*Studying Students Studying Calculus: A Look at the Lives of Minority Mathematics Students in College**

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Being invited to give this inaugural Dolciani Lecture is a special honor for me because I had the opportunity to sit in on some of Mary Dolciani's courses at Hunter College while I was a high school student, many years ago. I am frequently reminded of Professor Dolciani when I see her books as I do often in classrooms throughout the United States.

Tonight I would like to describe the evolution of a project that I developed some 15 years ago at the University of California, Berkeley. Let me begin by stating the problem that we were addressing, namely, the rate of failure of Black and Hispanic students in calculus. Calculus was then, and remains today, a major barrier for minority students seeking to enter careers that depend in an essential way on mathematics.

At the time we began work on this issue, the problem of minority student failure in mathematics and science was seen by many as principally a political issue: a question of social justice, as a moral failure of the university. Finding solutions to this problem had little to do with institutional survival. The number of minority students in colleges and universities was relatively small and the number of non-minority students interested in mathematics and science was relatively large. Minority student failure did not affect enrollment, the life-blood of public institutions.

Today we have an added problem: one of institutional survival in the face of fundamental demographic change. In the State of California for example, over the next fifteen years the University of California alone will need 10,400 new faculty members. The California State University System will need even more. Who will they be, where will they come from? The answer, of course, is from today's elementary and middle-school students. If you want to get a feeling for demographic change, take a tour of the kindergartens in the community surrounding almost any college or university near an urban area in the United States.

What started out for us as a problem of helping certain students pass calculus has become a much larger problem connected to institutional survival and, in fact, the survival of our society. As we look around the world we see country after country being torn apart by ethnic violence. It remains an open question whether we can create in this country a democratic society which respects diversity and enables individuals to participate in all aspects of American life in meaningful numbers. The melting-pot is a great symbol but sometimes it seems like the pot's been on the stove too long. Some of the ingredients have been burned.

It now seems to me ironic that my involvement in this work was the result of an accident. I was a graduate student at the University of California, Berkeley, working on my doctoral dissertation. I was also working with a faculty member, Blaine Lawson, to develop and pilot a new training program for our department's

*A Mary P. Dolciani Lecture

teaching assistants. The two of us were trying to improve the quality of instruction in introductory calculus at Berkeley. At that point, we were not focusing on minority students, because very few enrolled in the course. And then a wonderful accident occurred that fundamentally changed my professional life.

It was about 1974, and I had a model section of freshman calculus. The idea was that I would teach a section as the "Great Teacher" and try out all of these exciting innovations I had been reading about. I didn't happen to take note of the fact that I actually didn't know how to teach. But I was determined. I picked a section, and hoped that the new teaching assistants and perhaps some junior faculty would visit, get ideas, and become inspired to work on improving their instruction. The rub was that the students did not share my interest in innovative instruction, such as it was. They seemed to be interested mainly in becoming engineers, business professionals and physicians; they merely wanted to "get through" this course. I said, "You guys, you're really going to interact with each other and you're going to love mathematics." They said, "Will it be on the test?"

So, it's a few weeks into the term and I'm pushing and they're pushing back. Then I receive a letter from two graduate students in the School of Education. It said, "We are engaged in a master's thesis study of the validity of students' teacher evaluations." (The question of whether student evaluations of instructors should be considered in promotion and tenure decisions was, at that time, very controversial.) "Your students have identified you as either one of the ten best or ten worst teachers on this campus, and for the purposes of our study, we cannot tell you which." The great and wonderful insult was that their plan was to videotape us in action, and show these tapes to *real* teachers, and see if they agreed with the students' assessments of our teaching.

So let me set the scene. The classroom was set up for videotaping. Twenty-four students were working, four to a table. Each table had a microphone and I had a lapel mike. The students were told that their mike would be live only when I was interacting with them. (I, of course, had told them the session before that from now on I would give credit for classroom participation.) I thought to myself, "The heck with their research, this is my reputation and I'm going to look good."

