used are tests and examinations where high grades are considered indicative of appropriate learning. However, given the time and effort involved on the parts of both student and fac-

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ulty, a test or an examination should be more than a way of evaluating learning and assigning a grade; it also should be a method of furthering student learning.

In addition to the importance of learning the content of a particular course, most educators would agree that students in all academic disciplines need to have frequent opportunities to utilize and improve their written communication skills. However, it is often difficult to determine appropriate writing assignments in disciplines such as accounting where foundation work consists primarily of numbers and calculations. Yet today's business environment demands that accounting professionals utilize oral and written communication skills daily in a variety of ways. The technically knowledgeable accountant fails in the workplace if he or she cannot communicate relevant information to others (See for example: Accounting Education Change Commission, 1990; Big 8, 1989; Messmer, 1999; Stowers and White, 1999; Gingras, 1987; Henry and Razzouk, 1988).

Nonetheless, the traditional accounting curriculum has been, and often still is, based more on a model of "how to prepare" rather than "how to communicate." Accounting instructors must begin to include more emphasis on communications skills in their curriculum because recruiters base their hiring decisions on both technical expertise and interpersonal skills.

The old stereotype of the number-cruncher hovering over a desk reflects the profession before the introduction of computers. In today's world of more advanced technology, the basic bookkeeping function is performed primarily by computers. Even though the accounting professional is still required to understand the concepts and to know how to perform these functions, his or her more important roles are that of administrator, supervisor, consultant, and advisor. These roles demand good communication skills. Unfortunately, the accounting student often doesn't realize the importance until he or she reports for that first job (Accounting Education Change Commission, 1990).

Accounting students typically select a career in either public or private accounting. Certified Public Accountants act as consultants for their clients, perform audits, prepare tax returns and participate in other consulting engagements. Private industry positions range from that of the Chief Financial Officer (CFO) who is the primary financial decision-maker of a business, to the controller who supervises the organization's daily financial accounting activities.

Procedures for Administering an Exam Retake

Examination retakes can be relatively simple to manage. While grading the original exams, the instructor determines the need for a retake and the number of potential points to be given for accurate completion of the

retake. (Ultimately, these additional points add only minimally to the final course grade. For example, a fifteen-point retake on an exam that represents 20% of the course grade only adds three points to the end-of-the-semester average.) Points should be prorated for the number of problems missed originally and the number corrected accurately on the retake. Points should be based on the accuracy of objective answers ***combined*** with the clarity of the written explanations. Students who do poorly on the retake are targets for additional assistance and tutoring. Students whose writing is substandard should be referred to the school's writing center for further aid.

For the effect to be most beneficial, the original exam papers should be graded and returned as soon as possible to ensure that material is still somewhat fresh in the student's mind. The retake can be done either in class or out, and either with or without text and notes, depending upon the professor's perception of needed research. Students look at the completed, graded exam and learn from their mistakes by redoing all missed problems—hence the term *examination retake.*

Students are instructed to focus on either their original incorrect answer or the correct answer. Calculations must be clearly labeled and discussed. If students choose to concentrate on the original answers, they explain WHY their answer was incorrect. Students who focus on the correct answer explain the correct answer and present the appropriate theory behind the solution. In either case, students write as if they are "teaching" someone else. This gives the professor some insight into the student's thinking and insures that the student does not get the right answer for the wrong reason!

As an example, suppose an introductory accounting exam question is as follows:

> The Unearned Revenue account is classified as a(n)
> (a) Asset
> (b) Liability
> (c) Revenue
> (d) Expense

The correct answer is **B** - Unearned Revenue is classified as a liability account. Assume the student chooses **C** and misses the problem. The student's retake should explain the correct answer or the reason why his answer was wrong. One student might write: ***Answer C is not correct. Due to the matching principle, revenues cannot be recognized until they are earned. An unearned revenue is one that is not earned and therefore cannot be classified as a revenue. This means that the money has been***

received but the services have not been rendered (or the product has not been delivered). Unearned revenue should be classified as a liability.

Another student might, on the other hand, prefer to explain the correct answer as follows: ***Unearned revenue is money received in advance by a business for services that have not been performed or products that are not yet delivered. Unearned revenue is often called prepaid income. The monies received must be returned unless they are earned. Therefore unearned revenue is considered a debt of the business until earned. Debts are classified as liabilities.***

A student who can articulate corrections such as those shown above demonstrates not only critical thinking skills, but also written communication skills. Additionally, he/she gains a stronger depth of understanding of the course material.

The accounting instructor needs to evaluate student writing not only on content but also on mechanics. Accountants and other professionals require proficiency in the basic tools of writing. Today's student who depends upon computer spell check and grammar check functions for mechanics often can camouflage a lack of skills with these technological aids. Failure by the instructor to consider the importance of these skills, including using the computer software correctly, may impede maximum development of student writing skills. Consequently, exam retakes include assessment of the mechanical aspects of student writing in addition to an assessment of content.

At first glance, this seems to be a tremendous additional burden to an instructor's already overloaded schedule. However, there are several "tricks" to administering the examination retakes that make the process less onerous:

· Students should have a clear idea of instructions. Several examples should be given to avoid papers being returned for rewriting, resubmission and, ultimately, a third grading by the professor.

· Not all problems missed by the student need to be corrected on every exam. Specific essays, problems and objective questions can be selected by the instructor to reduce grading time and to focus on concepts most difficult for the class as a whole.

· Students should be required to type their work, to label the correct answers clearly, and to give brief and succinct explanations.

Benefits of Using Exam Retakes

Several benefits occur with the exam retake. The student naturally focuses on the opportunity to improve a test grade. Instructors are concerned with, and see a chance to enhance, writing skills and student learning. Less obvious benefits relate to exam structuring, student motivation, knowledge retention, faculty evaluations, improved higher-level cogni-

tive skills, and a better understanding by the student of exam preparation and structure.

Most professors will confess to curving grades occasionally, typically when the overwhelming majority of the class performs below expectation. Exam retakes, on the other hand, require students to **earn** the extra points. Retakes offer an opportunity to increase an exam grade by demonstrating an increase in learning. Each student decides whether or not to exercise the option of the retake; and, because additional points earned are justified, artificially inflated grade ceases to exist.

Another benefit of the exam retake is the opportunity for the accounting student to write. While "writing to learn" may be a concept advocated by many in the more traditional writing disciplines, accounting often is still perceived as number-oriented. Some accounting students mistakenly believe they always will have a secretary available for their written communication needs. Accounting faculty must clear up this misconception, beginning in the first introductory accounting course. While term papers and other long written assignments aren't always feasible; exam retakes provide an efficient and effective opportunity to practice writing skills.

Sometimes, students express the view that accounting exams are incomprehensible or "tricky." Text and notes that were studied appear to be written in plain English; the accounting exam appears to be written in something worse than a foreign language. Consequently, students who perform poorly on an exam may try to justify a poor grade with the excuse that "the exam questions were not anything like what they studied." The exam retake overcomes this misconception. When required to research their text for the theory and explanation behind a question, students begin to realize how exams are structured. Irrelevant data are no longer seen as placed in a question as a trick, but rather as a way of determining whether the student fully comprehends what is being asked and what is important in making the needed decision. This mirrors real life where the accountant frequently must ferret out irrelevant data on a tax return or in an accounting document in order to focus on the information necessary to perform the calculations.

Retakes may improve student attitudes toward studying for the dreaded exam. The "all or nothing" mindset becomes less of a factor when students receive a second chance to improve their grade. The anxious student focuses on his or her study without the feeling of being overwhelmed. Should the instructor not offer a retake or should the points given on the retake be less than hoped for, the student realizes that peers, on average, were better prepared.

Forcing the student to explain the material and his/her thought processes also benefits higher learning skills. Edgar (1969) found that we

tend to remember only 10% of what we read and only 20% of what we hear. According to *College Reading and Study Skills,* being required to teach a subject results in a 95% retention rate of the material whereas only passively reading the material has been found to result in a long-term retention rate of only 10% (McWhorter, 1995). The examination retake, by requiring students to explain as if they were teaching someone else, pushes student toward the highest long-term retention rate.

Disciplines outside of accounting can reap similar benefits with the exam retake. Randy Boehm and John L. Gland, chemistry professors at the University of Michigan, reported favorable results using what they describe as "a positive learning exercise" after the return of their exams. Boehm and Gland required students to complete a separate "follow-up" exam—one that focused on the more difficult problems from the original exam. The researchers found that students who took part in the exercises had fewer misunderstandings about material covered in the textbook, were "more confident and relaxed," became "aware of the concepts underlying the questions," and "developed more interest and confidence in the course" (Boehm and Gland, 1991).

Our observations indicate greater student satisfaction with the retake method because of the extra points earned and the increased understanding of the course material. Students view the retake as an opportunity for extra credit. Out-of-class time consumption is less of an issue and the text research required becomes less burdensome when students see the opportunity to increase their grades through an "open-book, open-notes" retake.

Examination retakes potentially benefit all disciplines. Writing skills and critical thinking skills represent important components of the development of students in all academic areas, regardless of the chosen profession or field of the student.

Although this learning strategy requires some additional work by the professor, overall, examination retakes are beneficial in that they offer students a maximum increase in knowledge and an opportunity to enhance written communication skills in exchange for a minimum increase in grades.

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Evidence and Interpretation: Teachers' Reflections on Reading Writing in an Introductory Science Course

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Abstract

The use of writing as a means of assisting students to learn and of assessing their understanding in an introductory science course intended primarily as a terminal course for non-science majors is considered in the context of a discussion of cognitive development. We suggest that, particularly where students are asked to justify their understanding by referring to concrete evidence, writing samples are a sensitive indicator of cognitive position. We demonstrate this with examples of four different types of writing used in our course: short answer exam questions, exam essays, take-home essays which may be revised, and informal journal writing. The information gained from writing assignments can be useful as feedback to an instructor regarding (a) an individual student's assumptions about what can be known in science and what form this knowledge takes, (b) what individuals and the class as a whole are prepared to understand, and (c) in what ways particular subject material is likely to be misunderstood. We conclude that these different probes can reveal different aspects of development, and that the use of any of them requires attentive reading by the instructor.

