

Student Diversity Requires Different Approaches To College Teaching, Even in Math and Science

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It now appears that all traditionally taught college courses are markedly (though unintentionally) biased against many non-traditional students, and, indeed, against most students who have not attended elite preparatory schools. Thus, when we teach merely in traditional ways we probably discriminate strongly on grounds quite different from those we intend (assuming that we intend only effort and merit). Easily accessible changes in how we teach have been shown repeatedly to foster dramatic changes in student performance with no change in standards—in some cases, no students now earn failing grades. Similarly dramatic improvements have been shown in the uniformity of outcomes. For example, the gap between Black performance and the performance of other groups can be entirely eliminated, even in "hard" courses such as calculus.

When I first encountered them, the arguments challenging professors to address diversity in our classrooms seemed to be largely specious and not likely to have any positive effect in most science courses, certainly not in those I taught in biology. Subsequently, I have come to understand that much of what I took as neutral teaching practice actually functions to keep our courses less accessible to students from non-traditional backgrounds. If my current understandings are a reasonable reflection of reality, then (almost) all traditionally taught courses are unintentionally but nevertheless deeply biased in ways that make substantial differences in performance for many students.

TREISMAN'S WORK AND ITS IMPLICATIONS

Let me start with an example. It once would have seemed to me that mathematics is so abstract and free of particular cultural constraints as to make it difficult to conceive how one might possibly teach it in a culturally biased

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way. Nevertheless, when Treisman (1992) began examining calculus at the University of California at Berkeley, he found that about 60% of the Blacks who had completed calculus there in the preceding decade received grades of D or F—grades so low that they could not proceed with a major in mathematics, science, or technology.

Treisman surveyed the faculty for possible explanations. All suggestions (save one) proposed that something was wrong with the students (a motivation gap, inadequate preparation, lack of family support, or just a function of income), thereby exonerating the faculty of culpability for the lower achievement by Blacks. Each suggestion failed to withstand scrutiny. Indeed, Treisman found that for Black students at Berkeley, math entry scores were negatively correlated with achievement in calculus—the more math the students already knew when they began, the worse they were likely to do! Similarly, for these students family income was negatively correlated with grades in calculus. The ones who did best came disproportionately from families of school and civil service employees. Of course, Blacks are not the only group that does poorly at Berkeley or elsewhere. Treisman also worked with Hispanics. And related studies (some discussed in Treisman, 1992) applying Treisman's approach have found that similar problems and similar remedies apply to Blacks, Hispanics, and rural Whites in a variety of other colleges and universities.

Students in the groups that did not do well in calculus at Berkeley, and in calculus and other science courses in related studies elsewhere, usually have had certain experiences in common. They have tended to come disproportionately from high schools that were not heavily oriented towards college preparation. They thus had few peers to study with in high school. Moreover, they often have been taught that only weak students study together (as in remedial study halls) or even (as I learned growing up in rural Kansas) that working together on homework was cheating. Finally, in their high schools studying and academic achievement have typically carried negative social prestige—they made you a nerd. Thus many of the students from these groups studied alone and in a "closet." Treisman (1992) found the greatest contrasts with students from some Asian American groups, many of whom formed study-squads to get through calculus, groups in which social status was increased by one's ability to help others.

Treisman's responses can be seen as taking control of the social system. He invited the students from the less successful groups into honors—not remedial—discussion sections. He told them that homework would be easy both because their math scores showed that they were ready for calculus and because the class would prepare them to do the homework before it was assigned. In some of the versions of his implementations, he told them that the homework had to be submitted on time. Further, to help the students get it right, they were required to do peer checking. With this required collaboration, the time required for in-class discussion of the homework dropped from all period to an average of three minutes a week. The students had mostly taught themselves the homework. However, the core of Treisman's success hinged on his use in-class of collaborative small groups—groups working on problems harder and different than the

normal homework (Treisman, 1992). Note the use of a coaching approach. If you want students to run a 100 yard dash, you don't let them stop at 100 yards. If you want them to do well on an exam at the level of the homework, you must lead them beyond it.

