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ABSTRACT

This paper first evaluates discipline classification schemes and general differences between disciplines associated with the natural sciences and those associated with the humanities. It then reviews research which either asked students how professors in these fields teach, observed teachers in their classrooms, or asked students to describe their reactions to professors teaching science and humanities classes. Findings include: more pauses in lectures by professors of the humanities; different attitudes toward and uses of grades; emphasis by students on the instructor's efforts to connect content to student's lives and clarity of presentation; a tendency for students to report that good humanities classes are those which "interest" them and good science classes those which they "understand"; and differences in personality and learning styles (convergers/divergers and assimilators/accommodators) of students choosing either science or the humanities. Three paradoxes are identified: (1) between the collaborative nature of scientific work and the lecture method of undergraduate instruction; (2) between lower grades in the sciences than the humanities despite higher college entrance scores of science students; and (3) between the different instructional styles of the fields despite similar student ratings of good teaching behaviors. The existence of these two cultures in the university suggests needed changes in institutional procedures in evaluating teacher effectiveness, awarding student honors, and curriculum organization. (Contains 27 references.) (DB)

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The Two Cultures of Pedagogy:

Teaching And Learning in the Natural Sciences and the Humanities

Prepared by the Lea..ing Research Center/The University of Tennessee

This number of TEACHING/LEARNING ISSUES has been prepared by Howard R. Pollio. Dr. Pollio is the Alumni Distinguished Service Professor of Psychology and a Research Associate in the Learning Research Center at the University of Tennessee, Knoxville. The author would like to thank Dr. W. L. Humphreys of the Department of Religious Studies at the University of Tennessee, Knoxville and Dr. Kenneth A. Barbee of the Department of Biomedical Engineering at Hahnemann Medical University in Philadelphia for their helpful reactions to an earlier version of the present paper.

*You cannot teach a man anything;
you can only help him to find it
within himself.*

Galileo

Learning Research Center
The University of Tennessee, Knoxville

In 1956 the English physicist and novelist C.P. Snow wrote an article for the *New Statesman* that later was republished as a small book entitled *The Two Cultures and The Scientific Revolution* (1959). The basic premise of the book was that science and humanities represent two different ways of knowing and understanding the world. Snow believed that the two cultures, in 1959 at least, were in danger of becoming so estranged as to speak different languages, engage different values and attract different audiences. He also felt that this state of affairs could only lead to a breech in contemporary thought and, for this reason, suggested that universities develop educational policies to help students bridge the gap between the sciences and the humanities. He further argued that if we continued to teach science without reference to literature and literature without reference to science, we would only exacerbate the major problems of his/our age: nuclear destruction, overpopulation, and the disparity between rich and poor nations.

Snow hoped his analysis would lead to changes in how science and literature were taught. Even though his thesis of the two cultures was generally accepted as reasonable, he was totally unprepared for the passionate and somewhat abusive reactions it seemed to provoke in both scientists (Yudkin, 1962) and humanists (Leavis, 1962). Snow began a rejoinder to his critics in the following, relatively benign, tone:

> From the beginning, the phrase "the two cultures" evoked some protests. The word culture or cultures has been objected to; so too has the number two. No one, I think, has yet complained about the definite article. (Snow 1974).

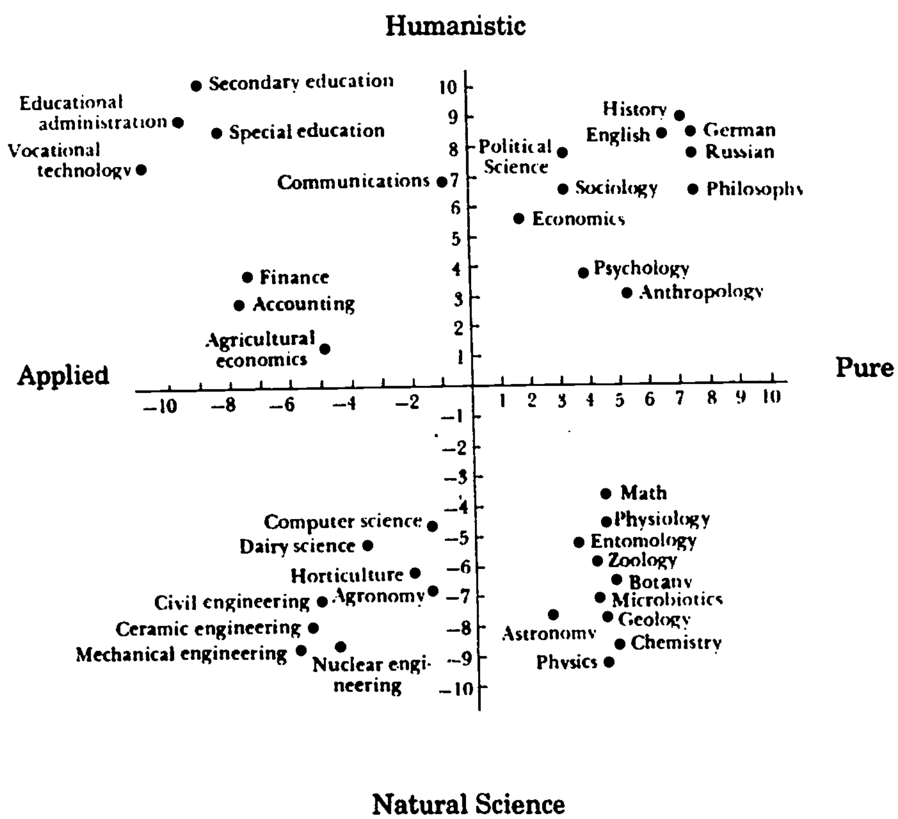
The objections raised concerning the word culture seem to revolve around a quintessentially British concern: to call someone "cultured" in something implies an invidious comparison to someone not so cultured in that activity. Hence, to be "cultured" in science but not in literature or to be "cultured" in literature but not in science automatically implies a bit of snobbery—which Snow denies ever intending to suggest. Instead, he meant the word culture to be used in its anthropological sense, as describing a collection of individuals linked by "common habits, common assumptions, a common way of life." Under this reading, both science and the humanities meet Snow's definition of a culture.

In regard to the second problematic word—two—Snow points out that "the number 2 is a very dangerous number; attempts to divide anything into two ought always be regarded with suspicion." Although in a second look at the two cultures, Snow sometimes did seem to expand his numerology to three—including the social sciences and other disciplines at the boundary of the two original cultures—he continued to find that the simpler and more paradigmatic use of two presented the problem in its clearest and most dramatic form.