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Introduction

While it is generally accepted in many circles that writing can be useful both to enhance and to assess learning (Kleinsasser *et al*., 1994), introducing writing as an integral part of college science courses remains an elusive goal. This is largely due to the fact that knowledge of science is traditionally thought to reside in such skills as identification of facts (memory) or quantitative problem solving (algorithmic thinking). Thus biology lab "practicals" may require the naming of organs identified by pins bearing numbers, multiple choice tests in several disciplines may involve selecting the correct names of processes and relationships hidden among distractors, and solving word problems can require students to use the appropriate knowledge to balance a chemical equation or find the range of a projectile. Where in these activities is there a place for writing? In this paper we briefly describe an introductory lab science course designed to incorporate writing, discuss the nature of several different writing exercises that we have used, and examine some examples of student writing as a means of demonstrating what may be expected from non-science majors. In fact, in most instances the "prompts" for the writing assignments have been constructed so as to emphasize specific cognitive activities. Thus, not only are we frequently looking to see how the students use evidence to justify their answers, but the writing samples themselves are the evidence that we are using as the basis for our interpretation of the students' cognitive positions.

Despite the activities included in traditional science courses, many teachers who have taken such courses acknowledge that they only *really* learned a subject when they had to teach it. If our goal is for students to learn science, then we must rethink our course requirements to include activities that will engage our students in the same sort of processes that we go through as we prepare our new courses. This does not mean that we have to make our students teachers in fact; we can, however, get them to approach information in a manner that somehow mimics what we do. Outlining is of course part of this process, but for what purpose? and in what context? Most science texts are highly structured, and simply rewriting the chapter and section headings is not what we have in mind. Rather, when we prepare a course, we think of what we will say about each major point. This being the case, it is reasonable that we find ways for our students to do likewise. Because students are less skilled and knowledgeable than we, they should not be required to say it (i.e., organize and present their thoughts orally), but they should commit their connected thoughts to paper. In this way writing can be brought into the science class as the appropriate way to encourage learning.

Foundations of Science

The course we discuss in this paper is *Foundations of Science* (Shahn, 1990). This is a one year course with three hours of lecture and three hours of lab each week. The course is introductory, and can be taken by freshmen. In fact, since it is primarily taken by non-science majors in partial fulfillment of a distribution requirement, it has students at all levels, but the instruction remains introductory. Lab sections are small – 15 to 20 students – and discussion is encouraged in them, covering lecture and reading material as well as lab activities. All sections meet for the same lecture, typically about 75 to 100 students. With regard to content, the course is multidisciplinary in the sense that it covers material drawn from the more traditional areas of astronomy and physics, chemistry, and biology and geology. We have organized the course around three themes, each of which is covered in about 10 weeks. Topically, the three themes deal with celestial and earthly motion, the nature of matter, and the history of the earth and life on earth. Alternatively, these themes can be characterized as dealing with the emergence of the heliocentric model of our planetary system, the fundamentally particulate nature of matter, and the theory of evolution. Each of these stories is treated historically; rather than state contemporary beliefs, we devote our time to following the development of the major concepts that lie at the foundations of science today.

We have chosen this approach for reasons that are discussed in detail elsewhere (Shahn, 1990). These include the idea that this historical approach demonstrates the fact that today's scientific concepts have resulted from a process of continual modification. We believe that, compared to a simple declarative statement, this repeated demonstration is more sound as a way of countering the often implicit belief that scientific knowledge is a form of "truth" that is "discovered" in a form that lasts forever. In addition, we believe that for many students the story-lines that we develop provide a structure that can support the scientific information that on its own may be too forbidding. (Unfortunately, interviews with our students have shown that a number of them view this historical framework as just that much more material that has to be memorized. As will be indicated below, this immediately tells us something about the cognitive positions of those students.) Finally, the use of our narrative structure enables us to show the frequent instances where science is a part of a cultural whole and both depends on the contemporaneous intellectual environment for its development, even as it contributes to this environment.

The content of our course includes material that can be covered in the traditional way. That is, we can ask students to recognize names, reactions and objects, to solve problems dealing with motion and reactions, and to say (i.e. write) something about sequences of discovery or

patterns of events. Because we know that many of our students are weak in math we have tended to avoid an exclusive emphasis on numerical manipulation. While problem solving of this sort is important, if this were too heavily stressed we believe we would be dooming too large a part of the class to poor grades before the course even began. Moreover, given that most of the class has little intention to continue in science, it is not clear that success in algebraic and arithmetic problem solving would have significant future benefit. We have also tried to avoid the necessity of memorizing names and relationships. Many of our students think that such rote learning is equivalent to knowledge (they may have learned in high school that memory is the road to academic success), but we consider understanding that can be demonstrated by giving individual and personal responses to questions to be more important than memorization.

Writing and Cognitive Development

Our approach to assessment, which we believe enhances learning for understanding, is to pursue two different but related uses of writing involving short answers and more extended essays. We have also experimented with informal journal writing which seems to tap yet other avenues of learning. In all cases, we are looking for students to demonstrate through writing mastery of both factual knowledge and understanding. As an audience for their essays, we ask students to choose other students, say classmates who have missed part of the course work; we are not looking for mini-encyclopedia entries or sections of texts. In reading our students' work we can easily see whether the facts are correct; but while necessary, we see this as being only part of the way towards providing a fully satisfactory ("A" grade) response. Beyond this, we look for the way in which evidence is used to justify answers, and the way in which this evidence is initially selected; subsequently described, summarized, or identified; and finally evaluated in the process.

Implicitly, we believe that the successful outcome of the study of science is science literacy (Shahn, 1988), and this entails a growth in cognitive ability. Three models which are relevant to appreciating this statement have been provided by Piaget (1972), Perry (1970), and Kitchener and King (1990a,b). (The following summary provides a background against which our student writing samples can be judged. It is not intended to represent the complexity of the discussions in developmental psychology that have grown out of criticisms and extensions of these works.)

Piaget (1972) identified several stages in the cognitive development of children that to a large extent can be described in essentially mathematical or quantitative terms. The "highest" of these is called formal operational thought, and includes a number of cognitive strategies: the isolation and control of variables, combinatorial, correlational, probabilistic

and proportional reasoning. Related to these is the ability to recognize a contradiction between a prediction and an observation. Formal operational thought follows a "preoperational" stage, in which reality is closely connected to the individual (up to about age 7-8), and an "operational" stage, in which the significance of such reversible operations as addition and subtraction are mastered (by age 11-12). Although Piaget thought that individuals became formal operational by late adolescence, it has in fact been documented that many if not most students entering college do not function at this level (Herron, 1975). It has also been shown that acquisition of this level of thinking can be enhanced by instruction (Lawson, 1985). The spread of abilities among our entering class is further justification for not stressing quantitative problem solving as one of our major goals. But also for this reason we structure our labs with enough time to work through the numerical aspects of data acquisition and reduction.

Apart from mathematically related abstract thinking, concern with the use of language has been part of the history of cognitive development theories from the beginning. In his earlier work ("Judgment and Reasoning in the Child") Piaget (1959) considers such aspects as grammar and logic (Chapter 1), formal thought and relational judgments (Chapter II), and the notion of ideas of relativity (Chapter III) in terms that are not so quantitative as appear later. This association between language and formal thinking has been further investigated by Lawson and Shepard (1970), who were interested in the relationship between written language maturity and formal reasoning. They used a quantifiable concept of the "T-unit" (Hunt, 1965) (involving the number and length of independent and dependent clauses in a sentence) as a measure of language maturity, and standard Piagetian tasks to assess formal reasoning. They concluded that there was a significant correlation between the two for males, but not for females. While language maturity in this study was quantifiable, its relationship to "writing" in a more extended context, and "thinking," remained vague. At best, a correlation was shown to exist, but not a way of using writing samples as an indication of cognitive level.

There are a number of related approaches to describing and analyzing cognitive development which go beyond Piaget. These are called "post-formal operational" or "post-Piagetian." The latter designation may just as well refer to the fact that they were developed after Piaget. As will be obvious, their description does not so heavily depend on quantitative concepts, and many people who might be described as almost innumerate may still place highly on one of these scales. In a sense, Piaget describes cognition in terms of how children *work with* the world, the alternate approaches somehow deal more with how children (and adults) see the world, or *conceive of* knowledge about the world. Most of these post-

Piagetian models grow out of the Perry scheme, originally developed by William Perry (1970).

Moore (1991) has summarized the Perry scheme and discussed it in conjunction with a number of assessment techniques, and the results of some longitudinal studies. Following Moore's approach, the scheme posits 9 positions that have been grouped into four major categories: *I* Dualism (1-2), *II* Multiplicity (3-4), *III* Contextual Relativism (5-9), and *IV* Commitment within Relativism (7-9). The earlier positions (1-5) deal primarily with cognitive growth involving knowledge and knowing, the latter with ethical concerns involving issues of identity and commitment. For our purposes, we are only concerned with cognitive growth.

In *I* (Dualism), the individual's view of knowledge is truth, or fact. This knowledge is possessed by and obtained from specific personal experience and from authorities. Thus this view of knowledge is tightly tied to an approach to education. While position 2 acknowledges other opinions or beliefs, but only as being wrong, people at position 1 cannot even get that far.

With positions 3 and 4 in Category *II* (Multiplicity), the situation changes; this occurs as people encounter discrepancies among authorities. Since an authority cannot lightly be dismissed, these disagreements are seen as reflections of uncertainty, but initially against a backdrop that asserts that certainty will emerge. In the process of confronting and accommodating many sets of multiple answers, peoples' responses change from "We don't know yet" (but we will or we can – position 3) to "We'll never know for sure" (position 4). It follows from this that if we *can't* know, one person's answer or knowledge is as good as another's. Multiplicity is thus tightly bound to what some perceive as relativism.

