The Academic Excellence Workshop demonstrates that achievement of underrepresented minority students in mathematics and subsequent persistence in SME majors may be associated less with precollege ability than with in-college academic experiences and expectations.

Increasing Minority Students' Success in Calculus

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During the past ten years the undergraduate calculus course has attracted an unprecedented level of national interest. Since the release of the David Report (David, 1984) concerning the state of undergraduate and graduate mathematics in this country, the National Science Foundation has spent more than $5 million on programs to strengthen the calculus. Professional organizations such as the Mathematical Association of America (MAA) and the American Mathematical Association of Two Year Colleges (AMATYC) have regularly included in their professional meetings sessions on "calculus reform" and "the first two years." Indeed, about a quarter of the sessions at the 1993 annual joint meetings of the American Mathematical Society/Mathematical Association of America conference dealt with undergraduate mathematics education. Although both opinions and practices of teaching the calculus vary widely, the calculus reform movement has affected nearly every two-year and four-year college and university in America (Steen, 1987).

Among the most widely recognized intervention programs in college mathematics is the calculus workshop model that was developed for African American students at the University of California, Berkeley by Uri Treisman in the late 1970s (American Mathematical Society, 1988; Fullilove and Treisman, 1990; Selvin, 1992; Treisman, 1985). The Berkeley model, known now as the Emerging Scholars Program (ESP), has been adapted in mathematics courses at more than a dozen major universities across the country (Selvin, 1992), with

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more than a hundred two-year and four-year colleges initiating trial ESP-type programs in the past five years. In a recent issue examining pipeline issues for minority students in science, mathematics, or engineering (SME) majors ("Minorities in Science . . . ," 1992), *Science* reported that some ESP programs have dramatically lowered dropout rates and increased the number of minority students majoring in SME fields. For example, the graduate program in applied mathematics at Rice University and the undergraduate mathematics program at the University of Texas at Austin each award approximately one-fourth of their degrees to African American or Latino/Latina students (Selvin, 1992). In 1992, Treisman received a MacArthur Award for this work, in recognition of its national impact on the success of underrepresented minority students in mathematics-based fields.

Purpose of the Research

The present research represents the first longitudinal investigation of the effects of workshop participation on persistence and achievement of underrepresented minority students enrolled in mathematics, science, and engineering majors. The study also investigates students' interpretations of the effect of their workshop experience on their academic performance and academic choices. The study is based on the workshop model implemented at the California State Polytechnic University, Pomona (Cal Poly), a comprehensive state university that is recognized for its achievement in technical fields. This study extends the Berkeley report in three ways. First, the study considers the efficacy of the workshop model in an academic setting different in goals and selectivity from Berkeley; second, the study examines the effectiveness of the model for other underrepresented groups (primarily Latinos); and third, the study traces the effects of the workshop experience over a significant period of time.

The Academic Excellence Workshop Program at Cal Poly

The Academic Excellence Workshop (AEW) program at Cal Poly is jointly sponsored by the College of Engineering and the College of Science. The workshop program began in fall 1986 with one section of first-year calculus. Although the present study considered only the performance of students in calculus, the AEW now includes workshops in chemistry, physics, and mechanical engineering. From fall 1986 to fall 1991, ninety-five different workshops have enrolled more than one thousand student participants.

The Academic Excellence Workshop program, like the Berkeley model, is premised upon excellence in student performance rather than remediation. The Cal Poly program targets Native American, African American, and Latino/Latina students. The purpose of the program is to build community and academic involvement among its constituents, with the ultimate goal of persistence and completion of an engineering or science degree (Academic Excellence Workshops, 1992).

Upon acceptance to the College of Science or Engineering, each African American, Latino/Latina, and Native American student received a letter and personal telephone call from a faculty member or student workshop leader inviting her or him to attend an informational meeting explaining the Academic Excellence Workshop program. Approximately half of the students who were contacted chose to participate in a workshop session for one, two, or three quarters of calculus. White and Asian American students were not eligible to participate in the program, although several students were allowed to join as "guests." The "workshop group" in the present study refers to the underrepresented minority students who participated in the workshop for one or more quarters.

The structure of the workshops was similar to that of the Berkeley program. Each student was enrolled in a traditional lecture section of calculus that included workshop and nonworkshop students of all ethnic groups. Unlike the large lectures at Berkeley, the classes averaged about thirty-five students and met for four hours per week. Since there was no recitation section attached to the course, student questions about homework problems and the like were covered in class by the instructor. Workshop and nonworkshop students were responsible for the same classwork, homework, and examinations.

