Minorities: Their Underrepresentation and Career Differentials in Science and Engineering: Proceedings of a Workshop (1987)

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MINORITIES:

Their Underrepresentation and Career Differentials in Science and Engineering

Proceedings of a Workshop

Linda S. Dix
Editor

Office of Scientific and Engineering Personnel
National Research Council

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PREFACE AND ACKNOWLEDGMENTS

This proceedings volume is the result of the joint interest of the National Science Foundation (NSF) and the National Research Council's Office of Scientific and Engineering Personnel (OSEP) in the nation's human resources. Each has had a strong, longstanding commitment to understand the populations comprising the scientific and engineering work force and has undertaken numerous studies to analyze supply and demand, education and utilization, and various demographic characteristics. The underrepresentation of minorities is a recurrent but unresolved issue in many of these studies.

OSEP conducted a Workshop on the Underrepresentation and Career Differentials of Minorities in Science and Engineering on November 20, 1986. Both that workshop and an earlier one on women were funded by NSF's Directorate for Engineering and Directorate for Scientific, Technological, and International Affairs. Many individuals at NSF and the Research Council contributed to the success of this project. Michael F. Crowley, study director of NSF's Scientific and Technical Personnel Characteristics Study Group (STPCSG), developed the idea for the workshops. Nancy Conlon, STPCSG program officer, managed the project for NSF. Other NSF staff who provided support were Carl W. Hall, deputy assistant director in the Directorate for Engineering; Mary F. Poats, special assistant to the assistant director in the Directorate for Engineering; and several individuals in the Directorate for Scientific, Technological, and International Affairs: Alexander J. Morin, director of the Division of Research Initiation and Improvement; William L. Stewart, director of the Division of Science Resources Studies (SRS); and Charles H. Dickens, head of SRS's Surveys and Analysis Section. Gwendolyn L. Lewis, OSEP's former data services officer, compiled information from numerous sources in order to structure the workshop's agenda and to ensure that scholars with the appropriate expertise would be involved in this exploratory workshop. Linda S. Dix, administrative officer, managed the project for OSEP, working with the authors, drafting the introductory chapter of this report, and shepherding this volume through the production process. We are grateful for the technical support of Yupin Bae, research assistant; Eileen P. Milner, manager of supporting services; and Joseph J. Quigley and Mary Wanyoike of OSEP's supporting services section. Finally, we express appreciation for the able secretarial support of Agnes Israelsen and Catherine D. Jackson.

The thought-provoking presentations of the authors whose commissioned papers are incorporated within this volume--Richard P. Duran, Howard H. Garrison, Cora Bagley Marrett, and Willie Pearson, Jr.--gave direction to the workshop. Furthermore, the critiques of Cheryl B. Leggon, Michael T. Nettles, and Amaury Nora offered additional insights into the current situation in mathematics, science, and engineering for blacks, Hispanics, and Native Americans; a critique follows each commissioned paper within this proceedings volume.*

We express gratitude also to Thomas Cole, who chaired the workshop; to James Ebert and John Moore, who commented on the importance of the issues from the perspectives of the National Research Council and the National Science Foundation, respectively; and to Kenneth Manning, who presented a historical overview of the situation of minorities in the fields of science and engineering. Finally, OSEP thanks those other participants who contributed to the thoughtful discussion that took place throughout the day.

The workshop enabled participants to review the issues in depth. OSEP is pleased to broaden the audience for the workshop through publication of this volume. We hope that this will clarify the issues and help to direct intervention strategies and research that will increase the participation and success of minorities in mathematics, science, and engineering.

Alan Fechter
Executive Director

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*Throughout this proceedings volume, the views expressed by the authors and other participants are those of individuals and are not to be attributed either to the National Research Council or to the National Science Foundation.

CONTENTS

INTRODUCTION

The substantial underrepresentation of some minority groups--blacks, Hispanics, and Native Americans--in this country's science and engineering labor force is a matter of national concern, particularly in the face of declining 18-year-old cohorts and increasing proportions of minorities within future cohorts. This concern led the Office of Scientific and Engineering Personnel, supported by the National Science Foundation, to sponsor the Workshop on the Underrepresentation and Career Differentials of Minorities in Science and Engineering, which examined the causes and patterns of this underrepresentation at all educational levels and in the work force.

The workshop was convened to review both the statistical trends of minority participation in science and engineering and the body of research that seeks to explain the differences in the participation rates of minorities. Papers and formal presentations focused on different educational levels and on different minority groups in order to better understand varying levels of participation, patterns of attrition, and their underlying causes.* Questions of interest included:

- How does their participation differ among groups and from that of nonminorities?
- What is known about the factors that lead to their lower participation rates?
- Where has progress been made, and why?
- Where might productive research efforts be directed?

Many factors were cited as possible impediments to minority students' pursuit of coursework in mathematics, science, and engineering and to their success in science and engineering careers:

- Low socioeconomic status of the family,

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- Lower expectations held for minority students than for their white peers by themselves, parents, and teachers,
- Insufficient counseling and remedial programs,
- Inferior precollege educational opportunities,
- Inadequate financial aid,
- Lack of minority role models and mentors, and
- Lack of well-organized institutional recruitment and admissions programs.

As one researcher noted, these factors all center around the "degree of compatibility between home, community, and school environments and experiences."

To counteract this serious condition--limited opportunities for minorities to succeed in science and mathematics courses and careers--numerous actions, including the following, might be taken:

- Providing better preparation in mathematics and science at the elementary and secondary school levels, through such programs as remedial classes and tutoring, in order to improve the quality of the pool of minority college-bound students,
- Increasing the number of intervention programs designed to promote positive attitudes toward mathematics and science by minority students and, subsequently, their enrollment in more advanced courses and greater pursuit of careers in the sciences and engineering,
- Increasing the number and kinds of financial aid available to students,
- Broadening the scope of student services provided by colleges and universities in order to promote the "academic and social integration of minority students on nonminority campuses," and
- Hiring more minority faculty members, particularly in higher education, who could serve as mentors and role models as well as "visible symbols of the institutions' commitment to racial equality."