Only about 4% of the Black students completing Treisman's "workshop" calculus made a D or F (versus the 60% earlier; see Fullilove and Treisman, 1990, for statistics). Moreover, the differences vanished between the average grades achieved by the Black students who did their workshop calculus and those achieved on the same exams by students in socially dominant groups, including Asian Americans. There thus were no differences in ability, industriousness, motivation, or background that were not totally nullified by making the social systems work more equitably for academic achievement. A key point is that the content of the course was not watered down—students from nondominant backgrounds were just taught better than before.

As a second example, Amendariz and McCaffrey (cited in Treisman, 1992) have developed a parallel program for Blacks and Hispanics at the University of Texas. There the grade point average for minority students is 3.53 whereas that for other students taught the regular way, but taking the same exams, is 1.67. Comparable success with similar approaches has been achieved at institutions very different from the University of California at Berkeley and in mathematics, physics, chemistry, and biology.

A key to achieving the gains towards uniformity of performance is a shift to structured, student-student group work. Such effective discussions must be distinguished from recitation. In recitation the teacher asks questions and the students respond one by one or, alternatively, the students ask questions and the teacher responds. Effective discussion, in contrast, requires that students work together in small groups (except, perhaps, for the small minority of faculty who can dependably conduct a good Socratic dialogue). To make discussions most effective, the teacher must make sure that the students are prepared for the discussion, that the students participate constructively and fairly evenly, and that the students are addressing questions that are sufficiently challenging. (For more on collaborative learning see Johnson, Johnson, and Smith, 1991; Meyers and Jones, 1993; and Nelson, 1994.)

DISCIPLINARY DISCOURSE: BRIGHTER AND HARDER WORKING STUDENTS

Different disciplines have very different standards for acceptable expression and adjudication (Bruffee, 1984, 1993). Rose (1989) provides eloquent examples of the barriers that result from implicitly assuming that the students have already mastered disciplinary discourse. In teaching teachers to teach writing across the curriculum, Colomb (1988) has found that the most difficult thing about writing is learning all of the reasonable things that one might say that are precluded by the literary conventions of the disciplines. For example, in English

classes, a student who comments that the jewelled eyes of toads (upon which Shakespeare remarks) reflect a nocturnally adapted redna, although accurate, will usually not expedite the teacher's goals for the day. Similarly, in science the student is not supposed to remark that the color of the pH indicator is exquisite, nor that it matches exactly the central stone in the student's grandmother's gamet brooch.

If students go to a good, college preparatory, secondary school they learn that expectations and literary conventions vary radically among disciplines. They also have had practice working in a dozen or so disciplines at levels that provide a good understanding of the expectations in freshman courses at college. In many cases where students have attended secondary schools that were not heavily college-oriented, the standards have been so basic that few differences between the disciplines were evident.

The prevalence of such basic standards among entering freshmen in most institutions makes it possible to produce brighter and harder-working students using only one hour of class time. Dr. Mitzi Streepey (personal communication), upon learning of the ideas connecting disciplinary discourse and bias, returned to her class and gave them an essay question over the material they had been studying. She included four or five answers that she had written to the question. The answers varied in quality in ways that illustrated the array she was used to getting on exams. She broke the class into small groups and had them decide which answers were better in what ways, doing a whole group synthesis at the end in which she further clarified her expectations. She then gave the students a second question to work on and had them compare their draft answers with the criteria they had developed. Her students suddenly became brighter and harder-working, as evidenced by their success on the next exam (the way we always tell when students are bright and hard working). Several students reported that they were now doing better than ever before in their other classes too.