In addition to attending the lecture class, workshop students met in structured groups of ten to twelve students twice a week for two-hour sessions outside of class to work collaboratively on calculus problems. Group leaders, or facilitators, represented mainly by upper-division minority undergraduate SME students, directed the problem-solving activities by constructing worksheets with calculus problems that helped reinforce concepts or expose weaknesses in the students' levels of understanding (see Treisman, 1985, pp. 42–44; Bonsangue, 1992, p. 279). The expectation, which was made clear to workshop students, was that they would excel in, rather than just get through, the course. A typical worksheet problem reviewing exponential growth as follows:

> Agronomists use the assumption that one-quarter acre of land is required to provide food for one person and estimate that there are 10 billion acres of tillable land in the world, so a maximum of 40 billion people can be sustained if no other food source is available. The world population in the beginning of 1980 was approximately 4.5 billion. Assuming the population increases at a rate of 2 percent per year, when will the maximum sustainable population be reached?

During the first half hour of the workshop session, students usually worked alone. Gradually, they began discussing the problems and comparing solutions. After an hour, the sessions became quite lively, with students explaining their solutions and interpretations to one another. The facilitator then could help individual students or direct the discussion of the group questions that arose. (The course instructor wrote the exams used in her or his course, so the facilitator had no information about exam questions.) The sessions also had an informal social aspect, with students sometimes munching on popcorn or

pizza while they worked. Moreover, the discussions often included nonmathematical topics as well, such as information on future course sign-ups or deadlines, upcoming departmental activities, or personal concerns.

Role of the Facilitator. The leader or facilitator, often a former workshop participant, was an undergraduate science or engineering major who had received special training by the Colleges of Science and Engineering in leading workshop sessions (see Academic Excellence Workshops, 1992). Unlike a tutor, the facilitator's primary role was to initiate and sustain interaction between workshop students by providing challenging and relevant problems. The facilitator usually did not respond to questions with direct answers but tried to foster a dialogue with the group. The goal of the workshop was to involve students in substantive mathematical or scientific problem-solving discussions with their peers. Workshop students were not permitted to do homework during the sessions. Rather, students understood that the worksheets done in the session were in addition to the regular homework assignments given in class.

The facilitator met weekly for several hours with the workshop program director and other facilitators to develop good worksheet problems and discuss concerns. He or she also met briefly once a week with the course instructor to ensure that the worksheet problems were relevant and appropriate to that week's lesson, and to verify class attendance of workshop students. The facilitator contacted the student after more than one successive absence from either the lecture or the workshop. The facilitator was therefore often the first to become aware of students' personal, financial, or logistical problems. Often these problems were resolved in a timely way with the help of the facilitator, other students, the instructor, or the workshop director. Thus, for many students, the workshop facilitator served as the critical academic and personal hook for initial and continued success in the course. The role and job description for workshop facilitators are detailed in the *Handbook for Academic Excellence Workshops* (Academic Excellence Workshops, 1992).

Research Findings

The characteristics and performance of Cal Poly students majoring in SME was followed over a five-year period, from 1986 to 1991.

Sample Characteristics. The workshop sample was composed of 133 Latino/Latina and African American students who participated in at least one calculus workshop section while enrolled in a traditional lecture calculus section. The performance of this group was compared with that of three peer groups of students enrolled in the same lecture sections of first-quarter calculus. These included 187 African American and Latino/Latina students not enrolled in the workshop, 208 white, non-Latino/Latina students, and 198 Asian or Pacific Island students, for a total sample of 726 students. The workshop sample was composed primarily of Latino/Latina students (116 were