Well, it was as if Plato has written the script. The students were arguing heatedly about mathematics. They had rival conjectures about the behavior of the derivative of $1/x$ when x is large in absolute value. This is the stuff you see, maybe, once a decade. And I had it on film. Two men and two women were locked in debate and as I walk away from them, you realize something is not quite right. What's wrong is that my mike and all the other mikes are dead except for the one at their table. Without their knowledge, everything they are saying is being recorded.

Just before I walked away from the table, I looked at one of the students in the eye and said, "Gee, that's really good work." The guy next to her looks straight into the camera and he says, "Yeah, this is a really good class." As I walk away, the students start whispering. Then a woman says, right into the mike, "(a four-letter expletive which, in her home state of Texas, was pronounced as a four-syllable word), do you ever understand anything that joker is talking about?!" From there, it went downhill.

When I saw the video, I was a little depressed and demoralized. So much for the great teacher. However, during the next class period I got my revenge and showed the film in class.

Because of my work with the TAs, I was becoming increasingly interested in how students actually learn calculus. Do they use a textbook? With whom do they discuss homework assignments? What do they do when they get stuck on a problem?—the really basic questions about how students learn mathematics. I began to design projects aimed at answering these questions. One of these projects involved having each TA interview especially successful and especially unsuccessful students in his or her sections. In the TA's reports it became clear that it was minority students who disproportionately were failing and this disturbed many of the TAs as well as myself. In fact, when we looked at the data we found that in the preceding decade 60% of the Black students who enrolled in and completed first-term calculus at Berkeley received grades of D or F. In no year did more than two Black or Hispanic students earn more than a B− in any calculus course at UC Berkeley. Of course, at that time there were very few ethnic minority students enrolled on the campus. In the typical freshman class of the mid-70s there were fewer than 150 Black and Latino students in a class of 3,600. Today, 32% of the incoming first-year students are Black, Hispanic or Native American. Only 38% are non-Hispanic Caucasians. The Berkeley campus finally looks like it's part of California.

To support our inquiry into minority performance in calculus we sought a grant from a major foundation. In the course of negotiating we were asked to produce almost instantaneously a clear statement of our initial hypotheses. What to do? We really didn't have a clue. We had to develop our hypotheses quickly so we asked a few thousand people who didn't have a clue either and made bar graphs displaying the distribution of their responses—a sorry view of social science research.

Let me state what we found in this survey because I believe that these assumptions are responsible for the failure of many university intervention efforts, and because these assumptions are rarely stated explicitly and then, almost never publicly. Four widely-held beliefs about the causes of minority student failure surfaced in the responses to our survey. The first was that there is a motivation gap. It's not that the minority students are unmotivated, this argument goes, but that they are not as motivated as certain other groups, namely the Asians. The implication was that small differences in motivation would have large effects in highly competitive and difficult courses. The few A's given would go to the students who, because of their high level of motivation, were willing to work extraordinarily hard. It was the students who were extraordinarily motivated who would excel and those students were disproportionately Asian.

The second argument named inadequate preparation as the culprit. Minority students often enter the university with fewer credit hours of science and mathematics from high school and with substantially lower SAT scores. The fault lies not in the university, but in what students bring to the university, namely motivation and prior preparation. In other words, "It's not our fault."

To take this argument a step further, several faculty pointed to the "vertical" organization of math and science. New topics depend on the topics which precede them; courses depend on the courses which precede them. This characteristic of math and science makes it difficult for students to improve their performance once they are having difficulty. Even if students are committed to improvement, the intensity and speed of freshman courses give them no time to catch up.

The third problem was a conjectured lack of family support or understanding of higher education. The idea was, roughly, that since the families of these kids did not have rich educational backgrounds, how could they pass on to their kids the survival skills they would need in college? Moreover, some faculty members thought that the parents did not push their kids hard enough. Of course, we had never met any of these families, but we seemed to have clear ideas about them.

