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# Striving Toward Equity: Underrepresented Minorities and Mathematics

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*In the first part of this article (*SIAM News*, March 2005), the authors provided graduation statistics for underrepresented minorities (URMs) and whites at the bachelor's and doctoral levels. Using two "parity ratios," they revealed a "double-filtration" system in place for underrepresented minority students, with, per population, fewer URMs receiving bachelor's degrees and then fewer bachelor's recipients going on to receive PhDs. The article, which is based on Mark Petersen's luncheon address at Diversity Day 2004, concludes in this issue of* SIAM News.

## K–12 Education

The data clearly show that URM representation in mathematics, engineering, and science, despite slowly increasing levels over the last twenty years, is much lower than for whites at the undergraduate and graduate levels. Statistics published by the National Center for Educational Statistics (NCES) show that Asians and whites have higher scores on standardized mathematics, reading, and writing exams as early as kindergarten, with the gap widening from elementary school through middle school and high school. Among high school graduates in 2000, 31% of URMs had completed an advanced mathematics course, compared with 47% of whites and 69% of Asians and Pacific Islanders [10]. Many URMs who continue on to college find that they have had inadequate counseling and preparation [4].

Traditional explanations of poor academic performance by URMs include inadequate school funding levels, teacher resources, and course offerings; insufficient access to guidance, encouragement, and role models; and family status (income, education of parents, parental involvement and expectations) [5]. Each of these explanations is related to socioeconomic status; economic disparities in families and school districts mean that many URMs do not have the same educational opportunities as whites. A 1993 study of science and mathematics classes, grades 7 to 12, for example, found that teachers had math or science degrees in 47% of classes composed of at least 40% minority students and in 62% of classes composed of less than 10% minority students [11]. Some studies have shown lower expectations of the usefulness of mathematics for future schooling and employment among URMs than among whites, which affects the students' interest in coursework.

Students' home and school environments have a strong influence on their academic performance, regardless of race and ethnicity. Exam scores collected by NCES are highly correlated with factors that include parental education levels; number of books in the home; percentage of students in the school who are eligible for free lunch; and number of family risk factors (living below the poverty level, primary home language other than English, mother's highest education less than a high school diploma/GED, and living in a single-parent household).

Recent studies of the achievement gap between whites and URMs have found that many of these traditional explanations, under closer inspection, play only modest roles. As summarized by Singham in 2003 [7], the average black child and the average white child live in school districts that spend almost the same amount per pupil; black/white income differences are found to have only a small effect on test scores; and traditional measures of socioeconomic status (income, wealth, and parental education) account for at most a third of the gap. Differences in study habits also fail to explain the gap. Both blacks and whites study very little outside of school. Median blacks and median whites do between two and four hours of homework per week, and only 14% of white students and 10% of black students do 10 or more hours per week.

These findings paint a confusing picture. If disparities in family income and school district funding are not the major issues, then what is? In one of the most thorough studies to date, Clifford Adelman of the U.S. Department of Education tracked 28,000 high school sophomores in 1980 to the age of 30 to investigate factors that affect college graduation [1]. He found *academic resources* (a measure combining a student's class rank, test scores, and high school curriculum) to be a much stronger predictor of college completion than socio-economic status. Among these students, 20% more whites received bachelor's degrees than their black and Hispanic counterparts. Among groups with the same measure of academic resources, however, students of all racial backgrounds completed college at nearly the same rate. The study concludes as follows:

> The story told by this voyage is clear, . . . that academic variables are much more potent predictors of college completion than social background variables. . . . It tells us that if degree-completion lags for any student or group of students, the situation is fixable. . . . One must acknowledge that socioeconomic status has a continuing influence in life-course events. But the analysis here (and elsewhere) indicates how much education can mitigate those effects.

Within the high school curriculum, mathematics has long been recognized as a critical filter, acting as a gateway to technological literacy and higher education. The Adelman study found that college degree completion is most strongly correlated with the number of years of high school mathematics a student has taken. For example, studying mathematics beyond Algebra 2 in high school more than doubles the odds of receiving a college degree.