Even if we do not adopt as spartanly binary a position as Snow, it seems clear a softer version applies—there are philosophical and methodological differences among various disciplines that make a difference in the ways disciplines are thought about and, more importantly for present purposes, how they are taught. What is also clear is that most major universities and colleges are organized according to these or similar lines of difference: thus, we have departments of history, English, biochemistry, psychology, physics, and chemistry. Our universities also are organized in terms of more broadly based categories such as the humanities, natural sciences, and social sciences, with these latter divisions coming perilously close not only to the idea of academic cultures but also to that most dangerous of numbers, two.

To determine how individuals in various disciplinary areas view their own field in relation to other fields of study, Anthony Biglan (1973a) asked 168 professors in 36 different fields at the University of Illinois and 54 faculty members from all departments at a small liberal arts college to sort different disciplinary areas "into categories on the basis of their similarity to you." Using a technique known as non-metric scaling, respondents in both groups produced results that could be plotted in terms of two different dimensions. In this type of scaling procedure, dimensions both emerge from and are defined by the way in which specific items (disciplines in the present case) are located on originally nameless axes produced by the mathematics of the analysis. Figure 1 presents

Figure 1
Classification of Academic Disciplines at the University of Illinois. (From Biglan, 1973a)



a plot of Biglan's results for faculty members at the University of Illinois.

Even a cursory look at where the disciplines fall relative to one another suggests four different groupings. The upper right quadrant deals with disciplines that characteristically have been termed the humanities, together with a smattering of social sciences. The lower right quadrant contains the sciences and mathematics, with specific disciplines ranging from physiology to physics. The lower left quadrant seems to contain applied disciplines that deal largely with the physical world whereas the upper left quadrant contains applied disciplines that deal with the social world, primarily education and business. Given this pattern, the two dimensions defining the major axes of the graph are relatively easy to name, with the horizontal axis stretching from the so-called pure to applied disciplines and with the vertical axis stretching from those disciplines concerned with the human world (humanistic) to those concerned with the physical world (natural science).

These results confirm what most professors and university administrators already know and provide a certain measure of satisfaction in verifying existing university organization. Not satisfied simply with categorizing academic areas, Biglan (1973b) also evaluated differences among the various disciplines on such matters as how individuals in various fields relate to their colleagues, their relative commitments to teaching and research, and the number and nature of their publications. In terms of social relationships, for example, Biglan found that natural science professors reported teaching with one or more other faculty members significantly more frequently than did professors in the humanities. The same pattern held true for research, where science professors reported being more likely to work with others in their discipline than did humanities professors. An examination of the average number of authors on published papers revealed that science professors had a significantly larger number of co-authored papers than did their colleagues in the humanities.

In terms of their relative commitments to teaching and research, there also were significant differences between humanities and science professors. For this analysis, professors were asked to distribute 100 points to indicate what proportion of time they would like to (and do) spend on various activities such as teaching, research, administration and public service. Since professors also were asked to provide the total number of hours they worked, it was possible to figure out how many hours they spent on various activities defining their work week. Professors in the humanities reported a greater preference for teaching than their science colleagues; they also spent a greater number of hours on it (26.4 hours to 19.1 hours). By contrast, science professors reported preferring research and spent more time on it than their colleagues in the humanities (23.0 to 15.1 hours). Finally, professors in the sciences produced fewer books and monographs than their colleagues in the humanities although they did produce significantly more journal articles. This result must be tempered by the fact that science professors are more likely to participate in group publication than is true for professors in the humanities.

These findings suggest that the pursuit of knowledge in the humanities is much more solitary than in the natural sciences. Professors in the humanities tend to work alone and to produce more lengthy works than their colleagues in the natural sciences.

Scientific work seems to allow itself to be accomplished by many hands—indeed, may even require it in the form of cross disciplinary expertise—and to be communicated in relatively terse and widely understood prose. As Biglan noted: "The common framework of content and methods which (natural science) provides . . . means that attempts to work together will not be hindered by differences in orientation . . . (and) to permit a more abbreviated form of communication. . . . (Finally) the greater commitment to research suggests budding scholars must be socialized into the regnant paradigm . . . and . . . this occurs (when) the graduate student works in research with a faculty member." Thus, for the natural sciences, research is teaching and such teaching occurs largely at the graduate level. The same cannot be said for the humanities, where personal scholarship is often quite separate from the teaching of students; in fact, graduate education in the humanities seems to require solitary research by the student in one or another corner of the graduate library.

Teaching and Learning in the Sciences and the Humanities

If faculty members in the humanities and the natural sciences have different work patterns and hold different values, we should also expect them to teach in different ways. To learn about the ways in which science and humanities professors teach, three different methods have been used: (1) asking students how instructors in the sciences and humanities teach, (2) going in and observing what science and humanities instructors do in their classrooms, and (3) asking students to describe their reactions to professors teaching science and humanities classes. No one as yet has systematically asked professors in the various disciplines to talk about how they teach and what they think they do in classes.

In an almost herculean evaluation of over 220 articles dealing with student views of the "superior teacher," Feldman (1976) came to the conclusion that it was possible to reduce student opinion to a set of some 19 traits including clarity, stimulation of interest, knowledge of subject matter, organization, enthusiasm for subject matter, etc. When Feldman looked at results across discipline, he found that students describing superior natural science professors put relatively greater emphasis on the "importance of teachers being able to explain things clearly" as well as on the "instructor's preparation and organization of course material." When a similar analysis was made of superior teachers in the humanities, students tended to emphasize the "ability of the teacher to encourage thought" and to be "intellectually and personally challenging."