Finally, the workshop participants identified topics of further research, including:

- Causes of the difference among various minority groups in preference to pursue science study,
- Determinants of self-assessed mathematical ability of minority students, and
- Effects of socialization processes and societal values on the access of members of specific minority groups to scientific and engineering careers.

OVERVIEW OF PRESENTATIONS

Cora Bagley Marrett analyzed the precollege situation of minority students. Achievement tests of precollege students show a narrowing but significant gap in mathematics and science scores between white students and those of black, Hispanic, and Native American students. Contributing to these differences in scores are differences in the availability and selection of science and mathematics courses and in their content. Rising minority scores, she said, can be attributed in part to the success of special programs designed to attract minority students to mathematics and science and to recent emphasis in the schools on upgrading basic skills. The gap between the achievement scores of these minority students and nonminority students is narrowing in part because of declining scores for white students. The existing gap is particularly alarming, however, because the scores suggest that the gap widens as students progress through school and that greater differences occur as higher cognitive levels are tested. Changes in enrollment in elective science and mathematics courses, as well as changing student attitudes toward science and mathematics, are also discussed in her paper.

Undergraduate science and engineering education for blacks and Native Americans was reviewed by Howard Garrison. Underrepresentation of these groups at the college level is the result both of their lower representation in higher education in general and of their distribution among fields. Although black enrollment in higher education more than doubled between 1968 and 1978, racial disparities in degree attainment remained marked. Blacks graduate from high school at 86.7 percent of the white rate, enter college at 76.3 percent of the white rate, and graduate from college at 52.2 percent of the white rate. For Native Americans the disparities are even larger. A number of factors are related to college persistence in general: socioeconomic background, level of parental education, strength of academic background, availability of financial aid, and integration into campus life. Type of institution is also important, particularly in contrasting students who begin their studies at 2-year versus 4-year institutions. Some of the factors assume additional importance for students who select science and engineering as their field of study. Having a college-educated parent not only increases the likelihood of a minority student choosing a quantitative major, but also equalizes the rate of choice from minorities and nonminorities. Part of this relationship is due to the effects of parental education on students' high school performance, their postsecondary education plans, and a wider knowledge of occupational opportunities. In addition, role models are particularly important to students majoring in the sciences, and research indicates that the race of the role model is also important.

Richard P. Duran reviewed the precollege and undergraduate education of Hispanic groups. Survey studies indicate that the educational achievement of Hispanic students begins to fall behind that of nonminority white students in the elementary school grades and that the gap in achievement continues unabated throughout the high school years. Many factors contribute to this gap. Personal background characteristics such as Spanish versus English language proficiency, socioeconomic level, and length of U.S. residence are related to achievement. Research indicates that Hispanic students take fewer academic courses, especially in mathematics and science, their grades are not as high as for white students, and they do less well on standardized achievement tests. The high school completion rate for Hispanics over the period 1972-1983 ranged from a low of about 45 percent to a high of only 52 percent.

Data for 1976 to 1982 show small but steady increases in the number of Hispanics attending 4-year and 2-year colleges, in the percentage of all college enrollees who are Hispanic, and in the number of Hispanics receiving bachelor's degrees. While encouraging, these increases result from a substantial increase in the population of Hispanics in the college-age group rather than from an increase in the number of Hispanic high school graduates who elect to attend college. When enrollments at 2- and 4-year institutions are separated, data indicate that Hispanics are twice as likely to attend 2-year colleges as 4-year colleges. Low enrollment of Hispanics in 4-year institutions is an important factor contributing to their failure to pursue graduate study in science and engineering. Persistence in higher education is also a matter of major concern. As early as two years into an undergraduate education, Hispanics have a persistence rate notably below that of students as a whole--in fact, the lowest for all ethnic classifications of students. Dr. Duran noted that research points to strong gender-related differences in students' pursuit of science and engineering and suggested that analyses of success rates based on ethnicity alone may be misleading.

The participation of underrepresented minorities in graduate education and their careers in science and engineering was the subject of Willie Pearson's presentation. Despite enormous increases in enrollment and degree attainment, black and Hispanic students remain underrepresented at the graduate level. A number of reasons for their low levels of participation have been suggested: (1) immediate employment opportunities may appear to be more rewarding to some minority students, upon graduation from college, than advanced study because of possible financial difficulties, the academic risk of graduate study, and labor market uncertainties; (2) a major reason given by black and Hispanic students for not pursuing higher education is lack of financial support; and (3) studies show that minority students, once in graduate school, are more likely to report feelings of isolation from other students and lack of encouragement from faculty.

The generally lower rates of graduate education participation of some minorities is even more pronounced in certain academic fields, especially science and engineering. Nevertheless, the numbers of minorities receiving the doctorate and entering the science and engineering work force is growing. In 1973, only 0.9 percent (or 2,000) of employed doctoral scientists and engineers were black. By 1983, that number more than doubled (4,900); that represents a 142 percent growth rate over the decade, although blacks comprised only 1.3 percent of the doctoral scientists and engineers in 1983. During the same decade, the representation of Hispanics increased dramatically and that of Native Americans remained unchanged. Data indicate that among scientists and engineers, minorities are more likely to be unemployed or underemployed than are whites. On average, minorities earn lower annual salaries than their white counterparts. Only small differences --some related to field distribution--exist among doctorate holders.

BLACK AND NATIVE AMERICAN STUDENTS IN PRECOLLEGE MATHEMATICS AND SCIENCE

Cora Bagley Marrett

Introduction

Scores of analyses have diagnosed the case of mathematics and science education in the United States and found it to be in serious condition. If the situation is grave for most students, it is dire for black, Native American, and Hispanic students, students who comprise an ever larger fraction of the elementary and secondary school population. Yet, the signs are not entirely bleak: on several indicators minority students have made gains. Moreover, the correctives that prove effective for nonminority students benefit minority students as well. To understand the mathematics and science problems of minority students might not require that we develop an etiology different from that which applies for nonminority pupils; instead, it probably demands that we identify the forces that make minority students susceptible to the problems. At present, we know more about the status of minority students in mathematics and science than we know about influences on that status. Consequently, improvements in mathematics and science education for black, Native American, and Hispanic students will necessitate analyses that move beyond the present kinds of surveys on enrollment and test performance to investigations on the ways in which student, teacher, and school conditions intersect to affect learning.