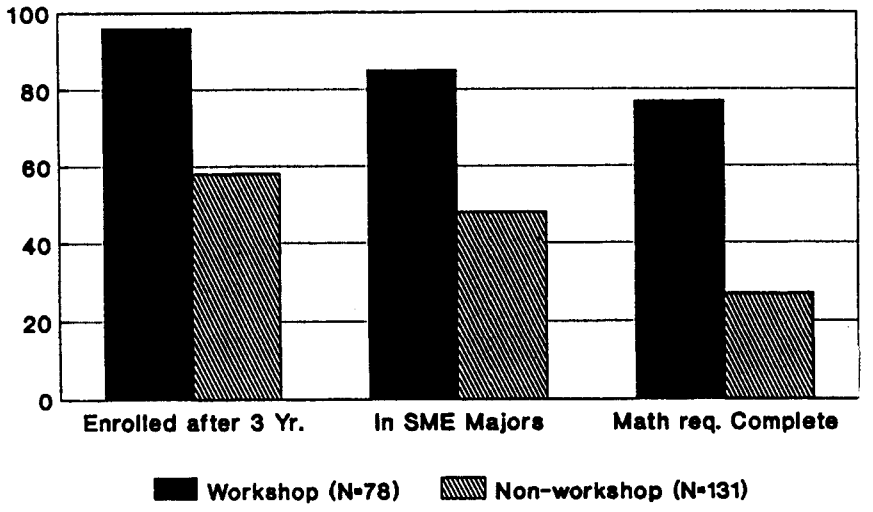
men, 133 were women); about one-fourth of the workshop students overall were women (36/133). The nonworkshop minority group was composed mostly of Latino/Latina students (159/187), and 21 percent of the total group were women. Both the white and Asian American comparison groups had a slightly larger percentage of women (30 percent).

Precollege Achievement Measures. The academic preparation of workshop and nonworkshop students was compared using SAT-Math, SAT-Verbal, high school grade-point average (HSGPA), and the student's score on the department's precalculus placement exam. There were no statistically significant differences between the minority workshop and minority nonworkshop groups in any of the four precollege academic measures. Likewise, there were no differences between white and Asian American students in SAT-M, HSGPA, or placement exam scores, although Asian American students scored slightly lower in SAT-V. African American and Latino/Latina students scored significantly lower on SAT-M and on the placement exam than did the white and Asian American group. High school GPAs were almost identical for all groups, with a mean of 3.33 for all students.

Thus, for this sample, students' selection into the Academic Excellence Workshop program was not associated with precollege achievement. However, the underrepresented minority students began their calculus sequence with lower measures of mathematics achievement than did their nonminority peers. Interpreting high school GPA as a measure of exposure suggests that none of the four groups had an initial advantage in adapting to the rigors of a university-level calculus course.

Results for Workshop and Nonworkshop Minority Groups. Although African American and Latino/Latina workshop students had no initial advantage in mathematics background or achievement over their nonworkshop peers, these students achieved a mean grade of more than six-tenths of a grade point above nonworkshop students in first- and second-year calculus. Moreover, within three years of entering the institution, 52 percent of the nonworkshop minority students had either withdrawn from the institution or changed to a nonmathematics-based major, compared with 15 percent of the workshop students. Furthermore, as a result of course failure, nonworkshop students required an average of one full quarter more to complete their three-quarter calculus sequence. Individual records showed high patterns of course-repeating, with nearly half (46 percent) of the nonworkshop minority students requiring five or more quarters to complete a three-quarter calculus sequence, compared with fewer than one-fifth (17 percent) of the workshop students. Moreover, 91 percent of the workshop students still enrolled in SME majors after three years had completed their mathematics requirement in their respective SME majors, compared with just 58 percent of the nonworkshop minority students (see Figure 3.1). These statistically significant differences were also found when comparing Latino/Latina workshop students along with their nonworkshop counterparts.

Figure 3.1. Persistence in SME Courses by Minority Students



The association of workshop participation with academic success and persistence was particularly strong among minority women, all of whom were Latina in this sample. All twenty-two of the women who had taken the calculus workshop were still enrolled at Cal Poly after three years, with nineteen (86 percent) remaining in a mathematics-based major. Of these, each had completed her mathematics requirement and was eligible for graduation. In contrast, only twelve (52 percent) of the original group of twenty-three nonworkshop minority women were still enrolled after three years. Further, only four of the original cohort of twenty-three nonworkshop women successfully completed her mathematics requirement and was eligible for graduation. These differences occurred even though no initial academic advantage was found for either group on precollege measures such as SAT-Math, SAT-Verbal, and HSGPA.