Table 1
Mean Standard Scores Obtained on 21 Items in Three Disciplinary Areas

Item	Science and math (N=349)	Social sciences (N=596)	Humanities (N=249)
1. Prepared for class	48.9	50.6	54.0
2. Made clear assignments	50.1	49.9	54.0
3. Set clear standards for grading	48.9	49.0	51.1
4. Graded fairly	49.1	49.3	53.2
5. Knew if students understood him	46.1	49.3	53.9
6. Spoke understandably	45.9	48.9	53.7
7. Answered impromptu questions satisfactorily	47.3	49.4	54.6
8. Showed an interest in the course	46.8	50.0	53.6
9. Gave several examples to explain complex ideas	46.4	50.8	53.3
10. Accepted criticism and suggestions	47.8	49.7	53.6
11. Increased your appreciation for the subject	46.6	49.6	53.4
12. Was dependable in holding class as scheduled	50.6	48.8	53.1
13. Specified objectives of the course	47.5	48.1	52.6
14. Achieved the specified objectives of the course	48.2	48.4	53.4
15. Promptly returned homework and tests	51.5	49.0	52.7
16. Showed and interest in students	47.3	48.8	52.8
17. Knew his subject matter	48.9	50.7	53.3
18. Was available outside of class	48.3	49.9	51.7
19. Encouraged student participation	44.6	48.7	54.0
20. The course was well organized	48.0	49.6	52.9
21. In general, taught the class effectively	47.7	49.2	53.9
Mean rating for all items	47.9	49.4	53.3

Derived from Pohlman, 1976

At the same time (1976) as Feldman was progressing through a journal search, John Pohlmann was examining over 30,000 student ratings of instructors in various disciplinary fields. In making these ratings, students evaluated 1439 courses at Southern Illinois University in terms of 21 different items (See Table 1). Included among the 1439 courses evaluated, 349 fell in the natural sciences, 249 in the humanities, and 596 in social science (which included history). In addition, there were 157 courses in education and 88 in business; these values are not presented in Table 1 to keep it as uncluttered as possible.

Although values presented in Table 1 have been transformed for purposes of statistical analysis into T-scores, with 50 as an average value, higher numbers still mean more positive evaluation. As may be seen, the highest values were received by instructors in the humanities, followed by those in the social sciences, and then by those in the natural sciences. An examination of results for item 21, which presents a global evaluation, yields the same pattern (53.9 to 49.2 to 47.7) and agrees with results presented by Feldman (1978) and Cashin (1990) at a number of other college and universities. Despite such overall consistency in rating, the pattern of scores on individual items for individual disciplines was quite different. In the humanities, for example, instructors received their highest ratings on items 7, 1, 2, and 19 and their lowest ratings on items 13, 15 and 18. Instructors in the natural sciences received their highest ratings on items 15, 12, and 2 and their lowest ratings on items 19, 6 and 5. For purposes of comparison, social science instructors received their highest ratings on items 9, 1 and 8 and their lowest on items 13, 14 and 16.

If we consider only similarities and differences between natural science and humanities classes, it seems clear item 2 (Made clear assignments) was a relative strength for both sets of instructors. More interesting are results for item 15 (Promptly returned homework and tests) and item 19 (Encouraged student participation), which revealed strong differences between science and humanities professors. Science professors received close to their best scores on item 15 whereas humanities professors did not, and humanities professors received their best scores on item 19 whereas science professors did not. If we consider these differences in conjunction with other items receiving the best and worst scores for science and humanities professors, it is possible to conclude that natural science professors are rated by students as being relatively good in regard to classroom form and procedure and that humanities professors are rated as being relatively good in regard to interacting with students in more spontaneous ways. Despite this, humanities professors received their lowest scores on being available outside of class (item 18).

To determine how ratings of an instructor's classroom behavior and personal traits related to student evaluations of classroom performance, Pohlman (1976) used item 21 on his questionnaire (In general, the instructor taught the class effectively) as an overall index of teaching and related it to scores on items 1-20. The assumption here was that if any of the items related highly to item 21, the trait indexed by that item could be considered an important characteristic of teaching effectiveness. Even though different items received relatively higher/lower scores for humanities and science professors, results indicated that regardless of whether an instructor was in the natural sciences or in the humanities, the most important relationships involving item 21 occurred between it and items 5, 7 and 11 (Knew if students understood him/her, Answered impromptu questions satisfactorily, Increased my appreciation for the subject). What these results suggest is that while students may rate science and humanities professors differently, they tend to value the same traits as aspects of effective teaching whether they are judging science or humanities professors. The three items presented above suggest the effective teacher in both science and humanities is one who is aware of being understood, exhibits a presentness to his or her students, and increases the student's appreciation for the subject.

A second strategy for comparing instructors in the sciences and humanities involves direct observation of what they actually do in their classes. To accomplish this task, Erdle and Murray (1986) had groups of undergraduate students, with the permission of their instructors, observe three separate one hour classes. After observations were complete each of the student groups was asked to score, on a 1 to 5 scale ranging from "never" to "always", how frequently each of 89 specific classroom activities took place. Students observed and rated 38 full-time faculty members in the humanities, 45 in social sciences, and 41 in the natural sciences, all of whom were teaching at the University of Western Ontario in 1984.

Whenever researchers have many different measures (such as 89 specific classroom actions) to consider at one time, they attempt to discover if there are redundancies across measures: Is an instructor scored as "giving a preliminary overview of his/her lecture" also likely to be scored as "putting an outline on the board" or is an instructor scored as "likely to help students with personal problems" also likely to be scored as "talking about his/her personal life?" The procedure by which redundancies are looked for is called factor analysis; in this technique each factor defines a group of items that go together. In the example above, "giving a preliminary overview of the lecture" is part of the same group (factor) with "putting an outline on the board" but not with "offering to help students with their problems" nor with "talking about his/her personal life." In the case of the present set of 89 ratings, factor analytic results suggested that classroom actions could be categorized into 14 different groups, with some groups having as many as 11 items and others having as few as 2 items.

After all items had been grouped by factor analysis, each group was named so as to account for all (or most) of the items falling within it. For example, one of the groups described by Erdle and Marshall was termed mannerisms and contained the following five items: "keeps hands in pockets," "Says ahm or ah," "rocks or sways on heels," "plays with chalk or pointer," and "leans on lectern or on desk."

When all statistical analyses were completed, what sort of things do professors in both the humanities and the sciences do in their classrooms, and are there differences between them? A look at Table 2 indicates that humanities instructors scored significantly higher than their natural science colleagues on the factor groups defining Rapport, Interest, Interaction, and Expression. Natural science professors scored higher on Organization, Pacing and on Use of Graphs than did their colleagues in the humanities. These results suggest that humanities professors exhibit interpersonally oriented actions more frequently than natural sciences professors and that natural science professors exhibit task-oriented actions more frequently than humanities professors.

Each professor also was rated on overall effectiveness, and these values then related to each of the 14 behavioral groupings presented in Table 2. An examination of these results indicated that most items correlated positively with overall teaching score for both humanities and science professors except for Mannerisms, which correlated negatively with overall teaching ratings for both groups. This means that despite differences in the overall frequency with which professors in the humanities and the natural sciences engage in actions defining the various factor groups, what made for good ratings of overall teaching effectiveness was quite similar for professors in both disciplines. For example, although humanities professors are more likely than science professors to make jokes and speak dramatically, the correlation of these items with overall teaching effectiveness was about the same for professors in both disciplines. Students rate the same behaviors in both humanities and natural science professors as defining effective

Table 2
Mean Frequency Estimates of Teaching Behaviors for Teachers in Two Adacemic Areas.