Four themes organize this discussion on the education in mathematics and science at the precollege level for black and Native American students.* The first is that in certain respects these students have made significant strides. The second is that even with these strides, black and Native American students still lag far behind their nonminority counterparts. Third, enrollment and performance on standardized tests seem attributable to the kinds of influences that also affect nonminority students. The final theme: there are dimensions still to be explored if we aim not merely to diagnose but also to improve the mathematics and science education of black and Native American students.

*Hispanic students are discussed in a separate paper by Howard G. Garrison.

Changes in the Mathematics and Science Education of Black and Native American Students

Indicators of Change

Changes in Mathematics. In 1978, 9-year-old blacks who took the tests in mathematics administered for the National Assessment of Educational Progress (NAEP) gave correct responses on about 43 percent of the exercises.[1] In 1982, the fraction had increased to 45 percent (see Table 1). Thirteen-year-olds registered an even greater gain: from 42 percent correct in 1978 to 48 percent in 1982. Particularly noteworthy is the fact that for the age group the increase was greater for black than for white students. Among 17-year-old black and white pupils, the scores for 1982 fell below those for 1978; the change was larger among whites than among blacks, however.

The NAEP results are not phenomenal; they merit attention because they parallel trends that other analyses have uncovered. High school seniors who took a test in mathematics during 1972 in connection with the National Longitudinal Study (NLS)[2] generally received higher

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[1]The National Assessment of Educational Progress (NAEP) began in 1969 what was to become a periodic examination of the educational achievement of young Americans. Since that time, NAEP has provided information on mathematics achievement for three periods: 1972-73, 1977-78, and 1981-82. NAEP administers a series of exercises designed to tap four cognitive levels: knowledge, or the ability to recall facts and definitions; skills, as assessed by the accuracy of computations, measurements, and interpretations of graphs and tables; understanding, or the ability to explain or illustrate mathematical skill or knowledge; and application, tested by exercises requiring the use of mathematics for problem solving. NAEP reports results for three race/ethnic categories: whites, blacks, and Hispanics. This information and that which follows on the NAEP Assessment of Mathematics come from National Assessment of Educational Progress, The Third National Mathematics Assessment: Results, Trends and Issues, Report No. 13-MA-01, April 1983. Also see Matthews, et al., 1984.

[2]A national sample of high school seniors served as the first respondents for the National Longitudinal Study (NLS), begun in 1972. These seniors took a battery of tests, including a test of basic knowledge in mathematics, and completed a questionnaire on attitudes, home background, and future plans. The same respondents were later contacted in 1973, 1974, 1976, and 1979. In 1980 a similar survey--High School and Beyond (HSB)--was launched. The HSB used many of the instruments from the NLS but included sophomores as well as seniors. HSB underwent a change in 1982, when it included students who had been in the 1980 sophomore sample. The group retook the battery of items they had first completed as sophomores. The HSB data set allows for two different comparisons: a cross-sectional comparison for the two cohorts of seniors and a longitudinal study of the 1980 sophomores. See Rock, et al., 1985a, b.

TABLE 1: Changes in Mean Performance on Mathematics Assessment, by Racial/Ethnic Group, 1978 and 1982 (in percent)

	Overall		Knowledge		Skills		Understanding		Applications	
	Score 1982	Change '78-'82	Score 1982	Change '78-'82	Score 1982	Change '78-'82	Score 1982	Change '78-'82	Score 1982	Change '78-'82
TOTAL										
Age 9	56.4	+1.0	68.3	+1.4	50.6	+0.8	41.2	-0.4	39.6	+0.5
Age 13	60.5	+3.9*	73.8	+4.5*	57.6	+4.0*	60.5	+3.9*	45.6	+2.2*
Age 17	60.2	-0.2	74.9	+0.2	60.0	+0.3	61.5	-0.3	42.4	-1.1
White										
Age 9	58.8	+0.7	70.8	+1.2	53.1	+0.6	43.4	-0.8	42.4	+0.6
Age 13	63.1	+3.2*	76.1	+3.9*	60.4	+3.4*	63.6	+3.6	47.9	+1.6*
Age 17	63.1	-0.2	77.3	0.0	63.0	+0.3	64.7	-0.1	45.5	-1.0
Black										
Age 9	45.2	+2.1	57.8	+3.5*	38.7	+1.6	31.4	+0.9	27.0	-0.6
Age 13	48.2	+6.5*	63.8	+8.0*	44.0	+6.7*	46.4	+5.9*	34.8	+4.4*
Age 17	45.0	+1.3	62.6	+3.0	44.2	+1.8	44.8	-0.2	26.0	-0.2
Hispanic										
Age 9	47.7	+1.1	58.7	0.0	43.8	+2.5	32.4	-0.2	30.5	+0.6
Age 13	51.9	+6.5*	65.3	+6.3*	49.2	+7.2*	49.7	+5.9*	38.8	+6.0*
Age 17	49.4	+0.9	66.1	+2.0	48.4	+0.5	49.7	+0.8	31.4	+0.4

NOTE: Scores represent percent correct for the areas.
*Change significant at .05 level.

SOURCE: National Assessment of Educational Progress, The Third National Mathematics Assessment: Results, Trends and Issues, Report No. 13-MA-01, Denver, Colo.: Education Commission of the States, April 1983.