The movement to position 5 is noted by Moore to be the most significant in the Perry scheme "because it represents a fundamental shift in one's perspective – from a vision of the world as essentially dualistic, with a growing number of exceptions to the rule in certain specific situations, to the exact opposite vision of a world as essentially relativistic and context-bound with a few right/wrong exceptions. This transition [in the view of knowledge] transforms the student's attitudes about learning and his/her role as a learner ...; the self is finally understood to be a legitimate source of knowledge along with the authority ... ." Compared to position 4, position 5 provides significant options because "the person has come to understand the significance of defining rules to determine the adequacy of arguments in specific frameworks; the person has become more comfortable with developing his/her own expertise; the person has explicitly acknowledged him/herself as a judger and a chooser."

Perry positions were originally determined as the result of interviews. An alternative approach in which writing samples were used is

described by Hays and Brandt (1992). They look at the way in which arguments for specific points are structured, as a debate might be, to convince or persuade audiences that are described to be sympathetic or hostile. By looking at the number of instances in which evidence is used in short essays, and the ways in which this is related to the thrust of the argument, they are able to assign cognitive levels to the writers. This approach is clearly cast in terms of situations in which there is a "pro" or a "con;" it is not clear that more traditionally academic subject matter can be treated in a comparable fashion.

Kitchener and King (1990a,b) have developed the Reflective Judgment Model which has its roots in the work of Perry (1970) and John Dewey. It relates cognitive development to a set of assumptions about what can be known and corresponding changes in how beliefs are justified when people are faced with uncertainty. These assumptions develop through seven stages. In (1), which they note is probably found only in young children, "knowing is characterized by a concrete, single-category belief system" based on a person's concrete experience. In (2), truth or knowledge is assumed to be attainable, but possibly still not at hand. For this reason, some people may hold "wrong" beliefs. Kitchener and King say that this stage "is most typical of young adolescents, although some college students continue to hold these assumptions."

By stage (3) the inaccessibility (if only temporary) of truth is acknowledged. "Beliefs," they say, "can only be justified on the basis of what feels right at the moment." They note that "[s]tudents in their last two years of high school or first year of college typically score at about Stage Three." In stage (4) "the uncertainty of knowing is initially acknowledged and usually attributed to limitations of the knower." This does not refer to a mental failing; it means that some things are just not susceptible to knowing. In stage (5) knowledge is contextualized. They say that the reasoning characteristic of this stage is most typical of graduate students. Stages (6) and (7) are characterized by an increasing appreciation of the relationship of knowledge to interpretation and context, and are rarely found among undergraduates.

Both Moore (1991) and Kitchener and King (1990a, King and Kitchener, 1994) discuss means of assigning appropriate positions or stages to individuals. Perry's original work grew out of interviews, and interviewing remains one of the preferred ways of probing a person's view of knowledge. But because it is extremely time-consuming, attempts have been made to develop standardized essay prompts and paper-and-pencil instruments for this purpose.

The results of both approaches indicate that students seem to improve gradually more as a function of schooling than as a function of age alone. That is, older students entering college for the first time will typi-

cally be positioned with their class, rather than with people of the same age who have completed several more years of school. Statistically, Moore (1991) notes that college freshmen have a Perry position of about 2.75, while seniors are at about 3.0. Where students have been followed for a semester, roughly half of them show an increase of 1/3 position or more. Kitchener and King (1990b) observe a change in average stage from 3.6 for freshmen to 3.99 for seniors. This sits in the middle of a pattern that shows continual growth from 2.79 for high school freshmen to 5.04 for advanced graduate students.

It is clear that the Reflective Judgment model is in many ways quite similar to Perry's scheme. In their description of it, however, Kitchener and King choose to emphasize how individuals deal with evidence, rather than on the learning environment in which knowledge is acquired. This makes it a particularly appropriate way to look at how science students approach the content of their courses. Thus, beginning students often believe that science deals exclusively with facts, and see a science course as one in which these facts are transmitted from teacher to student. It takes time for these students to realize that aside from measurements (which, in fact, may not even be exactly reproducible), science is a process of determining relationships among facts, and that this process requires interpretation of facts. That is, inferences must be drawn, and when appropriate, tested.

As for a relationship between actual "scores" or positions and academic performance, it has been frequently noted that when students approach a "foreign" subject (such as science), they are likely to regress, and function at levels below those which they show on other tests.

Writing in *Foundations of Science*

From these points of view, we can now describe how we use writing in science courses. We want students to express their understanding of science in terms of facts, application, and appreciation of the process by which significant generalizations have come about. This latter is part of the understanding that over time, even the most solid concepts of science have been and are likely to be subject to modification. That is, in developing an appreciation of the validity of scientific knowledge, students should also acquire a feeling for the limitations of science. Directed writing provides a means for ensuring that students devote the time and reflection necessary to develop this appreciation.

In Foundations of Science we use writing in two different ways: on exams, and in essays. Midterm and final examinations consist of a choice of 25 of 30 or so questions which can be answered in one or two sentences. The exam questions are selected from a larger number which have all been distributed at the beginning of the term. In all, we have prepared about four questions per lecture which comprise this set. By design, the

answers to these questions summarize the content of each lecture. We hope that students will direct their attention to preparing answers to this small number of questions. Since these are all available, students may check their answers with their peers; if a group agrees on the substance of an answer it is highly likely to be correct. For these reasons, our expectations of the answers to these questions are fairly high.

The second use of writing is in essays. There are four short to medium length assignments (1000 - 2000 words) per term. Three of these are returned to the students with extensive comment/criticism which they can use as the basis for a revised version. The revised paper is then used for grade determination in the course. In addition, beyond the three revised and one unrevised papers that are prepared at home, the final includes an essay question that is written under traditional exam conditions. The exact wording is not distributed beforehand, and there is no opportunity for revision.

Within this general format, we try to make the specific essay assignments increasingly sophisticated. Thus the first essay asks students to define, describe and give examples, but not to explain. The second essay asks for summaries of the use of models in explanations. The third essay asks that lab work be related to concepts that have been covered in reading and class contexts. And so on for subsequent assignments. Thus, we start with facts dealing with what the students actually observed, and descriptions of phenomena in terms that do not require explanation. We then proceed to use more complex relationships, and eventually to require that students evaluate their evidence to justify their conclusions. In the most common example, lab data must be examined from the point of view of reproducibility to establish its validity. By the end of the year, when we ask students to discuss the way in which different geological theories have been supported in the past, or for the type of evidence that supports the theory of evolution, we are expecting a much higher level of performance. We do not accept simple statements that a fact supports or is consistent with a conclusion; we want students to evaluate the evidence and lay out the reasoning that makes it relevant. For students with no prior writing experience it is unreasonable to expect cognitive growth to occur at this rate. But college courses typically do expect students to write some sort of explanatory text, and we feel that by working up to this stepwise, if not slowly, we may be able to help students realize that there really are differences in cognitive positions.

Clearly, the bulk of the student's grade is writing dependent (the only part that isn't is a 10 point contribution from lab work) over which the student has a considerable degree of control. By making writing important, we believe that students are shown that they should take it seriously.

Writing Samples

The following samples will be discussed in the context of their reflection of the students' cognitive level or position. All samples are drawn from student work in *Foundations of Science* at Hunter College. The majority of the students in the course – as in the College – are women, so we have elected to use female pronouns inclusively when we refer to an individual student's work. Our comments will concentrate on two points in the continuum of cognitive development discussed above, the student's relationship to knowledge (is it "truth"?) and the use of evidence. Neither we nor any other group we know of has reported significant cognitive development as the result of instruction in the course of one semester. Moore (1991) is quoted above as observing that roughly half of the students given pre- and post-course tests to determine cognitive position had increased theirs by more than one third, but both he and Kitchener and King (1990b) say that the change during all of college is only about 1/2 of a position. It is not clear how these two findings should be reconciled. In a personal communication, Kitchener notes that the 1/2 figure is based on averages across several non-equivalent samples; she also notes that longitudinal studies show individual changes of up to two stages. In fact, we are not really concerned with determining a student's absolute or relative cognitive position. In what follows we discuss student writing from a "naturalistic" perspective, because we believe that an instructor's awareness of how an essay can be read for purposes other than "writing ability" or scientific content can help in gauging the mode of presentation of material for a class, structuring assignments and providing constructive criticism for the student.

Short Answer Questions

Our experience with these questions has been mixed. Because they are all distributed beforehand, we are likely to see the results of pre-considered answers that have been memorized, or that are recollected. Also, since students are encouraged to study together, this recollection may reflect group effort, and not an individual's abilities. For these reasons, this is not the best way to see how individual students approach knowledge or knowing. In fact, we often see that students get high grades on some questions and low grades on others, indicating that in their preparation was uneven. Thus an average grade of 75 would not mean that the student got roughly 75 percent on each question, but, more closely, got 75 percent of the questions correct. In part, the fact that students do not get all correct answers indicates the way in which students misunderstand questions. That is, their answers are valid representations of what they believe to be correct, even with time to reflect on them. Some students, for instance, will avoid or do poorly on those questions that clearly demand

more abstract reasoning or understanding. Thus the differences that show through on these questions represent the variety of cognitive positions within the class.

The question from which answers will be discussed is one of the few on the final which specifically asked the student to deal with evidence; the others dealt with the more factual aspects of the course. **"What experimental (observational) evidence convinced Count Rumford that heat was a form of energy?"**

The type of answer we were looking for was supplied by one student: "As he rotated a cannon he found that heat was being produced and when he stopped the cannon from rotating heat was ceased and so was the work." A variation on this was, "He observed that when a force was exerted on a cannon, making it spin against a cutting tool, heat was formed. As long as work was done on the cannon, heat was produced. When the work stopped, the heat production ceased." These answers might be edited for print, but otherwise they are "textbook" examples of a long story in short form. They deal with evidence in a context in which a traditional inference is made.