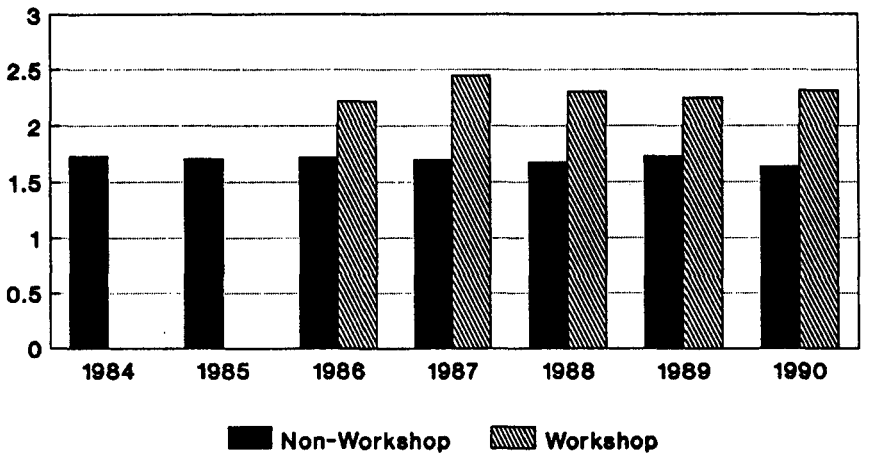
Comparison with White and Asian American Nonworkshop Groups. In the first-year and second-year calculus sequence, African American and Latino/Latina workshop students achieved the same grades as white students and slightly (but not significantly) lower grades than Asian American students. After three years, 50 percent of nonworkshop white students and 41 percent of nonworkshop Asian American students had withdrawn from the SME major or left the institution, compared with 15 percent of the workshop students. The pattern of repeating courses was almost identical for nonminority nonworkshop groups and workshop students, with each group averaging about 3.7 quarters to complete the three-quarter sequence. White and Asian American women had SME attrition rates of 38 percent and 45 percent, respectively, while those for white and Asian American men were 55 percent and 39 percent, respectively. Of the nonworkshop students who persisted in SME majors, 82 percent of whites and 89 percent of Asian Americans had completed their mathematics requirement within three years,

proportions that were similar to the 91 percent completion rate for African American and Latino/Latina workshop students.

Skimming and Self-Selection. The data reported in the previous section show that African American and Latino/Latina students who participated in the workshop calculus sessions achieved at levels as high as or higher than any other ethnic group, both during the first (workshop) year and afterward. Although social and personal factors undoubtedly influenced their achievement and persistence, this study found that traditional measures of precollege achievement were not associated with student success (see Bonsangue and Drew, 1992, or Bonsangue, 1994, for a more complete discussion).

The critical issue of self-selection cannot be fully addressed in this study because students were not randomly assigned to workshop or nonworkshop groups. However, the study did find evidence that calculus achievement for workshop students was, at least in part, a result of developing student talent rather than merely "skimming," or selecting and cultivating the most talented students. First, as noted earlier, precollege measures for workshop students were no higher—and were sometimes lower—than those of nonworkshop students. Second, a comparison of the grades of minority students enrolled in first-quarter calculus sections before and after the inception of the workshop revealed no change in average performance for the nonworkshop group compared with students in earlier, traditionally taught sections (see Figure 3.2). If the best students were selected into the workshop, we would expect the performance of the nonworkshop group to have declined. Before the workshop in 1986, minority students achieved a mean calculus grade of below 1.7, or D+. After 1986, the average performance of all minority students, both workshop and nonworkshop, rose more than two-tenths of a grade point, a statistically significant gain, surpassing the overall performance of white students in the sample.

Figure 3.2. Calculus 1 Performance, Underrepresented Minority Students



Student Experiences of the Program

Workshop students from the 1987–88 cohorts were interviewed to explore their perceptions of how their workshop involvement may have affected their academic patterns and self-perceptions. Seventy percent of the interviewees reported that they would not have done as well in their calculus courses had they not been in a workshop. This perception was especially strong among women.

The majority of workshop students reported two lasting effects of the workshop: (1) an early awareness of the academic expectations in technical courses, and (2) a recognition of the need to remain connected to their student peers, professors, and academic advisers throughout their college careers. Many students reported their initial surprise or even shock at the expectations and competition levels they experienced during their first year at Cal Poly. They associated their successful transition to college-level mathematics with their workshop experience. Drawing upon that experience, half of the students interviewed indicated that they have since regularly formed study groups in their upper-division courses, perhaps helping to account for their success in completing advanced mathematics requirements.

Gender and Minority Issues. Reports such as those of the National Research Council (1989, 1990) and "Minorities in Science . . ." (1992) have helped increase awareness of the disproportional failure of underrepresented groups (ethnic groups, gender groups, age groups, and disabled groups) of students. This study found some evidence of feelings of ethnic separation and academic inadequacy among those minority students interviewed in spite of their success in the program. However, feelings of exclusion and inadequacy seemed to be centered primarily on gender rather than ethnic issues.