TABLE 2: Changes in Mathematics Scores of Seniors, by Racial/Ethnic Group, 1972 and 1980

	NLS 1972		HSB 1980		
	Mean	Standard Deviation	Mean	Standard Deviation	Change 1972-1980
TOTAL	12.94	7.3	11.90	7.2	-1.03*
White	13.95	6.9	12.98	6.9	-0.98*
Black	6.50	6.2	6.69	6.3	0.19
Native American	7.74	6.4	8.28	6.5	0.54
Chicano	8.02	6.8	7.54	6.8	-0.48
Puerto Rican	6.33	6.2	7.19	7.5	0.85
Other Hispanic	8.04	5.9	8.08	6.8	0.04

NOTE: Scores scaled to the National Longitudinal Study Mathematics Test.
*p = .05.
SOURCE: Donald Rock, Ruth Ekstrom, Margaret Goertz, Thomas Hilton, and Judith Pollack, Factors Associated with Decline of Test Scores of High School Seniors, 1972 to 1980, Report No. CS 85-217, Washington, D.C.: Center for Statistics, 1985.

scores than did those seniors who took the related test in 1980 for the High School and Beyond Survey (HSB). The scores of blacks and Native Americans did not undergo the sharp decline that occurred for whites; in fact, for these two minority groups, the scores for 1980 were somewhat higher than those for 1972, although only minutely (see Table 2).

The NAEP and NLS/HSB studies show changes over time in enrollment patterns. In 1978, 55 percent of the 17-year-old blacks in the NAEP survey had taken at least one-half year of algebra; the figure for 1982 was 57 percent. In that same period, the figure for whites dropped slightly: from 75 to 74 percent (see Table 3). Enrollment in trigonometry went from 6.8 percent to 8.2 percent for blacks and from 13.8 percent to 14.9 percent for whites. The NLS/HSB data show that most of the 1980 seniors had had more mathematics than had the 1972 seniors. The difference across time did not reach statistical significance for whites; it did for blacks and Native Americans (see Table 4).

Evidence of change appears in more than the large-scale, national surveys. Native Americans in the state of Washington who attend their

TABLE 3: Changes in Mathematics Course-Taking for 17-Year-Olds, by Race, 1978 and 1982

	Percentage with at Least One Semester	
Course	White	Black
General or business mathematics		
1978	44.7	51.3
1982	49.4	54.8
Pre-algebra		
1978	45.6	46.5
1982	43.4	47.4
Algebra		
1978	75.4	54.5
1982	73.9	56.9
Geometry		
1978	54.9	31.2
1982	55.1	34.1
Algebra II		
1978	39.1	24.4
1982	40.9	27.7
Trigonometry		
1978	13.8	6.8
1982	14.9	8.2
Pre-calculus/calculus		
1978	4.0	2.8
1982	4.4	2.8
Computer mathematics		
1978	4.9	5.2
1982	9.6	11.3

SOURCE: National Assessment of Educational Progress, The Third National Mathematics Assessment: Results, Trends and Issues, Report No. 13-MA-01, Denver, Colo.: Education Commission of the States, 1983.

own schools[3] had scores on the California Achievement Test in 1980 that were well below the national norm. By 1984 their mean scores (51.8) had risen to a level just above the national mean for the mathematics test (50).[4] A study done among the Choctaw in Mississippi found that the achievement scores in 1979 were somewhat higher than they had been in 1977 (Brod, 1979).

[3]These schools operate under the Johnson-O'Malley Act of 1934, through which states can contract with the federal government to provide for the education of students who are eligible for services from the Bureau of Indian Affairs.

[4]The scores over the period were as follows (Brouillet, et al., 1984): 1980, 41.2; 1981, 46.3; 1982, 48.0; 1983, 46.0; 1984, 51.8.

TABLE 4: Changes in Semesters of Mathematics for Seniors, by Racial/ Ethnic Group, 1972 and 1980

	NLS 1972		HSB 1980		
	Mean	Standard Deviation	Mean	Standard Deviation	Change 1972-1980
TOTAL	3.93	1.8	4.06	1.9	0.14*
White	3.97	1.8	4.04	1.9	0.07
Black	3.86	1.6	4.28	1.8	0.42*
Native American	2.67	1.7	3.52	1.9	0.85*
Chicano	3.30	1.7	3.73	1.8	0.43*
Puerto Rican	4.09	2.0	4.26	2.1	0.18
Other Hispanic	4.12	1.7	4.07	1.9	-0.05

*p = .05.
SOURCE: Donald Rock, Ruth Ekstrom, Margaret Goertz, Thomas Hilton, and Judith Pollack, Factors Associated with Decline of Test Scores of High School Seniors, 1972 to 1980, Report No. CS 85-217, Washington, D.C.: Center for Statistics, 1985.

Changes in Science. In science, as in mathematics, the trends for minority students are positive, as the results from the NAEP survey of science illustrate. For 17-year-old white students, the scores on the component, "understanding of the science inquiry process," were lower in 1982 than in 1977; the scores of black students dropped as well, but not so dramatically. Among the 9- and 13-year-olds, blacks and whites moved in opposite directions: scores improved for blacks and declined for whites.[5]

Greater racial consistency prevailed for the component, "knowledge of the content of science," which was not administered for the 9-year-olds. Blacks and whites scored lower in 1982 than in 1977, but the change was sharper for the latter group than for the former. The result was a narrowing of the racial difference. Generally, both groups moved up on the measures of "knowledge of the linkage of science

[5]The primary source of information on the NAEP Assessment of Science was S. J. Hueftle, S. J. Rakow, and W. W. Welch, Images of Science: Summary Results from the 1981-82 National Assessment in Science, Minneapolis: Minnesota Research and Evaluation Center, 1983.

TABLE 5: Changes in Semesters of Science for Seniors, by Racial/Ethnic Group, 1972 and 1980

	NLS 1972		HSB 1980		
	Mean	Standard Deviation	Mean	Standard Deviation	Change 1972-1980
TOTAL	3.71	1.8	3.46	1.9	-0.25*
White	3.77	1.8	3.48	2.0	-0.29*
Black	3.52	1.7	3.45	1.9	-0.02
Native American	2.75	1.5	3.02	1.7	0.27
Chicano	2.96	1.6	3.05	1.6	0.09
Puerto Rican	3.67	1.7	3.57	2.0	-0.10
Other Hispanic	3.80	1.9	3.31	1.8	-0.48

*p = .05.
SOURCE: Donald Rock, Ruth Ekstrom, Margaret Goertz, Thomas Hilton, and Judith Pollack, Factors Associated with Decline of Test Scores of High School Seniors, 1972 to 1980, Report No. CS 85-217, Washington, D.C.: Center for Statistics, 1985.

and technology to society." Although black students made no special gains relative to the ones that whites achieved, neither did they lose ground. On an index measuring attitudes toward science, blacks maintained the lead in 1982 that they had attained in 1977.