The fourth idea is a corollary of the great liberal dream: "It has nothing to do with race or ethnicity at all. Income is the dominant variable. If you control for income, all the differences disappear." Then there were a few older faculty members who had views about the effects of race and heredity and the like. They are gone now, replaced by a small younger group of faculty with similar ideas. I want to mention, though, that one faculty member, whose views on the supposed genetic inferiority of Blacks were well-known on campus, wrote the only interesting response to our survey. According to his calculations—he was big on pseudo-statistics—"population characteristics" (by which he meant "race") could account for only about 4% of the failure. But the observed failure was so great that only the institution's behavior could account for it. What an irony. He was the only one to assert that something might actually be wrong with the institution.

Well, these were our hypotheses and, at the time, we believed them. Minority students' failure could be attributed to low income, low motivation, poor academic preparation and lack of family support, all factors, incidentally and conveniently, over which we had no control. Nonetheless, we were interested in how these factors worked. "On *which* calculus problems did these issues cause trouble? "*When* and *how* did they actually interfere with student success?"

Our initial idea was to interview students. A typical question: "How many hours to you study?" A typical answer: "I put in two hours for every class hour." The students weren't being dishonest, they just didn't have an accountant's view of how they organized their time. Our next attempt was far more intrusive. We embarked on our version of a social science study, mixing, not really consciously, two different methodologies: ethnography and the 1920's "industrial style" time and motion study.

We had picked 20 Black and 20 Chinese students for our study. The idea was that we would compare two ethnic groups, one that generally did well in our mathematics classes, and one that did not. We decided literally to move in with the students and to videotape them at work. We wanted to understand what was going on when they studied calculus, got stuck on a problem, etc.

First, we were struck by the enormous diversity among these groups and remembered that not one respondent to our faculty survey has written to ask us to *which* minority students we were referring. No one questioned the supposed homogeneity of these groups. Take the Black students, for instance. Some of them came from middle-class homes and had many White friends in high school. Others were the valedictorians of all-Black, inner-city schools; yet others were from military families and had grown up all over the world. The Chinese students were equally diverse.

The study was supposed to take ten weeks, but after four months we still didn't have a clear picture of why, as a group, the Black students were failing calculus while the Chinese excelled. We were advised by some graduate researchers in the social sciences to step back and question our hypotheses; this was really useful. Instead of looking at what happens when students get stuck on a problem, we were encouraged to look more globally at their lives. We went up to Lake Tahoe with hundreds of hours of unedited videotape. In a weekend all of our hypotheses fell apart.

Let's look at *motivation*. It is not as if our Black students thought to themselves, "Well, there's nothing happening on the streets, so let's go to Harvard, Caltech, Princeton or Berkeley." These students were admitted to one of the premier research universities in the United States, and we had presumed that their problem was motivation! Many of the inner-city students were socially isolated throughout high school; they paid a very, very high price to get to Berkeley. These kids were motivated! Unfortunately, we had been mistaking "disorientation" for lack of motivation.

The second factor was *academic preparation*. We had many years of data from Berkeley that called this hypothesis into question. We found, for example, that Black students' calculus grades correlated negatively with their high school Math SAT scores. Many of the "strongest" students failed early. Black men with high SATs often faced academic dismissal. The few successes, on the other hand, came from students who, on paper at least, appeared to be of middle ability. These data forced us to call into question our ideas about the role of high school background in college performance among Black students.

We studied the issue of *family support* by interviewing the families of our students. We came to appreciate quickly that many of the parents had decided before their children were ever born that their sons and daughters would go to college. These kids were, in large part, at the university because of the concerted and organized efforts of adults who cared about them. We found no parental apathy and quite a few parents who were themselves college graduates.

Income correlated negatively. Why? Because many of the Black students had parents who were public school employees. Some were teachers, some were secretaries, some were custodians; in any case, public school employees don't earn much. The second largest group were children of civil service workers. Typically, the parents had degrees from historically Black colleges, moved out to California in the 1950s and 1960s, and couldn't find jobs in their chosen fields. So they went to work at the Post Office.

So, what did we find by looking at our students? What did "studying math" mean for the Black and Chinese students? For the Black students it meant this: You wake up in the morning. You go to class. You take notes. You get your homework assignment. You go home. You do your homework religiously and hand in every assignment on time. You put in six or eight hours a week of studying for a calculus course, just what the teacher says, and what happens to you? You fail. An important point here is that the Black students typically worked alone. Indeed, 18 of the 20 students never studied with their classmates. The same pattern occurred among many of the blue collar Whites and rural students.