In view of the ramifications of high school mathematics on higher education, how are students performing? Consider one indicator, the NAEP (National Assessment of Educational Progress) for 12th graders. In 2000, the average scores were 308 for whites and 274 for blacks, with 288 denoting partial mastery of fundamental knowledge; 336, a proficient level; and 367, an advanced level [7]. By this measure, the performance indicators are discouraging—for blacks somewhat more so than for whites. Traditional strategies would focus on promoting URMs to the same level as whites, but should that really be the goal?

Improvements in K–12 mathematics curricula can boost both white and URM scores significantly [8]. In 1989, the National Council of Teachers of Mathematics issued the *Curriculum and Evaluation Standards for School Mathematics*, which combines problem solving, reasoning, and communication with mathematical content. It addressed "what it means to be mathematically literate in a world that relies on calculators and computers to carry out mathematical procedures and in a world where mathematics is rapidly growing and is extensively being applied in diverse fields." A study of Pittsburgh 4th graders compared classrooms that use traditional teaching methods with those that strongly implement the reform curriculum. The study showed increases in scores from 48% to 72% for whites and 30% to 75% for blacks for basic skills, 18% to 54% for whites and 4% to 32% for blacks on problem solving, and 20% to 60% for whites and 4% to 40% for blacks for mathematical concepts. Notice that although a gap between white and black student scores still exists for problem solving and concepts, it is smaller in reform classrooms, and both racial groups have overwhelmingly better performance in all categories. Many educators now advocate improving curriculum in this way for all students, rather than focusing on differences in performance among racial groups. Other reforms that are necessary for the improvement of mathematics instruction include long-term professional development for teachers, high-quality assessment aligned with curricular goals, and mechanisms for the evolution of curriculum.

## University Mathematics

As at the K–12 level, improving the odds for URMs at the university level involves making changes that are beneficial to all students: developing a learning community and mathematics culture among students, interactive teaching methods, and strong mentoring, among others. Several of the following examples come from the five-book series *Changing the Faces of Mathematics*, published by the National Council of Teachers of Mathematics. The books include numerous articles on successful programs and teaching methods for college classrooms as well as K–12 instruction. The strategies discussed here have been shown to improve URM success in undergraduate and graduate mathematics programs.

Successful black graduate students at the University of Maryland, in surveys conducted by Duane Cooper, indicated that attention from faculty mentors and involvement with peer groups were important components of their education [3]. Many students said that particular mentors had recognized their potential as undergraduates and encouraged them to pursue further education. In the transition to graduate school, the support of fellow blacks, including other first-year students, senior graduate students, faculty, and staff members, was important. These survey responses underscore the importance of a diverse faculty in attracting and retaining minority students.

Seven themes emerged from a study of factors that made a difference for Hispanic students in science and engineering [2]: family support, an honors program, a challenging and interactive curriculum, college preparation in high school courses, caring and kind teachers, small class sizes, and small communities.

In the 1970s, as a new professor at UC Berkeley, Uri Treisman was dismayed to find that a disproportionate number of black students failed his first-term calculus class [9]. After questioning fellow faculty members, he listed four possible explanations: a motivation gap, inadequate high school preparation, lack of family support, and lower family income. Interviews with the students, however, revealed no significant differences between the black students and the rest of the class for any of these factors. Treisman then investigated further, comparing the study habits of black students and Chinese students, who were also a minority but generally did well in the calculus classes. The two groups studied the same number of hours, he found, but the black students studied in isolation while the Chinese students checked each other's homework, discussed solutions, and quizzed each other before exams, in addition to individual studying. The support of a peer group in discussing concepts and in quickly identifying and remedying errors made studying more efficient and effective for the Chinese students. Based on these results, Treisman created a workshop in which all his calculus students worked on challenging problems in groups. With the development of a community of peers, black students' grades rose by as much as one letter grade.