Native Americans in the 1980 senior class completed slightly more science courses than did the 1972 cohort. That trend countered the one for whites and blacks. In fact, for the general population, enrollment in science courses decreased over the period. The drop was sharp enough among whites to reach statistical significance; it was not as precipitous for blacks (see Table 5). In science, as in mathematics, the change among whites accompanied a movement away from academic programs and curricula. Students on the academic track increased the amount of science they took; but these students represented a smaller percentage of white seniors in 1980 than in 1972.

The downturn in enrollment among whites, alongside a more moderate decline for blacks and stability for Native Americans, resulted in greater similarity across the three groups in 1980 than in 1972. By 1980 the nonminority-minority difference in enrollment for advanced courses was not nearly as evident as earlier studies had found. Twenty percent of the white seniors in the class of 1980 had taken chemistry, but that was true as well for 19 percent of the black students and 17 percent of the Native Americans. The evidence on enrollment does not show any widening of the disparities between 1972 and 1980. It is perhaps of little comfort to know that this results more from declining white enrollment in science than it does from increasing Native American and black participation.

Changes in Attitudes Toward Mathematics and Science. Test scores and enrollment patterns represent the outcomes most commonly used in the research on minorities in precollege mathematics and science. Student attitudes have drawn attention as well, often on the assumption that minority students hold negative views about mathematics and science. Green (1978) found support for that assumption as she traveled across the country in the late 1970s, trying to discover reasons for the virtual invisibility of Native Americans among the ranks of scientists and engineers. She uncovered among the students with whom she talked a profound ambivalence about mathematics. That ambivalence prevailed not only among people who planned nontechnical careers but also among persons who had chosen scientific and technical fields. According to Green (1978:2): "Most non-science students avoided math whenever they could, and they and the science students struggled painfully with it when avoidance was not possible."

Little evidence exists in the large-scale surveys that the attitudes of minority students depart noticeably from those of nonminority students. The NLS/HSB survey asked seniors about the quality of the instruction they had received and their views on the emphasis given to academic matters. Native Americans and blacks were neither overly positive nor overly negative about the academic instruction in 1972; this pattern had not changed by 1980. In 1972, white seniors had been slightly more favorably inclined toward the instruction than had the other seniors, but by 1980 the reactions of whites had moved closer to those of the other groups. All three groups expressed stronger reservations about the degree of emphasis on academic subjects in 1980 than in 1972. In other words, by the second period, large numbers of students had come to the view that the school gave too little emphasis to basic academic subjects.

As pointed out earlier, the NAEP survey determined that the attitudes toward science of black students were more favorable than were those of white students. Among white males, the mean score declined for each age category between 1977 and 1982. Among black males, the attitudes of 9- and 13-year-olds were even more positive in 1982 than they had been in 1977, and although the mean for 17-year-olds dropped, it still did not fall to the level for the equivalent white segment.

Explanations for Change

The modest changes in test performance that the large scale surveys have found seem to flow from changes in course participation. As minority students have taken more mathematics and science, their test scores in these subjects have improved. Moore and Smith (1984; 1985) have determined from the NLS data that differences in course enrollment explain much of the difference in the mathematics scores of black and white students. They conclude, ". . . if the curricula of black and white high school students were standardized to make the black students' course enrollments more similar to whites', a considerable amount of the black/white difference would disappear" (1984:18). Yet black and white students do not pursue identical curricula, even though the gap might not be as wide for the nation as a whole as once was the case.

In some instances, changes in performance--and in participation--may be the consequence of intervention efforts. A project in Columbia, Washington, that offered tutorial services to Native American pupils in grades two through six succeeded in raising the achievement scores in mathematics by at least one grade level (Brouillet, et al., 1984). The Native American Education Program, a series of activities for children in the elementary and secondary schools of New York City, reportedly has also improved performance in mathematics through a tutorial program (Cotayo, 1984). Apparently, programs designed to improve performance in and attitudes toward mathematics and science --Mathematics, Engineering, and Science Achievement (MESA) represents one of these precollege efforts--have had demonstrable effects on student outcomes.

Some of the gains reported here are microscopic, others are illusory: they represent relative, rather than absolute, advancement. On attitudes, however, the findings are far more substantial: minority students commit to the view that mathematics and science are useful and important subjects. Yet their test performance and their enrollment patterns would seem to belie that view. If the surveys of minority students find insignificant relationships between attitudes and performance, it is, possibly, because such students give answers they deem to be appropriate or acceptable. There are other candidate explanations, however. First, the attitudes may be consistent with the feedback that students receive routinely about their abilities and performance in mathematics and science. Second, test performance and course participation may depend on more than a view that a given subject is worthwhile.

Students are more likely to know their course grades than their scores on standardized achievement tests. Seemingly, minority students are more inclined to err in reporting their grades than are nonminority students. Farrell and Pollard (1986) discovered that the blacks and Hispanics in their sample more often than whites listed higher grades for courses than they had received. Brod also found a tendency toward grade inflation in self-reports of Choctaw students, although he had no non-Choctaw comparison. If grades and not achievement test scores represent the significant feedback for most students, minority students who perceive themselves as doing well may have little reason to think negatively about mathematics or science.

The students in the Farrell and Pollard study expressed strong interest in fields that required substantial preparation in mathematics and science. Many of these seniors aspired to a major in business, architecture, premedicine, or engineering. Only a handful had taken courses that could have prepared them for such majors, however.