What about the Chinese students? They studied calculus for about 14 hours a week. They would put in 8 to 10 hours working alone. In the evenings, they would get together. They might make a meal together and then sit and eat or go over the homework assignment. They would check each others' answers and each others' English. If one student got an answer of "pi" and all the others got an answer of "82," the first student knew that he or she was probably wrong but could pick it up quickly from the others. If there was a wide variation among the answers, or if no one could do the problem, they knew it was one of the instructor's "killers."

It was interesting to see how the Chinese students learned from each other. They would edit one another's solutions. A cousin or an older brother would come in and test them. They would regularly work problems from old exams, which are kept in a public file in the library. They would ask each other questions like, "How many hours did you stay up last night?" They knew exactly where they stood in the class. They had constructed something like a truly academic fraternity, not the more typical fraternity: Sigma Phi Nothing.

The Black students, on the other hand, didn't have a clue what other students in the class were doing. They didn't have any idea, for example, what grades they were going to get. The exams were like a lottery: "I got a B," or, "I got a C." They had no idea where they stood relative to their classmates. Moreover, these same students were getting A's in "Study Skills," and F's in the calculus class. What they were taught in "Study Skills" was of little help to them in calculus.

At this point it is useful to look at how universities attempt to deal with the problem of minority student failure. In the '60's, the university administration hired people to deal with this problem, which was then seen as essentially a political one. This is not to say that the administrators didn't care about these students; however, in hindsight we can say that their efforts were misguided.

Because of the political character of affirmative action, the administration took primary responsibility for minority student programs, even those which addressed academic issues. The political pressure to create these programs was felt on virtually every American college and university campus. If we look at these programs, even now, we see first that they are isomorphic. They have little to do with the special mission or history of the institutions in which they exist, which is remarkable given the diversity of American higher education. Student affirmative action programs are as similar as personnel offices. Second, they have very little, if any, connection to the faculty. They are staffed by very caring people, many of whom are minority, and who are devoting their professional lives to helping minority students avoid failure. But, unfortunately, they see massive failure and this has led to corresponding burnout and anger. In the large, their tutorial programs are disastrous. The tutors see the students the day before the exam; the counselors see them the day after the exam. Seeing the overwhelming failure of the students they care about, affirmative action program staff can easily develop a "bunker mentality." Counselors see the faculty as "the enemy" and advise their students to stay away from mathematics and science. This is a scary and depressing phenomenon—very depressing.

An equally disturbing phenomenon is the creation of remedial courses that lead nowhere and preparatory courses that do not prepare students for subsequent courses. On many campuses these courses have high minority enrollments and have become associated with minority students. At Berkeley, for example, we teach a course called "pre-calculus." In one year, 422 students enrolled in the course, only one of whom went on to receive a grade of B− or higher in second-semester calculus. The evidence is overwhelming that the few students who take remedial courses never complete science degrees.

So, at the end of our inquiry, what had we learned?

1) Many Black and Latino students entered the university wanting to major in math and science but very few completed the prerequisite entry-level courses.
2) Our ideas about why minority students failed calculus clearly were wrong.
3) Affirmative action programs were not producing math and science majors. It was clear that they were helping some kids stay in school, but they weren't helping students in our field.
4) Many minority students, especially Black and Latino students, did not use the services that were designed to help them.

This last point is of special importance because many Black students are suspicious of appeals made to them based on race. These students also dislike the idea of remediation. They see themselves as the tutors, not the tutees. When the university sends a letter as ours did, "Dear Minority Student: Congratulations on your admission to Berkeley. Berkeley is a difficult institution. You are going to need a lot of help and we are here to help you," the students disregard it. They associate "help" with the kids they had known in high school who were in the bottom of the class and in the compensatory programs. They do not relate to such appeals. Finally, they do not choose to come to a Berkeley because they want to learn about being Black. They choose it because they believe in the institution's ideals and elitism.