My own experience also illustrates the idea that students are often bright enough and hard-working enough to do well in class, but lack a clear understanding of what it is we want them to do. Thus, like Dr. Streepey, I find that many freshmen are not accustomed to checking to see whether they have explicitly addressed each segment of a complex essay question. Strangely enough, a similar problem exists for multiple-choice questions. When my biology classes are too large for exclusive use of essay questions, I often put on the overhead projector a multiple-choice question covering the material that I have just taught in the preceding 10- or 15-minute segment of lecture. I include a dozen answers, some of which are factually wrong, some of which are factually true but irrelevant to the question, and at least two of which are true. I find that students often think initially that any true answer is a right answer, so that judging the acceptability of the answer in combination with the stem of the question is a new skill. Many are also surprised to see that right answers can be expressed in several ways and that one question might have several strikingly different right answers. (This, of course, is what allows multiple-choice questions to be used to test student comprehension. And it is one reason that students must understand the material, and not just memorize it, even for multiple-choice exams.)

Expectations differ among courses in ways that extend well beyond answering questions. For example, in many high schools, most of the effort in reading a book goes into understanding what it says. In college, what a book means reflects the questions that one brings to it as much as what the author says. The same novel used in courses in economics, psychology, women's studies, and literature means different things in each course because we focus different questions upon it. Thus we need to provide explicit guidance to our students in reading and thinking about texts as well as in assessments. I typically give out a study guide with each reading assignment, at least early in the course. The study guide indicates specific questions that the students should be able to answer from that particular reading assignment.

When we assume that students must come to us already knowing how to read a text in our field and how to respond to questions on our exams we are in essence assuming that the students have gone to a good, college preparatory, secondary school and that they have paid attention. A small amount of effort showing the students what we want them to do can pay large dividends in terms of increased performance by students who have not previously learned how to proceed in our subjects.

ONE-SHOT GRADING AND SOCIAL BACKGROUND

I first began to think seriously about how my teaching might be needlessly perpetuating social class differences when I read an article by Bowles and Gintis (1973). They suggested that currently the major function of higher education was to sort the children of the upper classes into positions in which they would remain well off while convincing most of the children of the poor classes, first, that they were either unable or unwilling to do what it took to obtain a professional job and, second, that the system was fair and unbiased. They also suggested that teachers did this by basing their evaluations heavily on social class behaviors, such as the ability to complete assignments on time, rather than on the ability to understand and apply the content.

If we are sorting on social class behavior, it would make relatively little difference what major a student chose, so long as the conventions for evaluation were sufficiently social-class biased in every major. My concern for these issues has been deepened by several other readings, most powerfully by Rose (1989). Further support for the basic theses comes from my own experiences in high school in rural Kansas and from the reactions of many of the faculty from nontraditional backgrounds with whom I have discussed these issues. The presumption that students must come to us having already learned the disciplinary standards for reading, writing, and evaluation, as discussed in the last section, would of course be an example of how we assume that the students should have had a fairly upper middle-class background. This presumption is often heightened by the deadlines we use in grading.

When we assign a fixed, one-shot deadline for grading we typically assume, first, that the student can tell when she has adequately mastered the content with little or no feedback. Secondly we assume not only does she come to us knowing how to master the material but also knowing how long that it will take to master the material—so students often become fully aware before an exam that their mastery is short of their own standards but find that they have misjudged the time it takes to master the material. Our grades for them will then reflect neither ability nor willingness to learn.

Further, with one-shot grading we assume that students are largely isolated from worldly concerns. Thus a student may have learned to recognize A-level mastery, have a very good idea of how long it will take to achieve it, and have allowed an adequate time to do the work but still have these plans interrupted by externally imposed changes in work schedules, by sick children (especially in single parent households), or other nonacademic factors. Clearly, these constraints are least severe for upper middle-class students who have at best marginal jobs and have no children. These constraints are much greater for the nontraditional students who now form the new majority in higher education. All of these issues are intensified by the habit of teachers at most institutions of assigning deadlines independently. It is not unusual for a student to have exams or major papers due the same week in three of the four courses she is taking.