Teaching Behavior Group	Humanities (N=38)	Science (N=41)
Rapport	3.95*	3.57*
Interest	3.19*	2.77*
Disclosure	3.09	3.08
Organization	2.80*	3.07*
Interaction	3.69*	3.10*
Pacing	3.44*	3.75*
Speech clarity	2.97	2.88
Expressiveness	3.53*	3.13*
Emphasis	3.52	3.49
Mannerisms	2.24	2.25
Use of graphs	3.10*	3.99*
Vocabulary	2.66	2.60
Presentation rate	1.93	1.89
Media use	2.16	2.13

Note: All values marked with an asterisk were significantly different from one another.

Derived from Erdle and Murray, 1986.

teaching even though natural science professors do some of these things much less frequently.

A few additional differences in the verbal antics of classroom instructors remain to be discussed. The first of these concerns issues of verbal fluency; i.e., do professors in the humanities or natural sciences say "uh", "er" or "um" (what linguists call filled pauses) more frequently? Although this may seem a relatively recondite point, three decades of research in cognitive psychology (e.g., Goldman-Eisler, 1968) have demonstrated that filled (and silent) pauses provide an index of the unpredictability of the next word, phrase or idea in discourse. In short, pauses reflect diversity of linguistic choice.

To evaluate how frequently professors in both the humanities and sciences produced filled pauses during classroom lectures, Schachter, Christenfeld, Ravina and Bilous (1991) observed professors in nine different hour-long undergraduate classes in the natural sciences (biology, chemistry) and in nine different classes in the humanities (art history, English literature) and counted the number of filled pauses produced in each classroom. When all the figures were figured, the mean number of "uh's" per lecture for biology and chemistry professors were 1.13 and 1.62, respectively; the comparable values for art history and English literature professors were 6.06 and 6.54. To rule out the (counter-intuitive) possibility that individuals in the humanities are less fluent than individuals in the sciences, professors in both categories were interviewed on their views of graduate training. When the number of uh's per minute was computed in this context, there were no differences among disciplines: the values were 5.75 and 5.73 for biology and chemistry and 5.62 and 5.96 for art history and English literature.

These results seem to support the view that speakers are more likely to pause where there are more options in the language and in the methodology of the discipline. Building on this assumption, Schachter, Rauscher, Christenfeld and Crone (1994) analyzed the number of different words—not filled pauses—used in lectures and professional publications and found that natural scientists consistently use fewer different words than humanists. As a final *tour de force*, Schachter and his colleagues examined 62 different articles in *The New York Times* concerning issues relating to science or to the humanities. Results, once again, demonstrated that fewer different words were used in writing about science than about the humanities. This result was taken to suggest that concepts in the humanities are characterized by a greater number of synonyms than is true for concepts in the sciences.

Making the Grade in Humanities and Natural Science Classes

Grading defines another activity in which both science and humanities professors engage, and it is reasonable to wonder if this aspect of pedagogic practice is done in the same way across disciplines. Perhaps the most revealing study of grades and grading begins in the statistics produced by professors in the sciences and humanities, most especially, those evaluated by Roy D. Goldman and his associates at various campuses of the University of California in the 1970's (Goldman and Hewitt, 1975; Goldman, Schmidt, Hewitt and Fisher, 1974; Goldman and Slaughter, 1976). Let us begin with one of these statistics, the total SAT score of students in the sciences and the humanities. Refiguring values presented by Goldman and Hewitt (1975), the average total SAT score for students in chemistry and physics was 1243 whereas the comparable value for students in history and literature was 1110. Despite this, the average grade in introductory chemistry courses was 1.63 whereas the average grade in introductory history classes was 2.94 (Grades were not presented for courses in physics or literature).

Other relevant data may be found in results collected at Appalachian State University during 1972-1978 (Duke, 1983). Although Duke's article did not report SAT scores, he did provide grades for a number of different disciplines. The mean grade for introductory chemistry classes for the 6 year period studied was 1.95; for introductory physical science classes it was 2.12. By way of comparison, mean grade values for classes in history and English literature were 2.27 and 2.24, respectively. For these same years, the general college average for introductory classes was 2.44 suggesting that grades in all four of these disciplines were consistently lower than the general average across all courses. Taking all of these data for the sciences and the humanities into consideration reveals that disciplines (chemistry/physics) enrolling students with higher SATs give lower grades in their classes than disciplines (literature/history) enrolling students with somewhat lower SAT scores. The toughest grading takes place in fields where students have the best SAT scores.

These results pertain to the grading habits of professors in science and humanities courses at a number of different schools in the United States. But professors not only assign grades, they also have attitudes about the grades they assign and these attitudes undoubtedly affect how students feel about the grades they receive. Student attitudes towards grades have been described by Eison and associates (Eison and Pollio 1985; Milton, Pollio and Eison, 1986) in terms of two different value orientations students have toward college classes: one concerning grades and the other, learning. In general, grade-oriented students tend to view the college environment as a place in which they are tested and where the only reliable way of knowing how well they are doing is in terms of the grades they receive; hence grades become a valuable commodity in and of themselves. Learning-oriented students, on the other hand, find learning new material to be the single most important aspect of their college experience and tend to attach little specific significance to grades or grading practices.

Since this research was able to define students as either grade or learning oriented, a further question was whether or not college professors selectively promote one or another of these orientations in their classrooms. To determine if there are differences among professors, Eison, Janzow, and Pollio (1993; Pollio 1992) developed a questionnaire containing two different types of questions: one dealing with faculty attitudes (for example, "I wish my colleagues across the campus were tougher graders,") and the other dealing with faculty actions (for example, "I set grading standards that are designed to challenge the brightest students in my class,"). Using professors' responses to this questionnaire, it was possible to define a total learning oriented (LO) and a total grade-oriented (GO) score. When faculty members at three different institutions (Southeast Missouri State, Massachusetts, and Appalachian State) were asked to respond to this questionnaire, an average LO score (on a 1-5 scale) of 3.31 and an average GO score of 2.84 was found suggesting that faculty members, in all disciplines, rate themselves as significantly more likely to encourage students toward a learning orientation than toward a grade orientation.