The next answer, on the other hand, is not just "wrong;" although some of the imagery is correct, it confuses description of evidence with explanation. That is, it assumes the concepts that the observations are supposed to justify. "Heat was transformed against a cannon which was rotated against a cutting tool. Heat was exerted against the object to make it move because heat that was being generated was a form of work. When work ceased, the object did not move." The picture of a cannon being rotated against a cutting tool is fine, but heat is being used in too many ways: it is being exerted and being generated. These two usages are connected by "because," which also adds to the confusion; if anything, the second (correct) clause should precede the "because," not follow it. If this student had to name forms of energy, it is possible that she would have included heat, but this is not clear; while she equates heat with work, this may be simply a restatement of the question. Thus, while she may have the rudimentary concept of conservation of energy, she is not at all comfortable in discussing evidence, and may still see all "true" statements as of the same sort. That is, the description of an observation and the reasoned conclusion based on this observation may have the same truth value.

And what should one make of the following answer? "He accelerated two pieces of gum together and shot a ball out of a cannon." This student also has the cannon in the picture, but little else. In a multiple choice context, where the key words in different answers were cannon, phlogiston, caloric, and calx, it is likely that she would have made the right choice, but that would not really have indicated any sort of understand-

ing. In her written answer, however, one can actually see some other aspects of recall, given the context of the course. We discussed inelastic collisions, where mechanical energy was specifically not conserved, and considered the example of two projectiles fired at each other with chewing gum on them so that when they hit they would not rebound. We asked what would become of the kinetic energy, and suggested that it would be dissipated as heat.

A different piece of fancy is seen in this answer: "He observed the trembling and temperature change (very hot) of a cannon after it was fired – concluded that the energy from the collision (inside the cannon) was stored in the form of heat." The ring of truth here is the temperature change of a cannon, but for Rumford this was *not* after it was fired (he didn't fire the cannons he worked with), and not *because* of any collisions (the kinetic-molecular theory of heat was introduced much later, even though this "experiment" provided foundational evidence), and not because any energy was *stored* as heat (as usually described, heat is not stored in this procedure). There is certainly something to work with in this answer, but little to grade.

Finally, these students may know more than they are able to write about. The answer, "He observed a drilling of the hole on a cannon." provides the setting for the evidence, but that's all. In general, time was not a factor with students taking this test, so one cannot justify the idea that she was rushed. More likely, she really was not comfortable with the idea of evidence, and she was trying to construct a minimal understanding that included our story. A similar explanation may account for the answer, "When two objects were rubbed together quickly they grew hot." This is not wrong, but it omits the details of cannon boring, and the fact that Rumford noted that large amounts of cold water could be boiled away. Indeed, the realization that two blocks of ice could be melted by rubbing them together, and hence that work against friction caused heat, is often attributed to Davy. This student may really have a fairly good grip on the subject, but it is not expressed in context, that is, it does not address Rumford's experiences and his line of reasoning.

This last pair of answers gets to the nub of the problem of using short answers as a gauge of any sort of student mental activity – too much may be left to the reader's imagination. Often we are left with less than the hoped-for distinction between a right answer and a wrong answer; we seem to want to know *why* an answer is wrong so that we can distinguish between a wrong answer and a very wrong answer. And here we realize that the *why* above has at least two meanings. In the first place it is "in what way?" Is it a matter of fact that is misstated, or is it an interpretation, or an inference, that is wrong? In the second place it may be "for what reason?" That is, does the student go astray because he or she mis-

remembers; or reasons incorrectly; or is incomplete; or the correct answer is counter-intuitive, and the student is tied to recollections of prior personal experience; or ...?

Nevertheless, because they in some way force the student to go through the motions of formal thinking and justification, short answer questions of this type are still probably more valuable, and for many students less threatening, than the multiple choice questions that would take their place. While students may still have the option of viewing their grade as a sign that they are either "right" or "wrong," they also have the opportunity of seeing how their answers can be improved, and where they went astray in interpreting the statement of the question. Thus the reasoning processes that we hope are the central point of the students' learning experience are also the focus of the students' exams and grades. But in addition to the utility of this sort of question as a means of assisting in grade determination, the answers also provide the instructor who has the time with a clue about the way the student is thinking. The fact that several questions have been asked above, does not mean that we have reached an instructional dead end. Rather, these questions may be used as the framework of a conversation with the student. In this way both the instructor and the student may find out what the difficulty is, and the teaching process will have passed through a door that the use of a different assessment strategy would not have opened.

Exam Essays

The exam essays provide still other insights into what students know, and how they approach knowledge. Because there is more time and space devoted to the answers, they have more opportunity to show what they know. However, because we are not using questions that they have previously seen, we are not getting canned answers, but rather responses that are developed on the spot, and under some sort of pressure. For this reason they are also not edited, and show a variety of human errors.

The question discussed below asked students to **"Discuss the formulas for water proposed by Dalton and by Avogadro, and the evidence used by each."** The subject matter of this question was critical in the development of chemistry at the beginning of the 19 century; Dalton proposed that water was composed of only two atoms (one each of hydrogen and oxygen), whereas Avogadro suggested the still accepted three atom formula of H_20. Not all students had to answer this question – there was a choice – and of those who did, there were a number who ignored part of the answer, often that dealing with evidence. Another frequent confusion was the use of Avogadro's EVEN hypothesis (Equal Volumes of gases at the same temperature and pressure have Equal Numbers of

particles). We spent time on this in class, and its inappropriate inclusion seems to reflect partial knowledge, or simply an association.

The essence of a complete answer is shown in the following. It not only discusses the formulas in the context of who did what, but alludes the reasoning processes that are ascribed to Dalton and Avogadro. In this sense it ties together the process of science as we see it today, and by comparison indicates how it has changed. "Dalton and Avogadro used different techniques in determining chemical formulas for compounds. Dalton based his formulas on work done by Lavoisier whereas Avogadro based his formulas on work done by Gay-Lussac." [The work of Lavoisier referred to here consists of three parts: the identification of elements as simplest types of matter, the generally accepted notion of conservation of mass, and the beginning of the realization that chemical reactions take place between fixed proportions of the masses, or weights, of substances. Dalton used this as the basis of his atomic theory. In this context Gay Lussac is noted for making critical measurements of the ratios of the volumes of gases that combined with each other in chemical reactions. He concluded that not only were the masses proportional, but in the case of gases, so were the volumes. Avogadro inferred from this that equal volumes of gases must contain equal numbers of particles, even though these particles could not be seen or counted.]

"Dalton believed that elements combined in simple ratios. So his chemical formula for water would be H + O –> HO. This would mean that one [sic] volume of Hydrogen would combine with one volume of oxygen to [produce] one volume of water.

"Avogadro was familiar with Gay-Lussac's law of combining volumes. This law found that [two volumes] of Hydrogen would combine with one volume of Oxygen to make two volumes of water. Avogadro then found the chemical formula for water to be H_2O. He found that in their natural state, Oxygen is O_2 and Hydrogen is H_2.

"Dalton and others could not accept this but eventually they had to. By using the formulas H_2 and O_2 in other experiments it was found that elements combined in fixed ratio relations but not always in a 1:1 ratio."

This answer refers to the requested evidence in two ways. In the first place it uses the accepted shorthand of mentioning the names of the people who did the work – Lavoisier and Gay-Lussac. Then it goes further to give the main thrust of their observations and summary conclusions, especially the latter. Finally, it summarizes the reasoning used by Avogadro, and contrasts it to the beliefs of Dalton. In the context of this course, this answer is excellent. It shows the student's grasp of the both the scientific (i.e. phenomenological) and historical facts, and how they are related.

The following answer gets off in the right direction, but the writer doesn't seem to know when to stop. It's similar to the young child who

continues counting cars on a train after the train passes – the concept is not quite fixed. Evidence is mentioned, mostly in appropriate places, but it does not seem to be really digested. This student is using a rote approach (even though this particular question had never been asked), and will most likely build understanding on top of it. "Dalton believed in the atomic theory but believed that atoms combine in simple 1 to 1 ratios which tied in with Lavoisier's law of conservation of mass. According to Dalton water would be created by 1 atom of Hydrogen combining with 1 atom of oxygen to get 1 [atom] of water, which is true [sic], but Avogadro found when using electrolysis on water (which separates the hydrogen from oxygen) there was twice as much hydrogen as oxygen being separated out. Dalton felt that this could be explained by saying that perhaps hydrogen atoms are bigger than oxygen atoms and take up more space. Avogadro didn't think this was the case. He believed that elements could contain perhaps more than one atom in combination. The smaller atoms move faster than the heavier atoms bouncing off the wall of an enclosure more frequently than the heavier slower atoms." The last sentence has gotten off into the details of the kinetic-molecular theory, which was beyond the scope of the question.

This next student misinterpreted the use of the word "formula" in the context of the question. She wrote: "In this time, Dalton had his way of writing the chemical formulas which were circles in different amounts describing the compound. Avogadro had written his formulas in symbols according to their Latin meaning. This made it easier for the formulas and compounds to be understood. They were more like symbols than circles. It was less of a hassle to remember, and draw on to the paper." In answering in this way she completely ignored the last part of the question asking what evidence was used. Is this an instance of simple mis-reading, or of the fact that the concept of evidence was so foreign that it was not even seen?

By comparison, this answer shows that the student knew what evidence was in principle; it is part of the structure of her essay even though there are many mistakes of fact. Despite this, the justification for the "feelings" and "beliefs," that is the reasoning, is lacking. "Dalton felt that everything combined in a one to one ratio so he expected water to look like HO, while Avogadro believed that water combined as H_2O. Not all formulas will combine in a one to one ratio as they all have different weights.

"Dalton felt that 1 vol of hydrogen plus one gram of oxygen is equal to one volume of water. While Avogadro believed that 1 volume of hydrogen plus one volume of oxygen would give 2 volumes. ..."

The following sample ends with the personal parenthetical note to the teacher: "I know this is not well written and vague and sounds stupid, I can't explain how difficult it is..." In fact, it hits a number of the key points

very well. "Dalton and Avogadro disagreed about chemical compounds. Dalton believed that fixed numbers of atoms of one element combined in the same number of fixed atoms of another element to produce molecules. He believed in the simplest 1 to 1 ratio and, so, concluded water for example, to be one atom of hydrogen and one atom of oxygen or HO. He worked with data provided by Lavoisier and believed that atoms were indestructible and indivisible.