In 1978 we began to experiment with solutions. Our idea was to construct an anti-remedial program for students who saw themselves as well prepared. In response to the debilitating patterns of isolation that we had observed among the Black students we studied, we emphasized group learning and a community life focused on a shared interest in mathematics. We offered an intensive "workshop" course as an adjunct to the regular course. In contrast to the traditional remedial programs that offered reactive tutoring and time management and study skills courses which have a questionable scholarly base, we provided our students with a challenging, yet emotionally supportive academic environment. The project was supported under a grant from FIPSE, the Department of Education's Fund for the Improvement of Postsecondary Education.

Most visitors to the program thought that the heart of our project was group learning. They were impressed by the enthusiasm of the students and the intensity of their interactions as they collectively attacked challenging problems. But the real core was the problem sets which drove the group interaction. One of the greatest challenges that we faced and still face today was figuring out suitable mathematical tasks for the students that not only would help them to crystallize their emerging understanding of the calculus, but that also would show them the beauty of the subject.

Our goal was then and continues to be now not merely helping students pass calculus or even to excel at it but, rather, producing mathematicians (or at least students who could pursue graduate work in the field if they chose to do so). We knew that the program goals had to be congruent with the goals of the institution, i.e., focusing on excellence, on the production of Rhodes Scholars, and the like.

We were able to convince the students in our orientation that success in college would require them to work with their peers, to create for themselves a community based on shared intellectual interests and common professional aims. However, it took some doing to teach them *how* to work together. After that, it was really rather elementary pedagogy.

In a sense, the greatest break with the past was to take a genuinely empirical stance. We did not question that minority students could excel. We just wanted to know what kind of setting we would need to provide so that they could. We also recognized early on that we would be successful only if we depoliticized the issue of minority access. We had to link our program with other issues that the faculty cared about, such as producing quality majors, and de-emphasize the purely political characteristics of the program so that it could take hold in academic departments. From the beginning, therefore, we served students of all ethnicities, although students of color were, in fact, a clear majority in all the sections. The effect was that many middle-class Black and Latino students found it comfortable to participate because it was a way for them to establish quickly the multi-ethnic social environment in which they were most comfortable. For the urban Black and Latino students the workshops were an environment in which they were the majority and the White students the minority, making it easier for cross-ethnic friendships to form. In effect, the workshops provided a buffer easing minority students' transition into the academy.

The results of the program were quite dramatic. Black and Latino participants, typically more than half of all such students enrolled in calculus, substantially outperformed not only their minority peers, but their White and Asian classmates as well. Black students with Math SAT scores in the low-600s were performing comparably to White and Asian students whose Math SATs were in the mid-700s. Many of the students from these early workshops have gone on to become physicians, scientists, and engineers. One Black woman became a Rhodes scholar, and many others have won distinguished graduate fellowships.

By 1982, more than 200 ethnic minority students were being served in the workships, which were then run cooperatively by a faculty committee, the College of Engineering, and the Student Learning Center. In 1983, however, when our initial funding expired, there was open warfare. The faculty and administration were fighting for control of the program. Unfortunately, the faculty lost and a period of balkanization followed, with small, separate programs proliferating on campus.

But there was a more fundamental demogaphic change taking place in the mid-80s that would, in any case, have forced the reorganization of these programs. Today, on the Berkeley campus, there no longer is any dominant ethnic group. Fewer than 50% of all undergraduates are White and roughly one-third of the incoming freshmen are Black, Latino, or Native American. 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. Unfortunately, they are still rare individuals and their success will have important ramifications not only for the academic disciplines and professions they pursue, but for the very fabric of American society.

By the mid-1980s, the time had come when "adjunct" programs were no longer feasible or desirable. It was time to address the efficacy of the introductory courses. Each year, on average, 600,000 first-year college students take calculus; 250,000 of them fail. What I find even more amazing than this high failure rate is that calculus—now here comes my prejudice as a mathematician—is, by just about any standard, one of the greatest intellectual achievements of western civilization. The subject drips with power and beauty. It rendered thousand-year-old questions immediately transparent. Calculus is truly amazing. But, how many students who take the course as freshmen look up and say, "Wow! That's amazing!"? How often, math faculty members, have your students had that experience? I mean, the stuff just sort of goes by. No passion, no soul.