When a specific analysis was made of values produced by professors in the sciences, the average LO score was 3.12 and the average GO score was 3.03. For professors in the humanities, however, the average LO score was 3.52 and the average GO score, 2.77. Because there was some concern about other factors affecting these results, Eison, Janzow and Pollio (1993) looked at the effects of gender and number of years teaching on LO and GO scores and, in all cases, came to the conclusion that disciplinary affiliation affected LO and GO values more significantly than any other factor. The conclusion reached in regard to disciplinary differences in LO and GO scores is that faculty members in the sciences promote a stronger orientation towards grades in their classes than is true of professors in the humanities and that professors in the humanities promote a stronger learning orientation in their students than their colleagues in the sciences. Perhaps the clearest summary statement of these differences can be seen in the differential endorsement of the following item: "I don't mind if students enroll in my classes under a pass/fail or audit option." Humanities professors regularly endorse this item, science professors regularly do not. Not only do natural science professors give lower grades than colleagues in the humanities, they also regard grades as more significant and revealing of student achievement.

Student Descriptions of Science and Humanities Classrooms

A good deal of information concerning the student experience of science and humanities classes may be gleaned from student descriptions of their professors. As has been noted, the good physics or chemistry professor is one who is clear and well structured in his or her lectures and classroom assignments. In addition, natural science professors (good or otherwise) are judged to be impersonal and to answer questions only about factual issues. For English and history professors, the good instructor is one who solicits student opinions and who tends to reward students for making connections between academic issues and their extra-classroom lives. Humanities professors (good or otherwise) also are rated as being personal and interactive and as tending to go off-topic some of the time.

These results, describing the ways in which students characterize the classroom environments created by professors in the humanities and natural sciences, are all based on student reports of what they liked or disliked about their professors. There is another, somewhat less judgmental, way to recover the ambiance created in different classrooms and this technique depends upon student descriptions of specific classroom experiences. When this approach is taken, an analysis of student descriptions usually reveals five different themes and their interrelationships: connection, clarity, excitement, mastery, and power (Pollio, 1994).

The two themes that turn out to be of unique importance in distinguishing between natural science and humanities classes are connection and clarity. Basically the theme of connection refers to a student's awareness of the instructor's attempt to make a personal connection between the present topic and the student's extra-classroom world, what is sometimes called relevance. An additional aspect of this theme concerns feelings of personal relationship between student and professor. The theme of clarity concerns the student's experience of being able to follow along as the instructor presents factual and/or theoretical material or to experience the progress as one student put it: "from trying to get it, to getting it, to got it." The last stage of "got it" also has a tendency to yield a measure of personal excitement. In addition to describing clarity in terms of "getting" some piece of information or theory, the theme of clarity also was described in terms of how orderly (or chaotic) the instructor was in presenting material. If material was presented in a disorderly way, or at a breakneck or rushed tempo, students described experiencing the class as "jumbled and you get a lot of notes you can't understand."

Although these themes relate quite directly to student judgements of good (and poor) teaching in the humanities and natural sciences, they become most relevant to present concerns in terms of a serendipitous finding reported by Pollio (1994) regarding the use of two specific verbs by students in describing experiences in humanities and science classes: *interest* and *understand*. In going through student protocols in which one or both of these words was used (or some recognizable variant such as *interesting* or *understandable*), the following result emerged: of 37 descriptions concerning specific events in humanities classes, 29 used the word *interest* and 8 used the word *understand*. The values for 19 descriptions concerning natural science classes using one or both of these words were 8 for *interest* and 11 for *understand*. What this results suggests is that incidents described by students as "standing out" for them in humanities classes were those that *interested* them whereas those that "stood out" in natural science classes were those they *understood* or promoted *understanding*.

Personal Style and Disciplinary Difference

There is a complex and problematic chicken-and-egg relationship between disciplines and the people who teach them: are specific teaching behaviors required by certain disciplines or are individuals with certain personal characteristics attracted to specific fields such that their teaching practices simply reflect pre-existing "personality" differences? If we say, for example, good science teaching requires an impersonal mode of presenting objective facts and theories, then presenting class material in an impersonal and objective manner is a requirement of the field. If good humanities teaching requires openness and personal opinion, then being interactive and sensitive to student opinion is also a requirement of that field. It is, however, equally plausible to argue that individuals who are attracted to the natural sciences are oriented more toward facts and less toward people and, therefore, tend to teach in an objective and impersonal sort of way; thus, it is not the discipline but a fact of personal biography that explains the person's classroom behavior. By the same token, it is possible to argue that individuals who are attracted to the humanities are more oriented toward discussion and interpretive opinion and, therefore, tend to teach in a more interactive and personal way in their classes; and it is this fact of personal biography and not the discipline which explains their classroom behavior.

This way of posing the question sets it up as an either/or issue and, as Snow has reminded us, two is an extremely dangerous number. Perhaps a better strategy for posing this question is in terms of the way in which disciplines and people select one another. Setting the question up in this way recognizes that people are always in situations and that both the person and the situation invariably affect how the person will act in that situation. For example, Professor X may be quite comfortable in dealing with abstract thought problems but not very comfortable in dealing with concrete people. If X is in theoretical physics, things should work out quite well; if, however, X is in elementary education, things will not quite go so smoothly.

The more general problem then is the fit between person and discipline. In research terms, this comes down to a goodness of match between the person's way of thinking about and doing problems—his or her personal style—and the norms of some discipline or other. Although disciplinary norms include attitudes, values and social relationships, the major concern for education would seem to be how a student's style of learning relates to the teaching and research methods of some discipline. For the student—and for the professor who was a student before he or she became a professor—education in a particular discipline always implies a continuing process of evaluating the fit between personal learning style and the requirements of the field and its professors.

But how is a person's learning style to be evaluated? Here we need to consider an extended series of studies by Kolb and his associates in the late 1970's (Kolb, 1976; 1981; Kolb and Fry, 1975). This work begins on the assumption that learning is a four-stage process which starts with concrete experiences, moves on to observation, progresses to the development of abstract concepts and concludes, finally, in the application of such concepts to new situations. If learners are to be effective in some field they must be able to "involve themselves fully, openly, and without bias in new experiences; they must be able to observe and reflect on these experiences from many perspectives; they must be able to create concepts that integrate their observations into logically sound theories; and they must be able to use these theories to make decisions and solve problems (Kolb, 1981, p. 231-236)."

Considering this description in terms of people and not process, Kolb came to describe the mature learner in terms of two different dimensions: abstract-concrete and active-reflective. Using these dimensions as a starting point, Kolb (1976) defined four different categories of adult learner: convergers, divergers, assimilators and accommodators. For this analysis, convergers were characterized as having their greatest strengths in abstract thinking and in the practical application of ideas. Such individuals were thought to do best in situations, such as conventional intelligence tests, where there is a single correct answer to some question. They also were thought to organize knowledge in such a way as to be able to deduce effectively the correct answer to some specific problem. Convergers tend to work in a relatively unemotional way and prefer to deal with things rather than people; as a rule, they specialize in applied technical fields such as engineering.