It might have been that the attitudes toward mathematics and science had not been strong enough to propel the students in the right direction. More likely, the students had made their decisions about majors rather late, too late in fact for the decisions to have influenced their high school careers. The relationship of attitudes to performance is complex: the former sometimes bear only indirectly on the latter; in other cases, favorable attitudes can flow from rather than precede performance. In sum, the explanations for the nature of and change in attitudes need not be appropriate for assessments on test performance and course participation.

The Gulf Between Minority and Nonminority Students in Mathematics and Science Education

Indicators of the Gulf

The discussion thus far has stressed the positive signs: the greater change in certain test scores and enrollment patterns for minority than nonminority students and the continued favorable attitudes toward science. Let us now turn to the indicators that are not so positive, indicators that a chasm still separates black and Native American students from white students.

The Gulf in Mathematics. Students who, as sophomores, had taken a battery of tests in connection with HSB in 1980, retook the battery in 1982. All three groups--blacks, Native Americans, and whites--did better in 1982 than in 1980. But in 1982, as in 1980, white students were far in advance of the other two groups (see Table 6). In addition, the difference--on basic and problem-solving skills--that was evident in 1980 had widened by 1982. A re-examination of the data on high school seniors in 1972 and 1980 shows that in neither period did blacks and Native Americans match whites (see Table 2). It may be that the scores of blacks changed more impressively between the 1978 and 1982 NAEP assessments in mathematics, but the results for these years show a wide gap between blacks and whites (see Table 1).

The NAEP results suggest that between minority and nonminority students (1) the older the student, the wider the gap and (2) the higher the cognitive level tested, the greater the difference. The 1982 assessment found a difference of 13.6 percent between the proportion of exercises completed correctly by white and black 9-year-olds, 14.9 percent for 13-year-olds, and 18.1 percent for 17-year-olds. Among the 17-year-olds, the scores on the lowest level--knowledge--differed by 15 points and on the highest--applications--by 19 points.

The experiences of Native Americans further substantiate the thesis that minority students fall farther and farther behind as they move through the school years. Choctaws who were in the third grade in 1979 had a grade equivalent score in mathematics of 2.9, indicating that they performed almost at the level expected. Sixth-graders scored just below the level expected of fifth graders. Ninth-grade pupils had scores resembling those that seventh-graders should have had; and by

TABLE 6: Changes in Scores for Mathematics and Science, by Racial/Ethnic Group, 1980 and 1982

	Mathematics					
	Basic Skills		Problem Solving		Science	
Racial/ Ethnic Group	Score, 1982	Increase, 1980-1982	Score, 1982	Increase, 1980-1982	Score, 1982	Increase, 1980-1982
White	13.90	1.71	3.54	.49	11.22	1.00
Black	6.81	1.55	1.59	.32	6.36	.91
Native American	8.34	1.72	2.04	.34	8.77	1.12
Hispanic	7.24	.95	1.78	.22	7.40	.91

NOTE: The data are for persons who took the High School and Beyond tests for sophomores (HSB) in 1980 and retook that test in 1982. The tests had the following ceilings: mathematics, basic skills: 28; mathematics, problem solving: 10; and science: 20.
SOURCE: Valerie White Plisko and Joyce D. Stern (eds.), The Condition of Education: Statistical Report (1985 ed.), Washington D.C.: Center for Education Statistics, 1986.

the twelfth grade, the mean score was at the eighth grade level (Brod, 1979).

Perhaps as a consequence of this regression, blacks and Native Americans drop out of courses of study in larger numbers than do whites. Of the 1980 sophomore class, 12 percent of the whites as opposed to 17 percent of the blacks had left school by 1982. A survey of public school districts in New Mexico determined that the dropout rates for Native Americans--and Hispanics--exceeded those of Anglos and blacks. There was, too, a difference in timing. Anglos and blacks were most likely to leave school at grade eleven; Native Americans were inclined to quit in the tenth grade (Cavatta, 1982). Given the differences in dropout patterns, the minority-nonminority students who are being compared may not constitute the same groups across the school years.

Differences in persistence within courses occur, even among those who remain in school. More black than white students in the senior class of 1982 had earned less than one credit in mathematics during their high school years (West, et al., 1985a). A study of Native American girls in the Minneapolis Public School System documents a pattern of change. All of the girls in grades 7 through 9 were taking at least one course in mathematics; that was true for only one-third

TABLE 7: Course-Taking Among High School Seniors, by Race/Ethnicity, 1980 and 1982

	White	Black	Native American	Hispanic
1980 Seniors				
Percent completing 3 years, math	33.3	35.2	22.0	27.4
Percent completing 3 years, science	23.1	19.3	12.1	14.2
1982 Seniors				
Carnegie units in math: average*	2.6	2.4	2.0	2.2
Carnegie units in science: average*	2.0	1.6	1.6	1.5
Percent, intensive math preparation**	10.3	3.3	(na)	4.7
Percent, intensive science preparation**	11.0	4.0	(na)	5.4

* A Carnegie unit represents one credit for each 1-year course completed.

**Intensive preparation in mathematics requires four or more credits in mathematics, at least one of which was for the gifted and talented or was advanced. Intensive preparation in science requires one or more credits in either life sciences or advanced physical science.

SOURCES: W. Vance Grant and Thomas Snyder, Digest of Education Statistics, 1985-86, Washington, D.C.: U.S. Government Printing Office, 1986; Valerie White Plisko and Joyce D. Stern (eds.), The Condition of Education: Statistical Report (1985 ed.), Washington, D.C.: National Center for Education Statistics, 1986; and Jerry West, Wendy Miller, and Louis Diodato (eds.), An Analysis of Course-Taking Patterns in Secondary Schools as Related to School Characteristics, Washington, D.C.: National Center for Education Statistics, 1985.

of the girls in grades 10-12. To counteract such withdrawal, the researcher (Witthuhn, 1982) recommends an increase in the number of courses required for graduation and development of special programs to encourage enrollment in advanced courses. It was this second strategy that the University of Colorado selected when it established a mathematics-science institute for Native American secondary students, under the American Indian Educational Opportunity Program (Churchill, 1980).