"Gay-Lussac determined relative atomic wts and Avogadro's hypothesis was influenced by the atomic wt of particles. He determined that molecules could combine according to volume but the atomic structure of a molecule could be that of more than one atom of a same atom combined with a different number of atoms in another element although the simplest ratio was used. He thus observed that a water molecule could be two atoms of hydrogen with one atom of oxygen.

"This was controversial at the time, because scientists believed that "like" atoms would repel each other. The bonding principle of atoms of the same element was difficult to accept.

"Dalton believed in the simplest ratio of atoms combining only on a one to one ratio so could not accept this theme. Avogadro proposed that the volume could still be proportional with the same number of particles, but they could be rearranged in proportions [with H_2O] as the simplest form..."

The organization of the next essay, as well as its general literate tone indicate a high degree of understanding, but while it refers to the sources of evidence, it still manages to avoid detailed discussion. This is possibly due to the student's feeling that she really didn't understand the details. However, the structure that is presented here is certainly one that could be filled out. In reading this it is also interesting to note the care with which a number of distinctions are made. At this stage in the development of the atomic theory, there is a real conceptual difficulty in distinguishing among atom, molecule, and particle, and this student's response indicates an awareness of these problems. Her discussion of Avogadro's concept of the water molecule seems to touch all bases.

"... Dalton's point of departure was his belief that atoms were the simplest form of any element and it logically followed that they would combine in the simplest possible of ratios. Inherent in this concept was the belief that one particle of something would only have one atom. He took details of his theory from the work of Lavoisier, who showed that the sum of reactants in an experiment were equal to the sum of their individual weights – so Dalton interpreted the combinations of particles to be in the simplest forms possible. He hypothesized that water could only include one particle of hydrogen and one of oxygen and that they each had one atom each. He used the work of Lavoisier on conservation of mass, experi-

ments in combustion, and the reactions of elements with each other to back up his hypothesis. ..."[Here, and in the next sentence, the knowing reader will be able to follow the argument that is being presented, but the reader lacking specific knowledge will not be able to infer the specific evidence being referred to by names. This is where a detailed discussion would have helped.]

"Avogadro analyzed the work of Gay-Lussac concerning the combinations of substances and proposed that particles could contain more than one atom and combine with different ratios than Dalton had thought, and that a water molecule could only logically be constructed by the combination H_2O. His own notion [was] that each element had its own unique number of atoms per particle with which to combine, and that many of the ratios of common elements ... were always made with fixed proportions ..."

In the discussion of short answers we observed that the constraint of space might have made it difficult to interpret that student's intentions. In the several examples of exam essays just given we see that an incomplete answer might often be accounted for in a number of ways. In some cases it may seem clear that the student probably couldn't have done any better, but in others it may be that the limitation was a combination of reticence and inexperience. Even though our course had been concerned with the use of evidence, and this concern was exhibited in both the reading assignments and the way in which the corresponding material was discussed in lectures, and we had asked students to consider this aspect of the work in essays during the term, we may not have adequately indicated what our expectations were. Our recommendation to people planning to introduce a writing component in their courses would be that they be scrupulously clear to their students regarding the general nature of their expectations, and specifically how these expectations should be met.

Essays

Our experiences with more formal student essays have revealed several features that have been obvious to any reader trying to get past the question of whether a particular answer is "right" or "complete." One of these deals with definitions; many students confuse a particular example with a more general consideration. For example, "An angiosperm is a rose," rather than "An angiosperm is a member of the group of flowering plants." Beyond this is the issue of description; here the common problem is a confusion between an explanatory account and an observation. Even when this is the accepted explanation, it might not enable the reader to recognize the object or event independently. An instance of this sort of error is describing an eclipse as the passing of the moon between the earth and the sun (a solar eclipse), or into the shadow of the earth (a lunar

eclipse). While these explanations are correct, they do not convey the experience of either kind of eclipse. Last in this chain of accounting for events is the process of explanation; here students are often unable to string logical arguments together for more than one or two steps. This apparent inability to write clearly may well be correlated with a difficulty in reading with understanding as well. If so, this would be indicative of a need for changing instructional strategies so as to emphasize these particular rhetorical devices and provide students with the opportunity to master them, particularly early in an introductory course.

Other features of student essays reveal the students' preconceptions of the nature of scientific knowledge. Most simply, some students believe that science gives "true" answers, and that declarative statements are the hallmark of science. This is often seen in conjunction with the use of explanations when descriptions are requested. Strangely related to this is the fact that while many students refer all knowledge to themselves and their own experiences, they do not include in this experience an emphasis on clear observations; rather, they seem prepared to settle for an impression. More demanding yet is the ability to summarize and generalize; many students simply repeat what they find in their source and make no attempt to reduce it or relate it to other things they may know. Finally, there is the issue of being able to draw a conclusion that ties together the substance of the paper. The poor results offer platitudes reflecting the value of the progress of science; the good ones show a considerable degree of reflection.

In the context of reports on lab experiments these problems can all be seen to a greater or lesser extent. Most significant for all of them is the difficulty in dealing with evidence – in recognizing it, describing it, relating it to other contexts, interpreting it, and evaluating it. Indeed, these are the hallmarks of the measures of reflective judgment discussed by Kitchener and King (1990a,b).

The examples given below are identified with individual students by capital letter, and by the number of the essay. The same letter indicates the same student.

Our first essay deals with the roots of science in explorations of different kinds of phenomena. The assignment follows two hours of lecture and discussion in which we suggest that science has grown out of attempts to account for human experiences with and "outside world." It asks students to distinguish among (i.e., define), give some examples of, and describe periodic, episodic and craft-based phenomena. We are looking for awareness of personal experience with this outside world, and the ability to discuss it objectively. That is, we want students to demonstrate an awareness of those aspects of experience which are shared with other people, and to be able to describe clearly observations which may be

considered "evidence." We realize that this may not be the students' natural way of looking at things, but we believe that this is a way to introduce them to the way of the scientist. At this stage we are not looking for interpretation, evaluation or reasoning based on this description. Nevertheless, students' preconceived views of what science is – and what knowledge is – are sometimes seen in these answers.

(A1) One student's paper shows her inability to separate herself from the world. She writes: "Another example of [periodicity] would be my role as a student. It's the same routine over and over, I get up at six o'clock in the morning, eat breakfast, take a shower, get dressed and leave for school at eight o'clock in the morning. This is everyday. Now my schedule of classes isn't the same due to the fact that it's different classes everyday, different break hours, and everyday it's a different time when I go home. A third example would be the direct and retrograde motion of the planets; their movement is always either in the direct or the retrograde motion." While we were looking for personal experiences, we wanted them to be related to the outside world, and specifically to phenomena which were a stimulus for inquiry in early science. This is in part touched on with the afterthoughts dealing with the motion of the planets. One cannot tell from this example why this student did not focus more quickly. Did she not read the assignment carefully or consider it before she started writing? If so, then the remedy to be suggested is simple to give, and simple to adopt: think before you write. But if her approach was more dictated by a worldview which does not involve much consideration of phenomena in a natural setting then no such simple prescription is available. The procedure might be to find some way to engage the student in a one-to-one conversation as a prelude to giving any advice. If this is the approach to be adopted, it is clear that the commitment has to be acknowledged in the planning stages of a course, and reasonable time has to be set aside to pursue it.

(B1) By contrast, the following sample shows a more appropriate use of personal experience. "Not willing to admit defeat easily, man quests for knowledge in order to control nature. To accomplish this we see the need for an understanding of the world we live in. Perhaps this is what inspired us to literally get above it. One way to do this is aboard an airship such as a Zeppelin, a blimp. It took a questioning mind, a few disasters, more experience, knowledge and skill to create and perfect this desired phenomenon. First man had to discover the potential qualities of hot air, and then, those of gases that exist in nature, specifically helium and hydrogen. Next he had to apply his findings and develop the means to capture the gas and navigate it up to send us soaring. I saw one the other night lit against the black sky and moving so slowly between two skyscrapers. It was brilliant yet ominous. I thought, "What a strange phenom-

enon. I mean what a fascinating, craft- based phenomenon!"" While this is more modern technology than an example of craft-based phenomena that lie at the foundations of science, it is still an example of how one can generalize personal knowledge and relate it to a larger context. We must realize that few of our students have first-hand experience with metallurgy, glass making or ceramics.

(C1) Another student shows the common problem of looking for truth in short statements, and of confusing description with definition and explanation. "Hurricane seasons are periodic because there is a season for hurricanes in some part of the world. Typhoons are periodic. Places where typhoons are periodic are China and Japan. The area is mostly surrounded by water and that causes typhoons whenever the seasons come around." Some of these statements are wrong, and others may just be debatable, but that is not the issue. Even if these were totally correct statements, they would not address the question of defining or describing typhoons as examples of periodic phenomena. In fact, of course, they are not; the seasons in which they occur are periodic, but the typhoons themselves should be considered episodic in the language of the question.

(D1) By distinction, an example of a good description is the following. "To the ancient observer, one pattern that changed with some predictable regularity was the rising and setting of the moon, which assumed different shapes in a regular cycle. They observed the moon at its smallest crescent shape, when the convex side was facing west, and saw that the moon in this shape would set right after the sun. [They noted] that when the moon had filled out to become a half circle, it would take more time to set, a full six hours after the sun." Her transition to a discussion of episodic phenomena shows a recognition of the distinction between precise knowledge and indeterminacy. "People then began to distinguish between phenomena which occurred on a regular basis, and events which recurred from time to time, but were difficult to predict. These are called episodic phenomena. With episodic phenomena, one can only assume that an event may recur, but this is unverifiable, and cannot be accurately predicted. For example, many scientists agree that California is due for a major earthquake along the San Andreas fault within the next twenty years, but they cannot determine the exact date, because earthquakes do not occur with precisely predictable regularity."