Considerations such as these have led me to write two versions of each exam (finals excluded for logistic reasons). Students who don't like their grade on the first one can take the second exam two weeks after the first. They then get the higher grade of the two. Students can also opt to skip the first exam, do the work for their other courses, and then take the second exam. Practical considerations clearly affect the attractiveness of such changes. One issue to consider with such a scheme is the amount of grading. I have found that writing an exam that is about 70% as long as I used to use will keep me from doing much extra grading, because several students will elect to only take one of the two exams.

A second issue that arises when I discuss this extra-exams approach with other faculty is the loss of "coverage" entailed by using a second class period for an exam. Initially, I scheduled make-up exams in the evening at a time convenient to all of the students who wanted to take it. This is still a fine solution in modest sized classes but can be nearly impossible in larger classes. Eventually, I realized that the second exam caused most students to study many extra hours. Hence, I was teaching substantially more biology by giving the second exam than I could with any other use of class time. The increase in grades that this approach produces represents, of course, a corresponding increase in my success in fostering student mastery of the material.

A third issue here is that of appropriate professional conduct. Like most faculty, I want our graduates to be able to meet deadlines and otherwise perform in a professional manner. The question, however, is whether we assess in ways that eliminate as freshmen or sophomores most of those who come to us without these upper-middle-class skills in place or whether we should teach them the

skills during the time they are in our programs, fostering them in freshmen and assessing them in seniors.

In this article I have advocated the use of structured, small-group discussions, the explicit teaching of disciplinary discourse, and flexibility with respect to time deadlines. There are many other layers of bias built into our teaching, even in science (starting outline in Nelson, 1993). For example, deep changes are needed in what we teach (e.g., Beldacos, 1988; Harding, 1986; Rosser, 1986) as well as in how we teach (the subject of this article). Indeed, I became convinced some time ago that the only effective way to teach science is as a set of processes in which we look for the presently better alternative rather than suggesting that we have found certain truth (Nelson, 1986, 1989, 1997). This comparative approach fosters a deeper understanding of science as a set of processes for critical thinking, and thus as a concrete example of critical thinking. It is also both more representative of the real nature of science and much less threatening to the students when controversial issues arise.

However, I have concentrated in this article on changes in how we teach rather than what we teach. These may or may not be less satisfying philosophically than changing the basic way we structure the content. But they are the ones for which I know the strongest evidence that they make a real difference in student achievement.

FUNDAMENTAL CHANGES IN PEDAGOGICAL PARADIGMS

The first conclusion I want to draw from my experience and from these examples is that several alternatives to our traditional ways of teaching have been shown to lead to stunning improvements in student achievement. Angelo and Cross (1993) present many examples showing how to diagnose what changes are needed (a process they call classroom assessment) and how to assess the effects of those changes ("classroom research").

One of the examples from Angelo and Cross (1993, pp. 69-72) shows especially clearly that massive improvements are fairly easy to attain, even if one does not directly deal with diversity. A calculus instructor, frustrated with student performance, changed from five homework problems per period to four but added the requirement that the students take one of the four and explain in English sentences how they solved it (this counting as 20% of the day's homework grade). He then built upon these explanations during the in-class discussion of homework and related problems (i.e., he used what I above called structured discussions). To the teacher's surprise, not only were midterm and final exam scores much higher than usual, but "for the first time in nearly thirty years of teaching calculus, he did not fail a single student" (Angelo and Cross, 1993, p. 72).

Similarly, an economics professor who tried some of the ideas suggested here reported that he had created a major problem for his department (personal communication). He taught one of 10 sections of introductory economics, all

having a common midterm and common final. Scores on the common exams were assigned grades by a formula that gave a fixed percentage of the class each grade from A through F. He reported that in three years of using these approaches none of his students had received an F. Consequently, his colleagues were all eating extra Fs. However, they were quite unprepared for the question: How do you grade if some or all of you can teach in ways in which no students make marks as low as those that you used to call F?