Divergers have a learning style opposite to that of convergers. Their major strengths are in being sensitive to concrete experiences and in viewing such experiences from many different perspectives. They also usually are able to organize these perspectives into a meaningful whole. This type of learner is most effective in situations requiring the generation of ideas, as in brainstorming sessions. They tend to be interested in people and to be relatively emotional in their response to them and to ideas. They also tend to have broad cultural interests and to specialize either in the humanities or in the arts.

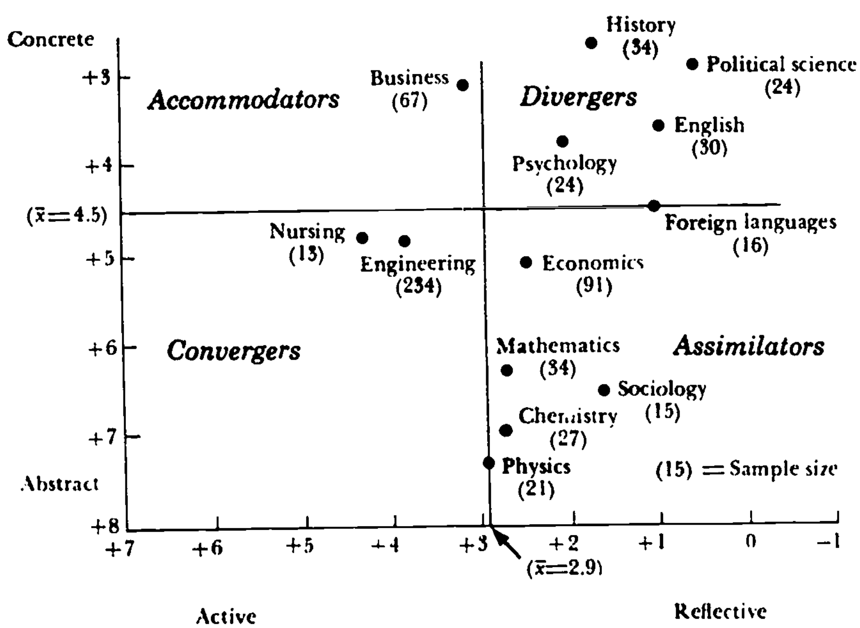
Assimilators have their greatest strengths in abstract conceptualization and in an ability to create theoretical models. They excel at inductive reasoning—in being able to combine many different observations into an integrated explanation. Like convergers, they are less interested in people and more in abstract concepts; they are, however, not particularly interested in the practical use of their ideas or theories. Individuals with this learning style tend to feel comfortable in basic sciences and mathematics; in business, they work most effectively in research and planning departments.

Accommodators have strengths opposite those of assimilators—they are best in doing things concretely and in seeking new experiences. They tend to learn best from hands-on experiences and to excel in situations calling for novel and somewhat risky actions. When a plan or theory does not fit the facts, they are likely to discard the plan or theory. They are at ease with people and tend to work best in nonacademic careers; in business, they prefer working in marketing or sales departments.

Once Kolb developed his Learning Styles Inventory, (1976) he tested it on students in a number of different majors. When results of this study (See Figure 2) were plotted in terms of the major style dimensions defining adult learning and learners—abstract-concrete and active-reflective—Kolb found that students in the natural sciences (those in chemistry and physics) produced extremely high scores on the abstract end of the abstract-concrete dimension and essentially neutral scores on the active-reflective dimension. By way of contrast, students in the humanities (say, history and English) produced high scores on the concrete end of the abstract-concrete dimension and somewhat lower scores on the reflective end of the active-reflective dimension. Although other disciplines produced their own unique pattern of scores, these specific differences suggest that students in the sciences tend to employ an abstract learning style that is no more strongly oriented toward action than reflection whereas students in the humanities tend to employ a concrete learning style more strongly oriented toward reflection than action.

One final piece of the puzzle remains: how do disciplines—not people—sort themselves on these, or similar, dimensions? Here we need only refer back to Figure 1, which presented judgements of inter-field similarities. As may be remembered, these results indicated it was possible to locate specific disciplines in a theoretical space defined by two dimensions; pure-applied and natural science-humanities. In translating these results into Kolb's terms, the first axis may be identified with reflective-active and the second with abstract-concrete.

Figure 2
Learning Style Inventory Scores for Students in Different Majors



Adapted from Kolb, D., 1981.

Taking both analyses into account, Kolb (1981) proceeded to locate various disciplines into one or another of four quadrants defined by crossing the categories of active-reflective with those of abstract-concrete. On the basis of this analysis, Kolb concluded that the abstract-reflective quadrant was largely defined by natural science disciplines whereas the concrete-reflective quadrant was largely defined by disciplines falling within the humanities and, to a lesser extent, the social sciences. For purposes of completeness, the concrete-active quadrant was defined by education, social work and law and the abstract-active quadrant by disciplines such as engineering and business.

The general conclusion to emerge from this analysis is that different disciplines value different inquiry procedures as well as different modes of describing their content. If we combine this with the fact that different students are blessed with different styles of learning, it seems clear that certain styles are more (or less) compatible with one or another discipline. This is not to say that certain skills *cause* the student to become a scientist or a humanist; only that the fit is better in some disciplines than in others. Looking at the issue in terms of fit moves it from a chicken-and-egg problem (one of cause and effect) to a systems problem (one of match) in which the discipline and the student select one another. If the match is a good one, the student becomes progressively more integrated into his or her chosen field; if the match ceases to be good, or if it was not such a good fit in the first place, the student is likely to choose a different field. There seems to be a certain comprehensible pattern to how we select our life's work that does not leave us or our students as automatons strictly at the mercy of personal skills and preferences. The discipline selects the student just as much as the student selects the discipline, and the goodness of fit is crucial in both cases.