Black and Native American students are somewhat less likely than white students to take mathematics courses in high school, as the NAEP and NLS/HSB data indicate (see Tables 3 and 4). A greater difference is obtained in type of courses pursued than in number of courses taken. Blacks, whites, and Native Americans in the class of 1982

TABLE 8: Grades in Mathematics and Science for 1982 Graduates, by Race/Ethnicity

	White	Black	Native American	Hispanic
Mathematics				
Percent with A average in subject	18.4	9.5	15.4	11.4
Percent with D or F average	22.4	39.7	31.0	35.3
Science				
Percent with A average in subject	21.1	11.3	11.8	12.5
Percent with D or F average	17.5	35.1	30.5	34.6

SOURCE: Valerie White Plisko and Joyce D. Stern (eds.), The Condition of Education: Statistical Report (1985 ed.), Washington, D.C.: Center for Education Statistics, 1986.

had similar numbers of credits in mathematics (see Table 7); but blacks were not nearly so likely as whites to have had advanced courses. Nor had the minority students performed as well in their mathematics classes as had their nonminority peers. Eighteen percent of the whites, 15 percent of the Native Americans and 9 percent of the blacks had "A" averages for at least some of the mathematics courses they had taken. A larger fraction of the blacks than of the whites or Native Americans had transcripts that contained "D" or "F" averages in mathematics (see Table 8).

Blacks and Native American students may be gaining on their white contemporaries; but if so, it is at a pace so sluggish as to make convergence only a distant possibility. Meanwhile, too many minority youth find their plans thwarted or their dreams set aside because of skills too inadequate for the demands that prevail. The Minnesota Chippewa Tribe wanted to know the fate of students who had won tribal scholarships to the University of Minnesota-Duluth. Of the students who were still at the university, over half commented quite critically on their high school preparation in mathematics. Most of the students thought that they had been adequately prepared in reading and that they had the interpersonal skills to succeed on the Duluth campus. They felt far less positive about their skills in mathematics, however. Among the students who had quit, one-fourth gave as their reason: "poor academic preparation" (Aitken and Falk, 1983).

Many of the minority students who graduate from high school do in fact seem to be more poorly prepared than nonminority students. A series of tests, administered to a national sample of adults for the Profile of American Youth, found that white respondents with high school diplomas had scores on arithmetic reasoning that were normally distributed around the mean 500.[6] Blacks with the same level of education had a lower mean score, as had Hispanics. The distribution of scores differed for the two minority groups, however. Whereas an identifiable fraction of Hispanics scored 600 or better, few blacks had scores above 500. On numerical operations, a small group of blacks and a larger groups of Hispanics had scores as high as those that whites achieved. But more of the scores of blacks and Hispanics were skewed toward the lower ranges (see Figure 1).

The national concern about mathematics education and the programs that have sprung up for minority students have not thus far brought the test performance and participation patterns of black and Native American students in line with those of white students.

The Gulf in Science. In science, as in mathematics, black and Native American students have not come abreast of white students. The former two groups improved their scores when they retook in 1982 a test in science they had first completed in 1980; but at neither time did their scores match those for the larger population (see Table 6). On still other indicators--course enrollment, persistence, course grades--the picture for science reproduces that for mathematics. Black and Native American high school graduates have slightly fewer science courses to their credit than do whites who graduate (see Table 7). Blacks are not as likely as whites to take such advanced science courses in high school as genetics, biochemistry, and physics.

Students tend to receive higher grades in science than in mathematics; this is true for both minority and nonminority students. Of every 100 blacks in the graduation class of 1982 about 9 had an average of "A" in a mathematics course and 11 in science. The equivalent figures for whites were 18 in mathematics and 21 in science. Among Native Americans, a higher fraction received A's in mathematics than in science, but a slightly smaller fraction earned failing grades in mathematics than in science (see Table 8).

Explanations for the Gulf

An earlier section argued that changes in course participation can produce changes in test performance. But for minority students course enrollment, test performance, and course grades are intertwined;