Why do so many students fail these courses? Our initial idea once again was to blame the students, albeit in a more sophisticated way than previously. The students, we thought, did not have "higher-order" thinking or problem-solving skills; they just did not know how to think, they didn't know how to pull the problem out from the words and find the relevant principles. However, when we tested this idea, we found once again that we were basically wrong. When we looked at students enrolled in first-term physics, for example, we found there were some students who couldn't find the relevant principles in a problem. But these students were relatively easy to help if they had enough prior exposure to physics. The majority of students having difficulty fell into two groups. Group one were the kids who had intellectual integrity, but no meaningful prior exposure to physics. When they came upon a hard idea—inertia, angular momentum—they would spend four or five days trying to figure out the concepts. They had learned not to let anything pass. The result was that they would get buried in an avalanche of formulas. To paraphrase a comment of Fred Reif's, we see the course as centering on four ideas; the students see only 400 formulas.

Other students had really strong math backgrounds. Their response to the massive amount of material that was dumped on them was to treat everything as an isolated, abstract, mathematical problem-solving task. They never had a chance to develop the underlying physical intuition (and the standard physics labs sure didn't help). They were treating physics as if were mathematics or logic. The courses contained so much material that students had no time to develop an understanding of the physical concepts, the connections among these topics, or the relationship between the physics they were studying and the mathematics they knew.

Once again, we were forced to deal with the fact that the problem wasn't the students. Students, in fact, respond to whatever you give them. What they were being given here were courses that had become so compressed, so devoid of life and spirit, that there was no way to really master the ideas at the level necessary to succeed, let alone become a major.

These introductory math and science courses took form at a time when there was a surplus of students interested in science and over the years came to be thought of as service courses. Everybody teaches their freshman courses for somebody else's major. Now, times have changed. Very few students are interested in math and science. A recent study by Sandy Astin and Ken Green using data from UCLA found that in 1966, 4.6% of high school seniors who took the SAT were interested in mathematics as a major. Today it is about 0.6%. We are teaching courses created at a time when filtering was a necessity. Now, freshman courses need to inspire students and invite them into the major.

Our approach at Berkeley was to eliminate the adjunct workshops and instead to strengthen and intensify certain sections of the regular freshman calculus course. (We recognized that if we were to try to improve instruction for everybody equally we could only make a slight difference. Our resources were relatively limited and we didn't want to lose the minority students.) Our idea was to construct a hybrid of the regular discussion sections and the "math workshop."

We encountered several difficulties. The first was the absence of genuinely challenging calculus problems to solve. What passes for problems in freshman calculus is a set of ritualized exercises that can be addressed by mastering a limited set of algorithms together with a few special cases. The exceptions—indefinite integration, convergence of series of constants, which are fun to teach and really are excellent domains for teaching problem-solving skills—probably have no place in a contemporary calculus course, as so many in the calculus reform movement have pointed out.

The second difficulty is that we don't have a clue how to teach problem solving in a way that promotes the development of generalized problem-solving skills. Using state-of-the-art materials, such as those developed by Alan Schoenfeld for teaching a topic like indefinite integration, we can help students to get very good at one particular task. Unfortunately, experience has shown that such instruction in isolation gives students little advantage in mastering subsequent topics.

The final issue, which we are only now beginning to address, is how to make it possible for faculty members who are interested in working on course reconstruction or on the development of minority mathematicians to do so as part of their professional work. In the past the individuals who worked on these, what were then seen as quasi-professional issues, did so as personal work, almost as hobbies. The scale of the problem is now such that many mathematicians will need to engage in activities that are necessary for the future life of the profession. If this is to happen, such work must become a regular and rewarded part of departmental life. This, in turn, will require that faculty and administrators redefine responsibilities of departments and support the redefinitions by new review and department budgeting procedures.