(E1) In addition to the dependence on declarative sentences, the confusion between explanation and description is shown in the following. "A lunar month is the average time between one new moon and another. The standard time between a new moon and another is slightly more than 29 days. The moon moves forward in its own orbit, while the earth has been rotating, so the earth must move farther than a complete rotation before "catching up" with the moon. Thus more than 24 hours pass be-

tween moon risings. The period of the moon's revolution is used as the basis for the calendar month." This passage has the form of standard scientific prose, but aside from avoiding the process of description, its concluding statement is wrong, that is, not in accord with convention. The length of the calendar month may at one time have been connected to the lunar "moonth," but it is now a matter of consensus, and is independent of the moon. The middle sentence, dealing with the relative speeds of the earth and the moon is also open to a considerable degree of questioning. Specifically, consideration of a detailed model of the currently accepted motions of the earth around the sun and the moon around the earth would probably show that the moon has to catch up with the earth, not vice versa. But note where this criticism has taken us: instead of describing a phenomenon, which was called for in the assignment, we are discussing a model, and in particular the language needed to describe the model. In the long run this may well be a critical part of the process of science, but that is beside the point of asking students to master the technique of description of their own experiences with commonly encountered phenomena.

(F1) Typical problems arose with the examples of an eclipse and the tides. In this selection, both appear in the same paragraph. "A solar eclipse involves either partial or total darkening of the sun when the moon comes between it and the earth. A lunar eclipse occurs when the earth's shadow is cast on the moon leaving it partially or totally darkened. Tidal action is caused by a combination of the gravitational attraction between the sun and the gravitational attraction of the moon. This combination causes an accumulation of water in both oceans and seas at two opposite points on the surface of the earth. As the earth rotates it has a series of two high tides and two low tides each day." It is clear that this student "knows" the material. In some contexts this response would earn high grades, and quite possibly she has been rewarded for this sort of answer. In this paper, however, she is confusing explanation with description in a way that shows little or no reflective thought; neither is presented in any depth. Thus it is likely that a person familiar with eclipses only from this description would be able to identify one should it occur, but it is highly unlikely that the ebb and flow that is experienced at the seashore would be associated with the account of the tides that is presented.

(G1) The conclusion of an essay may provide considerable insight into where the student is coming from. In this first essay we are asking for relatively little in the way of "higher level thought processes," and thus the conclusion we are looking for is rather modest. Nevertheless, we have this sample: "Our curiosity may not ever be satisfied because we are delving further and further into space as time passes, but at least we have a basic idea of how our world and heavenly bodies surrounding it be-

have." The paragraphs that preceded this were in fact quite good, but such an end seems more like the hero riding off into a sunset than a reflection on what has been discussed. Having said that, however, it is not immediately clear how an instructor should respond. The question of why the student chose to conclude in this fashion remains unanswered. Was she responding to previously learned ideas of the proper form of essays? Was she searching for some form of closure in terms of her own needs? Was she expressing her beliefs regarding general human motivation? And if the latter, were these long-held and carefully considered, or were they born out of the assignment? Clearly, answers to these or other similar questions are needed; how one encourages a student to grow, and the types of growth to be expected will depend on the ground in which this growth is rooted.

In our second essay we were looking for an ability to summarize old arguments, and equally important, for an understanding of what a "model" is and for ways in which evidence can be used as a reason for accepting a model or for changing it. Specifically we were asking students to consider early models of "the universe," to identify these models, name a person associated with each, describe the problems (i.e. the phenomena) they dealt with, and indicate how (outline the reasoning by which) the model accounted for the phenomenon in question. In this essay we are approaching the difference between science — and its concern with an outside world – and other disciplines.

(H2) This student had shown in her first essay that she was unusually able to revise her first draft; she went far beyond the all too typical minimalist approach of simply changing the "offending" word or grammar that had been marked on the first reading. On the first draft of the second essay her descriptions were commended. For example: "Heracleides, a contemporary of Aristotle, proposed a model in order to simplify Aristotle's model of the Universe. Heracleides proposed that if the earth was rotating on an axis, this would produce the same visual appearance of the celestial objects moving although they would in fact be still. [H]e observed that this would explain why objects appeared to move in smaller circles in particular areas of the sky and larger circles in other areas. He reasoned that when the stars are located closer to the axis of the earth in motion, that they would appear to move in smaller circles, and those objects further away would form larger circular motions. The visual appearance produced in the sky of the planets apparent motion is one that people are able to observe on earth. This new theory of Heracleides eliminated the extra spheres of Aristotle's model since he no longer needed to account for the motion of the celestial sphere." In spite of this relatively sophisticated passage, this essay concludes: "From the examples outlined throughout this essay, it is evident that the models proposed by various scientists

have allowed men to become aware of the many possibilities that can account for phenomena. Conclusively, models are the basis for scientific explanation which will always be beneficial towards man's constant exploration of phenomena." This peroration puts science on a pedestal, and does not recognize the importance of the use of models that had been so well described earlier.

(I2) A better conclusion, which did not follow as competently written descriptions of particular models, is the following: "Models are a way to explain how a particular phenomenon may occur. However, just because a model can provide a possible explanation for a phenomenon, it isn't necessarily an accurate explanation. Philosophers have and are presenting models that disprove the theories behind some models as well as reinforcing the theories behind other models. Hipparchus developed a model that enforced Aristotle's theory that the earth was the center of the Universe. Later philosophers presented models that contradicted this school of thought. Through reasoning and observations philosophers are constantly using and changing models to develop a better understanding of the universe." This sample is interesting in that internally it uses evidence of a historical nature to substantiate the conclusion that it is presenting.

(J2) Another example of how the goal of this essay can be realized is presented in this sample, which is included here as a demonstration of how much room there is for individual expression in the context of essays. We are not looking for uniform answers. "The Greeks, through many hundreds of years, had developed an approach to scientific problems which would eventually lead to an understanding of how the universe functions. They had learned the value of models, particularly mathematical schemes, in realizing the relationships that existed among the celestial objects. They had learned to test speculative theories against observations – to use empirical knowledge to validate or disprove theories. This was a large step in the direction of a modern scientific approach." Of course there is room for discussion here, but not for pejorative criticism. But it is the type of discussion that one expects to have with advanced students, not those taking a freshman course. Which again points to the utility of using essays in introductory courses. Given the time and the commitment, it is possible to approach each student at her level, and not be bound by "right" and "wrong" answers. In this case the fact that the Greeks used their observations of the otherwise unapproachable heavens as a test of models could be contrasted to their avoidance of theoretical and experimental approaches to other aspects of their world

(B2) This woman's writing has been presented before, and will appear again. It is recognizable for both its extremely personal style and for its competent way of dealing with content as well as for the cognitive

position it illustrates. "Heracleides discovered, much to my content, that Aristotle's model could be simplified if he reversed the order of things and rotated the earth, instead of the celestial sphere, eliminating all the extra spheres that were needed to cancel out motion. [Consistent] with what he observed, if the earth were spinning smoothly and slowly things on it would appear to be stationary but the heavens would appear to be moving. Like Plato, Heracleides succeeded in shifting our perspective tremendously.

"In conclusion, I am inclined to repeat myself and say how difficult it is to put myself in the early Greeks' position. To look towards the sky when one's mind is full of questions is common among all men, but it is those like Plato, Aristotle and Heracleides that, remarkably enough, found answers. Although the quest for an understanding of the motions of heavenly objects underlies the work of all three, each had previous information to either accept and build upon or reject and change in their own models. It is here, in these models that I come closest to seeing this as they did, a change in my present perspective. Their use of the model was to get them to see, to understand, to know what I have knowledge of today. My use of the model is to follow their progress, their reasoning and the evolution of heavenly knowledge; the ability to see what I cannot see with the achievements of man embedded in my mind; and perhaps, most importantly, to understand why I accept what I do today as truth." This student's first person exposition makes it clear that the writing and the ideas are hers. In some of the more descriptive passages this type of conclusion is less clear. In fact, in many places where the source of information is the reading material that we have assigned we simply see it copied or only moderately rephrased. This poses a problem, but one that can be addressed in a number of ways. Making sure that one sees samples of the students' own writing can be assured if a specific personal interpretation is requested, or, in a lab context, if descriptions of the students' own procedures and/or observations are part of the assignment.

In the third essay we asked students to summarize the beginnings of the modern mechanical view of the world and relate it to a series of associated lab exercises. Particularly, we wanted students to focus on the use of procedures to obtain data as a means of testing or validating "laws." In this context we see data as evidence, and the way in which it is handled as one means of observing a student's cognitive position. As indicated above, this is an occasion where we do get at the issue of seeing a student's own writing and thought processes because of our emphasis on specific lab-related observations. Interestingly, this is also the case where we often see discrepancies between the way in which students relate vicarious experiences encountered through words and the way in which they relate their own experiences which do not have a verbal component associated

with them. In some cases it would seem that vocabulary exercises would be extremely valuable, but we have not developed any of these.

(K3) A particularly articulate student started her paper with a lengthy discussion of her view of "modernité" which she conceived in very broad terms. She writes, "Frankly, I believe the Egyptians and the Babylonians were as modern in their view of acquiring knowledge about their world for practical, functional reasons as the civilizations that followed and benefited from them." Several paragraphs later, after referring to the astronomical observations of the Babylonians and Egyptians, and the functional role of their knowledge, she asks, "In this so-called modern, electronic age, do we always ask how a computer chip does its work in order to be able to use it? Our concept of what is modern may, in fact, only be a scientific "second-coming" or a scientific difference of opinion." She continues, "Having a "modern view" of our universe is neither better, nor worse, than not having one. It is merely another point of view and seems relative to one's cultural and/or philosophical values."

This student clearly writes well, and is familiar with a range of material that we do not cover in the course. Her conclusion is certainly not unique. What is disturbing is her lack of distinction between knowledge about the world, and about man-made devices, and the fact that the latter are designed to perform in certain ways on the basis of other knowledge. Further, in her last quoted sentence, despite its overt relativism, there is an implicit denial of the use of evidence in creating a scientific view of the world. Given this conclusion, it may not be coincidental that this student described the experiments and summarized the "desired" conclusions of confirmation, but neither gave nor discussed any data.