Impressions of Pedagogic Advice Given to Science and Humanities Professors

Each discipline has its characteristic mode of inquiry, and each has its characteristic mode of instruction. To facilitate the communication of new ideas on both fronts, most disciplines publish two different types of journals: one that deals with methods and theories and the other that deals with matters of teaching (in this latter regard, see the list prepared by Cashin and Clegg, 1974, which contains over 145 entries for some 75 different disciplines). Looking at the advice provided in the more pedagogically oriented journals it should be possible to gain some insight into how various fields view their own best teaching. To make the job of comparing teaching advice given to science and humanities professors manageable, it seems wise to focus on only a single discipline from the sciences and one from the humanities. For purposes of the present analysis, the two fields selected were chemistry and history and the two journals, *The Journal of Chemical Education* (JCE) and *The History Teacher* (HT). The mission statement in both journals suggests they are intended primarily for professors of college level classes and both are supported by their respective professional organizations—The American Chemical Society and the Society for History Education, an affiliate of the American Historical Association.

An impartial look at the two journals, by someone who is neither a chemist nor an historian, brings an initial impression of difference. First off there is size: The *Journal of Chemical Education* is 8 1/2 by 11, *The History Teacher*, on its tip toes, is 9 by 6. Then, there is the question of style: *JCE* is a glossy magazine with many photographs and high level lithography; *HT* is a modest, ecru-colored journal with no photographs except for a single historically significant image on the front cover. There is also the type of advertising contained in both journals: *JCE* is loaded with advertisements for any and all sorts of equipment and products whereas *HT* has only the odd advertisement for a textbook or more technical monograph. The prices and frequency of publication also differ: *JCE* appears monthly and costs $32.00 per year; *HT* appears quarterly and cost $24.00 per year.

Once inside the front cover of both journals, however, some points of similarity appear. First, there is the table of contents where both journals have somewhat the same headings in somewhat the same order:

JCE	***HT***
I Articles of General Interests	I General
II Features Relating to Education, (including book reviews, a section called Editorially Speaking and a summary of articles in the issue)	II The Craft of Teaching
	III The State of the Profession
III Secondary School Chemistry	IV Historiography
IV Laboratory Experiments	V Book Reviews
V Notes and Comments	VI Notes and Comments

The major differences concern the section on laboratory experiments in JCE that obviously does not appear in *HT*, and the section on historiography that appears in *HT* but not in *JCE*. Although *JCE* has a continuing special section on secondary school chemistry, it is clear after reading a few issues of *HT* that many of the articles in Sections II and III also deal with the teaching of history in secondary schools. Both journals provide book reviews although there is a clear difference in the amount of space devoted to them: never more than 4 or 5 pages in *JCE*; only infrequently fewer than 15 pages in *HT*. An additional difference concerns the editorial voice of the journal: the editor scarcely if ever appears in *HT*; in *JCE*, every issue has an educational comment as well as an editorial guide to the major educational articles in the issue.

As an overall impression it seems fair to say there is some degree of organizational similarity between the two journals, with the major points of difference related largely to the requirements of the discipline itself: an emphasis on book reviews and historiography in *HT* and on laboratory experiments and equipment in *JCE*. Finally, *HT* seems a bit more concerned about what it is to be a historian; there is little or no concern with the profession of chemistry *per se* in the pages of *JCE*. Over the 5 year period examined (1989-1994), the percentage of pages was relatively consistent over consecutive issues.

When a more detailed, but still impressionistic, examination was made of articles dealing specifically with teaching matters, additional similarities and differences emerged. Probably the major similarity was that both *JCE* and *HT* advise (and, in the case of *JCE*, sometimes exhort) their colleagues to make the discipline interesting to the introductory student. In *JCE*, this advice appears in the editor's introductory summary of pedagogic methods as well as in the introduction to articles presenting new ways of teaching difficult concepts or modes of representing data. In *HT* this advice is regularly offered in a discussion of the relevance of history to contemporary students; and, while history professors also are advised to make things relevant to their students, the message is more suffused throughout the entire journal.

Although only *HT* has a specific section devoted to the state of the profession, there are many editorial references in *JCE* to the state of student recruitment and/or to professorial activities relating to recruitment. The editorial voice in *JCE* is concerned most about where the next generation of chemists is going to come from and offers advice ranging from making chemistry more relevant to real world concerns to asking departments of chemistry to reward good instructors as well as good researchers. The professional issues discussed in *HT* are a bit different; here the major concerns deal with the status of the profession in the university and with the preparation of graduate students and young professors for teaching at the college level. Some concerns also are raised about the need to teach special topics in certain schools; i.e., a course on Jewish history in a largely Protestant state college.

While these impressions do not do justice to the diversity of articles, pedagogic or otherwise, presented in both journals, they do yield a sensible summary: both fields are interested in interesting students in their respective disciplines, and both suggest ways of relating obscure, complex or just plain difficult issues to the everyday lives of students. Both journals also stress an understanding of the content matter of the discipline, and both emphasize the methods of discovery presently used by the discipline. Although there is more concern in history about historical fact than method, method in chemistry is presented as a set of well-known techniques to be mastered.

All in all, then, there seem to be more similarities than differences, and what differences there are relate quite directly to obvious differences in the content defining both disciplines. Although what is taught is different, suggestions for how and what to teach are similar: make it clear, make it relevant, make it attention-getting, and make it understandable. Both journals also are aware that not all students like their discipline and that the instructor is required to deal with this problem not by throwing up his or her hands in despair over the current generation of ill-prepared students but by seeking ways to present the discipline so as to make it both attractive and comprehensible to contemporary students.

Paradoxes of Science and Humanities Teaching

Perhaps the best way to capture what we now know about teaching in the sciences and humanities can be summed up in terms of a single word, "paradox." Although the word "contradiction" also may come to mind, it seems so final and unrelenting whereas paradox seems a bit less final and a bit more hopeful. This intuition is reasonably close to the meaning of both words: *contradiction*, to speak against, and *para-dox*, a pair of opinions. Only the idea of paradox hints at the possibility of resolving the contraries that define it and, thereby, of providing insight into the why's and how's of teaching in both the humanities and the natural sciences.

But what are some of the contraries suggested by prior work concerning teaching and learning in the sciences and the humanities? Basically, there seem to be three of them:

(1) Despite the fact that undergraduate classes in science

tend to be presented as lecture monologues, the characteristic mode of mature scientific work is collaborative in nature. The case for the humanities is different: here undergraduate classes are interactive and dialogic, yet the characteristic mode of mature work is solitary. What is also of significance is that the pattern changes in graduate school: the graduate student in science is welcomed into the camaraderie of the laboratory and the graduate student in the humanities is sent off to the library. Close collaboration and dialogue dominate the graduate education of young scientists whereas almost monastic discipline and silence define the graduate education of students in the humanities.