Even though the workshop program was not designed to address gender issues, the most compelling results were those for women in the workshop. The Latina women enrolled in the workshop, of all ethnic and gender groups, had the highest persistence rate in the university and in their MSE majors. The nine women who were interviewed (see Bonsangue, 1994) indicated a direct effect of workshop participation on their success, both in study patterns and peer relationships. Nonetheless, each of these women reported feelings of isolation or self-doubt in varying degrees, even though they earned grades as high as or higher than those of their male peers. Overall, women described a college experience that was qualitatively different from that described by men. The relatively high attrition rates of nonminority women (more than 40 percent) may indicate that they, too, experience such feelings in technical courses. However, in the workshop program, minority women evidently found sufficient support to offset these negative feelings and to persist.

Passing Through the Gates: Benefits for Undergraduate Facilitators

One of the most significant effects of the Academic Excellence Workshop involves the benefits for undergraduates who served as facilitators in the

program. Between 1991 and 1993, at least fifteen Latino/Latina and African American facilitators were accepted at graduate or medical schools, more than triple the number of such acceptances over a three-year period before inception of the workshop. One possible explanation is the increased level of performance of facilitators on graduate entry exams such as the GRE and MCAT, especially for students who were workshop facilitators in chemistry and physics courses. Informal interviews with these students indicate that in facilitating these science courses, they felt that they mastered the material that provided a solid basis to score well on the graduate exams. Several students mentioned that they were planning to pursue doctoral degrees and teach at the university level, a new professional interest that was triggered by their workshop experience.

Analysis of Program Cost

The Course Attempt Ratio (CAR) was introduced as a measure of initial success and program efficiency. The CAR is defined as the ratio of the number of times a student attempted a course or series of courses to the number of courses successfully completed. Ideally, the CAR for a course is 1.00. CARs can be computed for an individual student or for a group of students for one or more courses. The workshop group had a CAR of 1.19 for first-quarter calculus, compared with 1.43 for nonworkshop minority students. Statistically significant differences in CARs were found between workshop and nonworkshop students in each of the first-year courses. For the three-quarter calculus sequence, the CAR for workshop students was 3.63 compared with 4.64 for nonworkshop students—a difference of one full course for the yearlong sequence (Bonsangue and Drew, 1992).

The financial implications of these results are significant. In a state institution, part of the cost of students' enrollment is borne by the university (and ultimately, the state). When students require an extra quarter to complete the basic calculus sequence, the university must absorb that part of the cost of the extra quarter not covered by the student's tuition. An intervention program that significantly reduces the CAR for a group of students could be cost-effective if the costs associated with the program are less than that for the student to repeat a course. An analysis of the costs for the Cal Poly program indicated that in fact costs to the institution were reduced by a third for students who participated in the workshop compared with their nonworkshop peers (Bonsangue and Drew, 1992). Savings of this magnitude are potentially significant for a state institution with a strong technical and scientific orientation and a desire to increase the number of students who persist in SME majors (Bonsangue and Drew, 1992).

Conclusion

The present research investigated the effects of participation in an academic excellence workshop program on achievement and persistence among

underrepresented minority students in mathematics, science, and engineering disciplines. The study found that an intervention program promoting academic excellence and meaningful peer interaction can have a direct impact on student performance not only in entry-level mathematics courses but also in subsequent courses, thereby validating recommendations of the National Research Council and others (National Research Council, 1989, 1990; Weissglass, 1992).

The findings on persistence, performance, and cost obtained from this longitudinal study underscore the need for academic institutions to have the facility to track accurately the academic performance of their students across time. The longitudinal analysis of course-repeating patterns for workshop and nonworkshop students indicated that a highly academic intervention program could be both time- and cost-effective for both the student and the institution, particularly if implemented early in the student's college career.

Questions remain about the effects of self-selectivity and the efficacy of requiring student participation in academically intensive programs. However, the Cal Poly workshop experience showed that a nontrivial number of students participated, succeeded, and formed the nucleus of a successful group of minority students in mathematics-based disciplines that currently have little minority representation. In summary, this study found that achievement among underrepresented minority students in mathematics, science, and engineering disciplines may be less associated with precollege ability than with in-college academic experiences and expectations.

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