(D3) More to our liking was the discussion by a student introduced above. "Through this series of labs it became evident that the process of experimentation is an essential tool in verifying scientific theories. The fact that each person in the class (or each pair) was working independently and all arrived at similar or related answers, to me proved that the results were reproducible and verifiable. We also saw that they were reproducible by the fact that we often repeated portions of the experiments numerous times and they came out relatively the same each time. Before conducting the experiments, we worked out the expected results with help from the formulas in the theories we were testing. In almost every case, the results of the experiment came very close to our predictions. In cases where it did not, the discrepancies were mostly attributed to human error. If they hadn't agreed at all, I would have interpreted that to mean that either the hypothesis was faulty, or the experiment was not appropriate for testing it, or there were major mechanical problems with the scientific instruments of the experiment. In general, experimentation is an extremely valuable tool in making abstract concepts tangible, and the theories we

tested became more convincing once we saw them illustrated three dimensionally. It would be extremely difficult to digest these complex theories if we had only read written explanations of phenomena which are difficult to conceptualize, and it would be ironic to study motion in the classroom if we didn't incorporate some hands-on activity in our analysis, and were always standing still." Our feeling is that the kind of appreciation of experimentation and data as represented by this essay is a more appropriate goal for the sort of course we have put together than would be a line through a set of points, or a statistical test of significance for a particular null hypothesis.

(B3) This woman, whom we have also met before, concludes her essay, "In the end, I feel quite satisfied that each hypothesis we set out to test was confirmed through these experiments. My new understanding of the methods developed by Copernicus, Kepler, Galileo and Newton, and their theories of motion, certainly would assist me in reproducing these experiments with similar results. More importantly, this experience gives me a foundation from which I may approach future situations where the process of "scientific method" is imperative. I won't dare say for sure, but this knowledge may just have more potential energy taking me closer to the moon than the Bible does. But then again, who knows?" As in the previous example, it seems clear that this woman knows what she's come up with. Both women display a degree of humor in their writing, which is not typical for scientific prose, but in this case that doesn't really matter. The difference, which is one of style, and not related to degree of success in the course, is that the woman whose work is quoted in this paragraph seems to take the enterprise more personally.

(L3) Another example of growth is seen in this sample. While her treatment of specific data was not as strong as we would have liked, her discussion of errors, and of the development of science both show the beginnings of a personal understanding.

"The experience of labtime is helpful in having a "hands on" relationship with experiments. In the process of verifying laws/theories, I found that our experiments were reproducible but our calculations did not always agree with our observations. I learned that even though our results didn't match up with our expectations, that it didn't mean that our hypothesis was wrong. I learned that in experiment we had to allow for errors. Errors can be caused by reaction times as in the experiments in lab 6, or just human errors as well as mechanical error. Averaging is also important because we can never really get an exact result.

"In conclusion, I would like to note that integrating the experiments with the development of a new modern view has helped me to see the whole story as one big piece rather than bit by bit. We saw how gradual change led us to a new modern view. There was a sort of domino effect as

each scientist knocked down an idea of the one before. We saw how Copernicus got rid of Aristotle's idea of a geocentric universe, how Kepler got rid of circular spheres, and so on. Learning how we came to today's conclusions has allowed me to better understand the laws of motion. My only gripe is that just as soon as I become comfortable with one theory, I am bombarded with the next."

Despite the gripe, it is clear that this student is reflecting on the material being covered. She has introduced her own analogy for concept modification. So, even though she complains of the pace of the course, she was able to grasp both our intention and the historical development of these concepts.

The fourth essay deals with the modern origin of the study of gases and asks that the work of four men be considered jointly. In a sense it is a "compare and contrast" exercise, but in addition we want the use of evidence to be considered, as well as the validity of using the behavior of a spring as an analogy for the compressible nature of air. Although as in the third essay we are again asking students to use evidence in an historical context, the events discussed are not so obviously sequential. This makes the structure somewhat more complex. At this point – after three revised essays – it is often possible to note changes in a student's sophistication as seen by her reliance on evidence to justify conclusions.

Many students followed the text they were given almost to the letter. In this case we were able to provide translations of 17th century sources, and in narrating what each man did, the same archaic language of the time was presented to us, as though that was part of the story. We take this to be a sign of lack of understanding at several levels. But not all students reacted in this way.

The writing sample and previous comments about this student (G1) suggested that while she could describe well, she was nevertheless looking for some grandly simple goal for science. In this essay (G4) she begins by saying "Due to limited information, the earlier scientists formed many false assumptions [about] atmospheric pressure and a vacuum. Torricelli was a mathematician who was influenced by the writings of Galileo. He demonstrated the weight of air by experiments with mercury filled tubes, and correctly distinguished weight and pressure. Torricelli believed that air is a substance, air has weight, and that a vacuum is natural. He also believed that the nature of the atmosphere can be more or less 'dense.'" She goes on to describe some of Galileo's experiments, but she does not relate these to his beliefs. It is almost as though she were following and revising a text, but not internalizing it.

She concludes this paper, "It is very interesting to see just how far our study of science goes. I must say that I never would've thought of experimenting with tubes filled with mercury to observe barometric pres-

sure. I would not have thought of different levels of pressure changing with altitudes. I am pleased to say that although I came into the course thinking that I had a barrier to science in my brain, now I do not. I am very interested in the observations and the experiments we've conducted, and the conclusions that we, like the ancients, arrived at. Simply, now I know that I do appreciate the study of science and also that if one applies the mind, anything can be accomplished and easier to accept." This very personal statement displays a mind aware of itself and in transition. More than most of the writing samples we have given, this one, jointly with the previous selection from this student, may indicate the kind of growth that writing can encourage and display.

(H4) In her summary descriptions, this student avoided both the language and the detailed narration of failure that typified the original and many of her classmates' papers. For example: "Otto von Guericke (1602-1686), a German military engineer, was aware of Torricelli's experiment with a column of mercury and how a vacuum was produced, and wanted to further investigate the existence of a vacuum in nature. He used a qualitative approach in which his aim was to construct an air pump which would indicate the existence of a vacuum. He reasoned that if he could construct a vessel, fill it with water and pump the water out, then there would exist a vacuum since there would be no air inside. This procedure was a complicated one and he was unsuccessful in his early attempts due to the pressure that was exerted on his vessels. Either his vessels would fly apart from the pressure, or the wood that he used was too porous to resist the strength of the pressure which allowed air to seep in. He eventually succeeded in his attempt by constructing a perfect copper sphere. Von Guericke's approach was primarily a qualitative one in which he designed an experiment to further explore the existence of a vacuum. He had not used any numerical quantities in his approach and it is therefore considered qualitative."

She finally reaches the question of whether the analogy of a spring is appropriate. "Boyle used the analogy of air in the atmosphere behaving like a spring. He was aware of an elasticity in the air and stated that air particles were like little bodies, one piled on the other and may resemble fleece of wool which are flexible and may compress or expand with the weight of a force applied, like a spring. This analogy is conceptually similar (to the wool) yet if we attempt to quantify [it], we see it breaks down and does not hold true.

"The atmosphere seems like a spring because with a greater amount of atmosphere above us, it becomes more dense and more compressed at the bottom and less dense and more rarefied on top. Yet, by looking at the results obtained when measuring the different lengths obtained as increased amounts of force are exerted on a spring, we can see a propor-

tional extension that occurs with the amount of weight applied. Yet, the force which occurs in the atmosphere does not behave in such a quantitatively linear manner. A larger force is necessary to compress air as it becomes more confined in a volume, and through analysis it is evident that there is a difference in the behavior of the force required to compress the air. If we graph the results obtained when testing this relationship we can observe that the air does not expand proportionally (with decreased force) and disprove Boyle's analogy. It seems that the analogy of the air being like fleeces of wool would be a more appropriate model since the force of each layer of wool would compress the bottom layer of wool and would necessitate greater amounts of wool to compress the bottom layer while the top layer would remain less compressed. However, if we would want to have this as a suitable model, it would be necessary to test this relationship."

Compared with her previous papers, in which she had demonstrated an ability to describe, but still had a tendency to be somewhat florid in her view of science, this student has come a long way. Her writing might be edited, but her concepts are remarkably strong. She summarizes Boyle's work by saying "By instituting an 'if...then' approach to his experiment with the mercury he was able to verify what he had predicted." She then goes on to conclude: "As with all areas of science, we may look at the progression of the various observations made by the scientists of the 17th century and notice that each man's contribution was significant to the growth of knowledge obtained in pneumatics. However, it is through the use of hypothesis testing to obtain quantitative results, such as Boyle used, that we may develop evidential conclusions to substantiate the implications proposed by these men. With Boyle's carefully thought out controlled experiments, he successfully obtained knowledge about the substance of air. This enabled future scientists to explore this substance further..." To be sure, a number of her images do come from the reading, but these were available to the rest of the class as well. Not uniquely, but unusually, this student used the concepts that had been presented, and integrated them into her own work. But what bears repeating so that it is not lost is the growth that is indicated in comparison with the concluding sentence presented in (H2). There, only a few weeks earlier, science was heroic; here science has become more mundane in the sense that it has a procedure that enables its practitioners to deal with the stuff of the world. We see this development, and the way in which it is based on and grows out of descriptive evidence, as an exceptionally clear example of the way in which personal change can be captured.

(K4) In this paper the student again shows the wide range of her interests and knowledge, and her superior writing skills in the introduction. She starts by quoting a lengthy description of an ancient Greek

"water organ," and continues: "But, what does this have to do with the study and development of pneumatic devices? Perhaps nothing at all, except that it pleases me to know that one of the earliest applications of this aspect of the hard sciences (pneumatics) reflects the meaning of its Greek prefix: 'pneuma' – the soul or vital spirit. If music gives voice to that 'vital spirit,' then the fusion of science and aesthetics may have occurred far earlier than the 18th century." But even with all her verbal gifts going for her, she concludes, "In answer to part 'C' for the requirements of this paper, the use of the analogy of a spring to understand the behavior of gases and vacuums is an appropriate one. A spring action results when air is compressed or expanded." Here, again, we have the problem of how we should interpret a "wrong" – or incomplete – answer. Is it due to lack of understanding of the more quantitative material? Or just being turned off, or not being turned on, to or by the matter at hand? Or might it more simply be the result of having missed the lab sessions in which we worked with springs precisely so that we could compare their detailed behavior (Hooke's Law: F=-kx) with the behavior of an enclosed sample of a gas (Boyle's Law: PV=const.). Mathematically and graphically the first of these is linear, and the second is not. Our lab conclusion was that Boyle's use of this word was appropriate as an analogy, but not beyond that. We hoped that the evidence which we had developed would be used to justify an answer. This student, again, chose not to incorporate evidence and related inferences into her discussion.