There is thus no doubt that we know how to make massive differences in overall student achievement. And, again, gains are not just on comprehension, but also on application, synthesis, retention, enthusiasm, and more (McKeachie, 1994).

My second conclusion is that these nontraditional approaches usually produce large gains by the groups of students who have been hardest to reach with standard pedagogy. This conclusion is supported not just by the studies such as Treisman's (1992) that have addressed the issue directly, but also by those that have looked just at overall classroom performance. Clearly, if no one is making an F, then no one from the hard to reach groups can be making an F either.

These two conclusions together make it hard to justify offering any course that uses largely passive pedagogies. Specifically, a straight lecture course is quite unlikely to be as effective overall as one making extensive use of structured discussion. And studies like Treisman's (1992) have made it clear that a failure to make effective use of these techniques is also (unintentionally) discriminatory against Blacks and other traditionally under-represented groups.

This raises the question of whether it has already become immoral to teach without extensive use of the active learning techniques that so enhance performance. Please note that I did not say that lecture and other traditional techniques have no place in a well-taught course. And let me stress that questions of morality must be carefully evaluated in the overall context of faculty teaching "loads" and support for innovation and for more time-intensive methods. Yet major effects can be achieved with effort no greater than that required to offer a new course, a task we each undertake occasionally.

The evidence that these alternative pedagogies are more effective and equitable is now so strong that it seems to me that the burden of proof has shifted. As a consequence, I would suggest that any faculty member offering (and any administrator supporting) a straight lecture course might be required to show that it is at least as effective in producing student learning as it would be if enriched with a generous admixture of these nontraditional approaches.

In so saying, I do not wish to understate the extent of change that is required. Two fundamental changes in paradigm must underlie any major improvements in higher education and, especially, in our prospects of success with under-represented groups. The first is the change from measuring teaching by what is taught (or other teacher behaviors) to measuring it by what is learned. Barr and

Tagg (1995) eloquently discuss the need to shift from a teaching-focused paradigm to a learning-centered paradigm. The second major change I see needed is a switch from seeing our roles as sorting out the unfit to seeing our roles primarily as coaches striving to maximize the success of all students in mastering our disciplines and attaining the a truly liberal education.

To achieve such shifts, we as individual teachers and administrators will have to seek out and take seriously the literature on the improvement of college teaching (e.g., Feldman and Paulsen, 1994; Halpem and Associates, 1994; Menges and Mathis, 1988) and will also need to use classroom assessment and research systematically in our own classes (Angelo & Cross, 1993). We will also need to pay special attention to the burgeoning literature on diversity and college teaching (e.g., Adams, 1992; Border & Van Note Chism, 1992; Turner, Garcia, Nora, & Reardon, 1996).

However, as Treisman (1992) emphasizes, the deeper issue is one of institutional reform—how institutions might make it possible and attractive for faculty members to work on course and curriculum reconstruction and how they might provide resources and rewards that encourage departments to pursue such changes. Thus individual faculty responsibility is joined to institutional responsibility.

Meanwhile, it has become clear that we each could fairly easily make large differences in student achievement and in the extent to which our courses and institutions are fair. As Treisman (1992) says,

Ultimately, one must realize that the Black and Latino students who do make it into higher education are national treasures and must be treated as such—their success will have important ramifications not only for the academic disciplines and professions they pursue, but for the very fabric of American society, (p. 371)

It is clear that we already know what to do first. And it is clear that much of it is doable without further delay—each of our classes can change in important and effective ways as soon as tomorrow morning. There are no risks and minimal costs in getting started. And much more than individual lives (as if that were not enough) hangs in the balance. On what grounds can we possibly justify further delay?

APPENDIX

For Further Information

- Angelo, T. A., & Cross, K. P. (1993). *Classroom assessment techniques*. Great tools for improving teaching.
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