Let me restate this. It means that the administration has to rethink what the collective responsibilities of departments are. Are departments only responsible for research and for body-count teaching? Or are they responsible, in some way, for the future of the institution and the future of their own disciplines? If the latter is so, one has to think about ways of rewarding departments for playing their proper role. Not that every faculty member should do this, but each department has to be responsible for contributing to solutions to these problems. The rewards for the departments have to be real: space, faculty appointments, support for more graduate assistantships, and so on.

For the most part, at least in the beginning, faculty members who do this work will have to be senior members of their departments, partly because junior people need to establish research careers, but also because the changes that have to be made are structural in character. Junior people have little insight into such work. Put another way, and visualize my tongue in my cheek, "It's not the young sap that holds up the tree, but the old dead wood." Further, it is important that the faculty who engage in this work are able to do so in ways that do not lead to stigmatization. A hint: don't confuse this work with better teaching. If you focus on teaching alone, you lose. Reform is about curriculum, allocation of faculty energy, and so on. It is about assuring the future of the profession and the future of our institutions. But it is not only the academic departments that need to change.

Whereas some of the work is academic, other parts are administrative. These include such issues as housing, financial aid, student organizations, and the like. When the university works it does so because the faculty plays its proper role and the administration plays its. We have to reexamine the ways faculty and administrations work together to help students advance. An especially important issue will be learning to work with the equal opportunity and minority affairs offices.

Now, instead of talking only about Berkeley, I want to talk about some of the other sites with which we've been working. One institution where this is happening, at least on a small scale, is the University of Texas at Austin. A group of faculty members led by Efraim Armendariz and an extraordinary administrator, Jackie McCaffrey, said, "Let's figure out what we have to do in calculus to produce lots of Hispanic and Black mathematics majors." They took our Berkeley idea: they intensified some sections of freshman calculus. They built group work into the course and made it clear to the students that it takes fifteen hours of work, not eight, to excel. They made it possible for the kids to take slightly fewer courses at a much greater depth and level of intensity. They unabashedly advocated for these students to become mathematicians. They set up a system where the kids in the intensive courses could be graded against the curve established by the regular sections—same exams. What happened? Minorities: 3.53 average GPA; others: 1.66. The department now has more than 100 Hispanic and Black math majors.

At CCNY, the faculty believed that their students would never become mathematics majors. The students were all working 40 hours a week and, the faculty assumed, had little interest in being challenged. Inspired by the Berkeley program, they decided to test their assumptions. A team led by Lora Shapiro interviewed students, and what did they find? Lots of these students had saved up tuition money so they could go to school. The strongest students found the courses uniformly unstimulating and unchallenging. In response, the department set up more challenging "intensive" sections and the result of the first semester was a 3.2 average grade for the minorities against about 1.8 for the class average.

In conclusion, the time has come to reexamine undergraduate instruction and to make it more responsive to the needs of today's students. We can no longer offer courses that half of our students fail, nor can we lower our standards. The challenge is to reconfigure undergraduate science and mathematics education in ways that will inspire students to make the choices we have made. This can happen only if we change the boundaries of faculty responsibility. It is the faculty that must take the lead.

Gather; Don't Strew

During the last decade or so of teaching my applicable-math course for junior physics majors here at Oberlin, I found it increasingly necessary to deliver the injunction, "Gather; don't strew!" to my students. Too many of them would too often convert a conveniently compact expression into an inconveniently strung-out multinomial that more often than not led to nothing useful.

Reading a set of student papers one day late in my career, I was confronted with

$$\int_0^1 (1-x)^3\,dx = \int_0^1 (1-3x+3x^2-x^3)\,dx = \ldots$$

on each of the first several papers I examined—in cold-blooded violation of my oft-repeated injunction. But then came a glorious burst of sunshine. At the bottom of a page of the next paper of the set, I read

$$\int_0^1 (1-x)^3\,dx = -\tfrac{1}{4}(1-x)^4\Big|_0^1$$

and my heart leapt with joy—until I found at the top of the page following:

$$= -\tfrac{1}{4}(1-4x+6x^2-4x^3+x^4)\Big|_0^1 = \ldots!!!!$$

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