Student (B) demonstrates a different approach. At the end of her paper on this topic, which she titled "From Voids to Vapors," she writes, "In conclusion, I think it is easy to see that, in a remarkably short period of time, the study of gases traveled quite a distance from Torricelli's theory of 'sea of air' to Boyle's discovery of a quantitative law. Understanding nature in order to advance craft-based phenomena required 17th century scientists to improve experimental techniques and record their data systematically. Experimental approaches ranged from metal pipes to glass tubes, exploding spheres to controlled instruments, sea level to mountain tops, outdoors to indoors, and most importantly, from voids to vapors. Clearly, the accomplishments of Torricelli, Pascal, von Guericke, and Boyle established the foundation for the modern study of gases by confirming air as a substance."

A last sample (J4) shows yet another way in which reflection can be pursued. In this case, the writer is self conscious about what she has done, even as she is actively engaged in comparisons. Her use of other sources is evident and acknowledged, although it was not required. Nevertheless, it is most likely a skill she has mastered, and in context it is appropriate. "I have compared the scientific work of Otto von Guericke to that of Robert Boyle. Actually, I think Robert Boyle's contributions to

science can, in many ways be more aptly compared to those of Galileo. Both of these men were indefatigable experimenters who were interested in many fields of science. Galileo contributed much more new knowledge to science, particularly with his study of motion. Additionally, Galileo and Boyle played similar roles in discrediting currently accepted erroneous scientific theory. Galileo, with his Dialogue on the Two Principal World Systems, exposed the weakness of Ptolemaic and Aristotelian astronomic theory. Boyle, with his Sceptical Chemist, also in the form of a dialogue, showed the fallacies of the Aristotelian 'four basic elements' theory and of Paracelsus' 'sulfur, mercury and salt' theory ['Landmarks in Science,' Robert B. Downs]. In the same way that Galileo prepared the way for Newton, so Boyle prepared the way for Lavoisier and Dalton, among others. With his definition of an element as a substance which cannot be further broken down or decomposed, he helped lay the foundations for one new science – physics. Boyle also established the importance of another new field of science based on the analysis of substances – chemistry. Indeed, he coined the word 'chemist.' The work of Galileo and Newton had revolutionized our view of the world. Boyle's work, along with that of Torricelli, Pascal and von Guericke, was also instrumental in bringing about a transformation in our understanding of the world."

Journals

We have noted in some of the writing samples above that a major goal of this course (which does not factor into our grading scheme) is for our students to transfer their understandings of principal course concepts to personal experiences and reflections. As a specific means of examining this, besides the comments students make in their essays, we asked students in two lab sections to keep journals. They were directed to make weekly entries which in some way related fundamental concepts developed in the lab to phenomena, experiences, or reflections outside the lab. This exercise was further intended to help the students generalize concepts. To facilitate reflective responses, journal entries were neither graded nor criticized for content, style or grammar; however, written responses were entered next to the students' entries to reinforce their efforts, to provide them with clarification and relevant examples, and to complete their ideas and generalize from them. These responses to their individual musings, as well as the personal challenge of finding appropriate topics, seem to have provided enough motivation for them to continue, as seen by their nearly impeccable regularity.

The journals, like other modes of writing, reveal misconceptions where we anticipate them. But more significantly, the freer, more personal format for expression afforded students opportunities to discuss areas where they were aware of cognitive dissonance. These discussions were

especially instructive to us in enabling us to amend instruction, and for insights they provided into our students' constructions of knowledge.

One concept that troubles students on their way to understanding theories of evolution is the idea of homology – characteristics uniquely shared by groups of organisms due to their presence in the last common ancestor of those groups. As phrased, this concept is based upon, as well as supports, the notion of descent with variation from a common ancestor, which is often visually summarized with a "family tree." The following entry shows that a student does not yet grasp that there are different levels of homology. In other words, she is not yet nesting or superordinating groups hierarchically, as is done in the Linnean system of classification.

"The idea that we (humans) and animals have derived from one common ancestor is hard to accept for me. If that is the case, why don't we have birds with pouches, fish with utters, or cats with antlers? [This student might have been as much at home with a medieval bestiary, which depicted the creatures she describes, as with a visit to a zoo.]

"Did the common ancestor have all these characteristics? Where did the common ancestor originate from? I can understand how animals can adapt to certain conditions, but is adaptation the only reason for the change in certain species? Perhaps these questions will be answered by semester's end."

Five weeks later the same student is much more at ease with concepts of evolution, and though she leaves much unsaid, there is an implicit understanding not only of homology, but of the nature of paradigm shifts in science. On her own initiative, and perhaps searching for journal material, she has read a popular science magazine and comments:

"I was fascinated by the controversy about the origin of birds. I can't help but sympathize with Sankar Chatterjee. It seems that history keeps repeating itself. New controversial hypotheses are always bombarded if they don't serve the purpose of reinforcing the main stream idea. The same happened to Copernicus, Galileo, Lamarck, Mendel, etc. I wonder if Chatterjee is really correct about the origins of birds. It would mean quite a big twist in the evolutionary theory for some. But, does it matter when species branch out? Does everything have a time table? Why can't they accept the fact, or thought, that an ancient bird could come from a reptile versus a dinosaur??"

While she sympathizes with the underdog (Chatterjee), she still cannot judge the evidence herself – as so few can. Nevertheless, she does appear to see that the evidence (one very crushed partial skeleton) may be plausible, though not strong, for the reptilian vs. dinosaurian origin of birds. She now seems to have grasped different levels of homology and different times and events of origin.

Another student considers characteristics of kangaroos and rabbits to answer for herself which are unique to each group and which are analogs, and whether kangaroos and rabbits share a recent common ancestor. Her familiarity with the animals is superficial, yet she partitions their attributes in order to consider evidence for homology and analogy. She does not discuss the evidence, and likely is not prepared to do so, though she may be prepared to read a discussion. Her writing is in outline form.

"Kangaroo Homologies:
Pouched (for carrying young)
Fur
Mammaries
"Analogous Traits of Kangaroos & Rabbits:"
Large hind legs and paws for jumping
Erect quadrupedal posture.
"Non Analogical Traits of Kangaroos & Rabbits:"
Rabbits born with fur (kangaroos are not)
Length, structure & function of tails are different
<Too many differences>
"Are kangaroos in own class because of pouch?"

Her conclusion is correct, that is, kangaroos and rabbits are not closely related, but the issue is not a particularly challenging one, and her use of evidence is spotty. Nevertheless, on her own she has constructed both the problem or hypothesis, and the tests.

One last example of transferring knowledge from the classroom deals with the interaction of ionic salts and polar molecules. As one experiment in the laboratory, salt was applied to samples of gelatin, and it was observed that the salt "pulls" water from the gelatin.

"I was trying to understand one of my childhood's greatest mysteries: why snails (the ones without a shell) melt away when salt is poured on them. My mom killed them that way. I don't think it was such a nice [thing] to get rid of them, but it worked.

"After our latest lab experiment ... I could identify the snail with the gelatin. When salt was poured on top of it, the salt "pulled" the water out of the gelatin. Whatever snails are composed of, it must be very polar because the way the salt diminishes it. My snail research is not over yet. This is just food for thought."

In sum, because it is non-directive, journal writing is less effective than other assignments in allowing the instructor to finger a student's abilities to select and use evidence. But also because it is non-directive, journal writing compels students to find personal relevance where they may otherwise not, and this often happens in apparently unlikely places.

Students frequently remarked that writing in their journals was the most difficult requirement of the course (which is also the most difficult and demanding of their courses), and in fact they spent days thinking over the one or two paragraphs they were to write. This was their part of the course, and these comments reflect a new-found pride in the possession of knowledge. They also claimed that they had never been asked to actually apply knowledge from one context to another, and especially not scientific knowledge.

Conclusions

In a recent discussion of science concepts among adolescents, adults and experts, Lewis and Linn (1994) note that in contrast to adolescents and adults, experts typically see the world more "holistically," integrating their formal knowledge with their intuitions and everyday experience. We believe that we have seen such an effect in the writing of a number of our students. This has been referred to above with regard to the Journals (which were collected during the second semester of the one year course), and also in other aspects of the second semester, as when they discuss the role of polarity in being able to account for the beading of water on a car's windshield, or in doing laundry. We believe that without writing as a vehicle for self expression, we would neither have encouraged, nor have been able to see, this aspect of intellectual growth.

The collective view of the many examples of student writing presented and discussed above all serve to demonstrate one theme. Beyond correctness and completeness of content, and beyond demonstration of "writing ability," student writing provides an invaluable window on cognitive position. Different modes of writing do this in different ways, and the way that is preferred in any given context should probably be determined with a clear idea of how this information will be used. Most simply, as opposed to errors of fact, students reveal the depths of their misconceptions when they are given the opportunity to express themselves, and these can be addressed on a one-to-one basis in comments on papers. Where students also show that their approach is out of touch with that of a course, this too can be addressed on a personal basis, either in writing, or possibly more easily in discussion. Finally, when one sees the spectrum of a class's response to certain questions it is possible to address particular issues in a number of ways. It may be necessary to create text material for the class covering particularly thorny issues, open letters to the class may be written which will give the students something to mull over, or class presentations may be adjusted to reflect the nature of the class, as opposed to the knowledge of the instructor. Any of these pedagogical responses, however, requires that the instructor first have a valid assessment of the character of a student or a class, and we believe that this can

be achieved by assigning appropriate writing exercises, and reading them attentively.

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