(2) Despite the fact that undergraduate students in the natural sciences tend to score best across-the-board on pre-college achievement tests, grades in natural sciences classes tend across-the-board to be considerably lower than those in the humanities. The differences are sufficiently marked as to suggest that not all Bs are created equal, with those in the humanities becoming Cs in the sciences and those in the sciences becoming As in the humanities. Instructors in the humanities regularly question the assumptions underlying the use of precise grading schemes whereas natural science professors tend to take grades and grading schemes at face value. Even though natural scientists pride themselves on the rigor of their grades *vis a vis* the humanities, they see nothing wrong (or, at least, do not complain about) calculating a GPA composed of deadly unequal sub-metrics. In fact, natural scientists take pride in their tough grading practices and tend to view, with public alarm, the tendency toward grade inflation and its presumed effect on the "lowering of academic standards."

(3) Despite the fact that the same teaching behaviors are highly rated by students evaluating natural science or humanities professors, natural science professors often lecture with little or no continuing attempt to engage their students as individuals. These events take place despite the fact that journals devoted to the teaching of science regularly exhort instructors to be engaging and relevant in the classroom. What seems to be most significant in the sciences, if we are to judge from classroom actions and not pedagogic advice, is to be clear, to return homework promptly, and to teach students the facts of science and how they are represented (i.e., in terms of graphs and formulas). Humanities instructors act in class in such a way as to indicate they are less interested in what is already known—the facts—and more interested in articulating their own and their students' perspectives on the material under consideration. If technique and certainty are to be understood by the student in a science class there is only the personal

relevance of ambiguous material to be attended to in humanities classes; hence a good science class is one that is understood; a good humanities class is one that is interesting.

These then are the paradoxes; do they necessarily entail a contradiction? As an opening possibility, let us begin by supposing that the meaning of various professorial actions in the classroom are not paradoxical to professors either in the sciences or in the humanities. Let us further assume that the meanings of these actions make sense to the teacher of science and to the teacher of humanities as precisely what is required to produce a scientist or a humanist. Beginning with this assumption, it seems clear to science professors that real science education does not begin until graduate school and that the undergraduate years in science education are simply a long apprenticeship in the language, facts, methods and modes of thought characteristic of the mature researcher and theorist. What the undergraduate student is learning is that science is a discipline that can only be approached incrementally, and only after the student (as neophyte) has proven worthy—in short, only after the would-be scientist accepts the rigors of a scientific calling and, despite seldom being encouraged by his or her professors, still learns its facts and chooses to make it his or her life work. Then, and only then, is the student ready to begin and then, and only then, are his/her teachers ready to encourage the young researcher as a protege and potential scientist.

The case for the budding humanist is different. Here the student must come to understand that undergraduate education is designed not only to interest him/her in the discipline but also to forge a connection with other scholars he or she will encounter only intermittently in the later pursuit of disciplinary knowledge. The reason for dialogue, and for the solicitation of personal opinion, is to prepare the young scholar to develop his/her own perspective on things and to be ready to defend it against established views. There are few unimpeachable facts to be learned in the humanities—only continuing interpretations of a set of ambiguous concerns. The scholar who is not strongly connected to the issues raised by the discipline will surely be unable to complete a requisite course of study. Since no number is ever adequate to describe the quality of personal insight and imagination, grades are to be questioned and ultimately rejected.

So what exactly is it that gets learned in undergraduate classes—certainly the facts, methods and concepts of the discipline. What also gets learned, and is probably equally as significant, are the mores of what it means to be a scientist or a humanist. In the former case, these include fellowship and the certainty of a scientific approach to knowledge. In the latter case, they include an emphasis on uniqueness, combined with a commitment to those eternal problems of human life that do not yield unequivocal answers. Of course the undergraduate classrooms are different; how else could it be if the classroom is to teach not only content but, in C.P. Snow's words, to en-culturate the student into the values defining science and/or the humanities?

Teachers in the humanities and in the sciences are not trying to do the same thing in the classroom. There are no paradoxes here nor are there any contradictions to be resolved. The nature of undergraduate education in both science and the humanities is designed to convey the need to be worthy of one's future discipline. For natural science, this means to be knowledgeable of its past achievements and methods and to speak the clear language of scientific understanding. For the humanities, it means to be worthy of evaluating prior perceptions and of developing a potentially unique linguistic voice that may leave the person alone and without any guarantee of being able to resolve the ambiguities of present concerns. To be a humanist is to accept a degree of isolation and ambiguity; to be a scientist is to accept a specific language and method as well as a content open to clear understanding.

The existence of these differences suggest that the university is, in fact, composed of two cultures. Both cultures present significant perceptions on the meaning of life and the world, and both compliment one another in their relative emphasis on clarity and ambiguity, isolation and connection. In more mundane terms, this means that institutional rewards and evaluation procedures for both cultures must be different. Take, for example, the case of teaching effectiveness. It seems clear that the crucible for teaching excellence in the humanities is the undergraduate classroom. In the sciences, however, undergraduate education is viewed largely as a long corridor to graduate school; hence, teaching effectiveness should be assessed not in undergraduate but in graduate courses.

A second place in which to adjust institutional procedures to differences in disciplinary cultures concerns the nature of student honors. Any locale in which GPA is used to decide on honors, such as Phi Beta Kappa, necessarily penalizes students in some disciplines while rewarding those in others. Perhaps, selection of equal numbers of students by the relevant faculties might prove a more equitable way of going about the business of awarding honors without the assumption that numerically equivalent GPAs define equivalent levels of student achievement. In this way, each field gets to reward its own superior students without having to assume that GPAs measure the relevant achievements of students in the sciences and/or in the humanities.

Differences between the sciences and the humanities also imply different types of curricula. For the sciences, a reasonably circumscribed and progressive curriculum would seem required by the demands and needs of natural science learning. For the humanities, more individualized, and uniquely sequenced, curricula would seem appropriate to the needs of that culture. If differences between the disciplines are not to grow too wide, however, students in the humanities should be expected to know something of the sciences in much the same way as students in the sciences should be expected to know something of the humanities. To this end it seems reasonable to expect that some science departments and some humanities departments will have a senior person interested in relating the perspectives of his or her discipline to students in other fields. If no one is able to accept this challenge within one or another of the cultures, it seems clear that interdisciplinary courses, taught by the most senior members of the relevant departments, could prove an exciting adventure not only for the student but also for the professor.

While it seems true that there are two distinct cultures of scholarly activity in the modern university, no one ever said they had to be exclusive or in conflict with one another. There is a dynamism that comes from experiencing diverse perspectives, and this would seem no less true of two academic cultures than of two disparate domains of thought that come together in a genuinely creative idea. All that is needed in either case is an openness to the novelty and excitement of unexpected combination.

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