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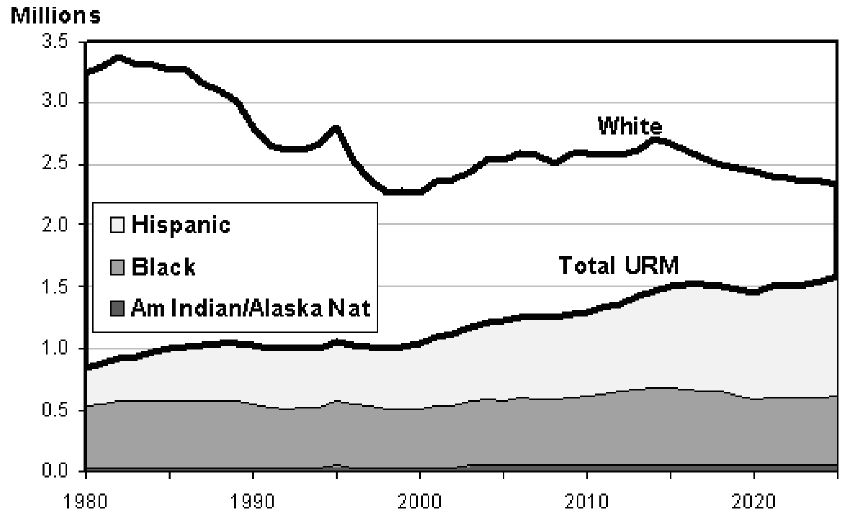
More recently, Janis M. Oldham of North Carolina Agricultural and Technical State University found that about a third of the minority undergraduates in introductory analysis and abstract algebra courses—their first proof-based courses—did not participate in a learning community in which mathematical ideas are verbalized and shared with other students [6]. These students had difficulties in writing organized solutions, maintaining clear notes, and constructing proofs. They saw analysis and algebra as courses to suffer through, and did not identify themselves as part of the "mathematics culture." They did not often ask questions outside of class or attend office hours.

To encourage more effective studying, Oldham implemented several changes. Groups of students were assigned to present proofs or reading sections to the rest of the class, which encouraged group interaction and communication, and reinforced the lecture material. Students were required to attend one office hour per week. If the students did not ask questions, Oldham asked them questions. Extra credit was given for a math notebook that included dated lecture notes and a running list of definitions and theorems, and each student was required to discuss the proof of a specific theorem with the instructor. An additional introductory course on mathematical logic and proof techniques that included many of these requirements was added to the curriculum for the students' sophomore year.




*Population of 24 year olds by demographic group in the United States. Data for 2001 to 2025 reflects the mid-range prediction of the U.S. Census Bureau (http://www.census.gov/popest).*

The results of Oldham's changes have been positive. Required group problems and presentations encouraged the development of a mathematics culture among students and improved their mathematical communication skills. As Treisman had found decades earlier, a support network is an important component of a successful mathematical education; URMs may be particularly susceptible to isolated working conditions.

Several factors motivate a student to pursue graduate education in mathematics, science, and engineering. Among them are exposure to graduate school and research, awareness of the jobs available to people with master's and doctoral degrees, confidence of success in graduate school, and strong mentoring. In our experience, undergraduate research positions are invaluable in exposing undergraduate URMs and women to the opportunities and advantages of higher education. Before students can take the leap of applying to graduate school, they must be able to visualize themselves as professors or researchers. Programs providing research experiences for undergraduates increase their skills through hands-on work, boost confidence, and provide close interaction with mentors. For the many URMs who are the first in their families to receive bachelor's degrees in technical areas, this exposure is essential to envisioning themselves as successful graduate students.

We have worked with two summer research programs for undergraduates: Significant Opportunities in Atmospheric Research and Science (SOARS) at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, and Summer Multicultural Access to Research Training (SMART) at the University of Colorado at Boulder. In both programs, students from under-represented groups work on ten-week research projects with science mentors at the institution. Important components of the experience include scientific writing and communication workshops, tutorials in computer skills, a final research paper, and oral presentation of results.

As the accompanying figure (Figure 2 from the first part of this article) shows, URMs will become a larger fraction of the population in the coming decades. At the same time, success in a growing number of jobs will require mathematical literacy and technical abilities. Professional opportunities and income increase with education, and completion of a bachelor's degree is closely correlated to the number of high school mathematics courses completed. Obviously, students' comfort and abilities in mathematics throughout their education have ramifications for their careers. Society has a responsibility to provide high-quality education to all students, and in particular to those groups that have been historically marginalized and continue to have lower access to higher education and technical professions.

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