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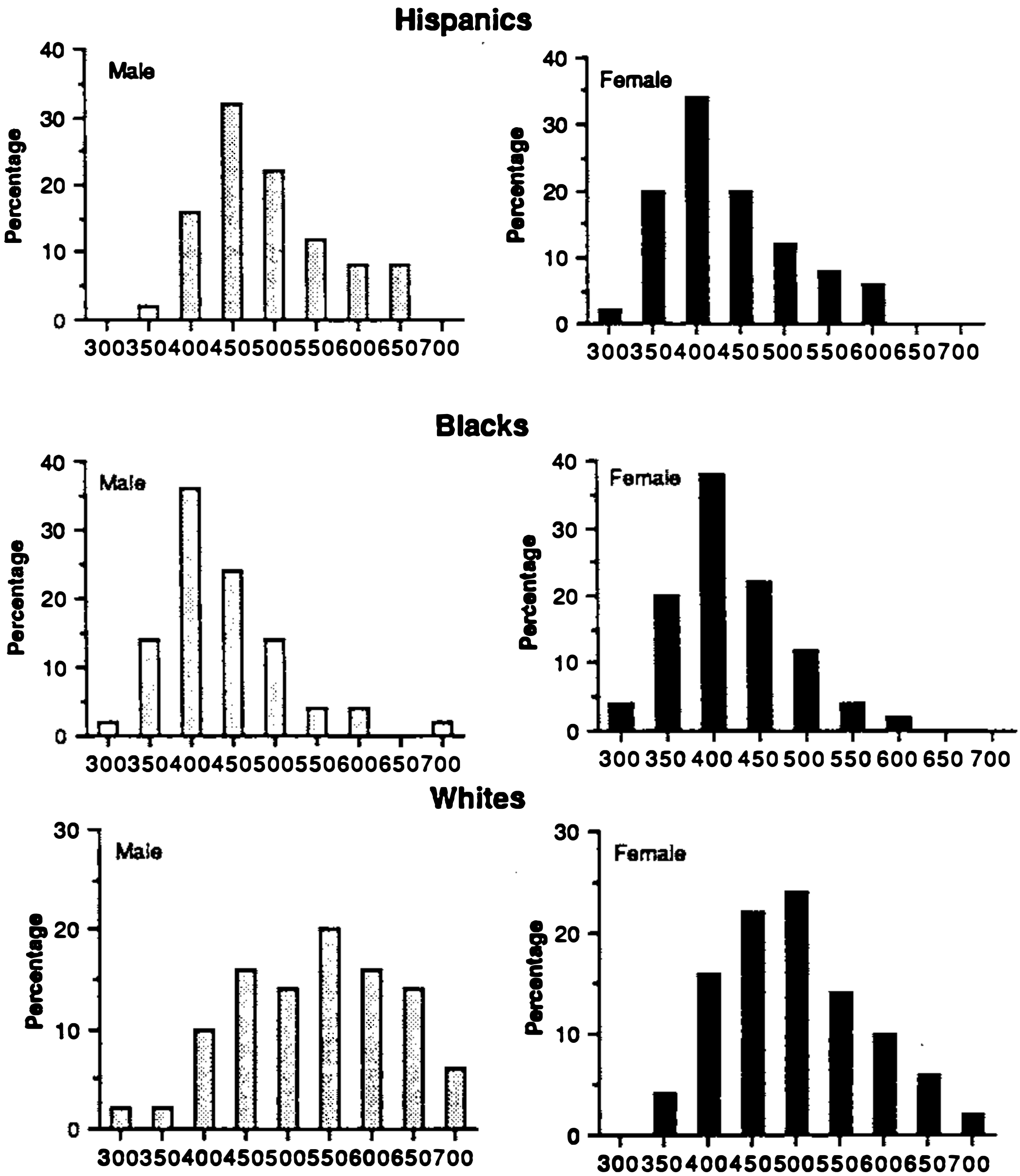
[6]The Profile of American Youth was undertaken in 1980 to develop norms for the Armed Services Vocational Aptitude Battery. NLS subjects took several tests, three of which have mathematics content: arithmetic reasoning, requiring the application of such operations as addition, subtraction and multiplication; numerical operations, measuring the ability of the respondent to perform arithmetic operations with whole numbers; and mathematics knowledge, a test demanding knowledge of mathematical terms and the ability to carry out algebraic operations. The profile contains information on whites, blacks, and Hispanics but not on Native Americans (Bock and Moore, 1985).



SOURCE: R. Darrell Bock and Elsie G. Moore, Advantage and Disadvantage: A Profile of American Youth, unpublished manuscript, 1985.

Figure 1 Distribution of scores on arithmetic reasoning for whites, blacks, and Hispanics with 12 years of school.

and on none of the indicators have these students made progress that matches the pace nonminority students have set.

Continuation in mathematics and science depends on performance in prior courses. Because of their poor grades, considerable numbers of black and Native American students cannot enroll in advanced courses. Their concentration in general and remedial courses limits their exposure to the range of topics in mathematics and science that standardized tests may include.

It would seem, then, that minority students are caught in a vicious web in which failure begets failure. This view implies that there is nothing unique in the minority experience that would account for the patterns of enrollment, performance, and persistence: any student can get caught in the web. The next section examines the contention that the study of minority students in precollege mathematics and science does not require a set of models different from those which would describe and explain nonminority education.

Portraying the Education in Mathematics and Science of Native American and Black Students

An argument can be found in the literature that the conceptual and empirical frameworks that depict the experiences in mathematics and science for nonminority students apply as well for minority students. Support for the argument appears, among other places, in a study on white, black, and Chicano middle-school students in which the researcher (Exezidis, 1982) sought to predict student scores on the problem-solving component of the Iowa Test of Basic Skills. She took into account the score any given student had made on the vocabulary, reading, concepts, and computation components of the test and considered the gender of the student as well. Two findings merit attention: the model that Exezidis developed explained a significant amount of the variance in problem-solving scores; and there was no statistical interaction between the variable, ethnicity, and the scores on vocabulary, reading, concepts, and computation. Stated another way, the relationship between the four measures and problem solving did not differ depending on the ethnic group to which the student belonged. The model worked quite well for all three groups.

Jones and his associates (1984, 1985) have shown from the NAEP data that the factors associated with nonminority achievement in mathematics also account for minority achievement. The researchers identified two categories of influence: (1) student background characteristics, including the parents' level of education and the number of years the student had taken mathematics and (2) school characteristics, such as the regional location of the school, the type of community, and the proportion of the student body in mathematics courses. According to their results, performance on the NAEP was more nearly associated with the student's history of course-taking than with other background characteristics. Moreover, the number of high school courses taken in algebra and geometry was predictive for both the black and white samples. The school-level variables were better able to account for the black-white differences than were the individual level measures. What this indicates is that blacks and whites often were enrolled in very different schools; that, not their individual traits, produced the contrasting test scores. Overall, differences among the schools were more important than differences among the students:

> The average number of years of algebra and geometry taken in schools with less than 70 percent white was 1.3. Note that 73 percent of all black students, but only 8 percent of the white students, were attending such schools. In contrast, 66 percent of all white students, but only 7 percent of the black students, were attending schools that were at least 90 percent white, where the average number of years of algebra and geometry taken was 1.8. This striking difference among schools appears to explain to a considerable extent the average white-black difference in mathematics achievement (1984:161-162).

A study based on the data from HSB would appear from a cursory review to contradict the finding that black students are found in schools with courses and course-taking patterns that depart noticeably from the norms for schools with predominantly white populations. West, et al., (1985b) wanted to know if the types of courses offered in mathematics and science and the proportion of students taking those courses varied, according to the racial make-up of the student body. They did not find a pattern. Generally, a larger fraction of the schools with larger black enrollments than with small numbers offered general mathematics. Yet some of the more advanced courses--advanced mathematics and physics--were found most often in those schools that the researchers designated as "intermediate" on the measure, "percent black." Nor did the authors find a direct relationship between the percentage of black enrollment in the school and the proportion of all students taking advanced courses.

A closer look at the West, et al., study (1985b) shows that it does not in fact refute the findings from Jones, et al. (1984). West, et al., used only three categories to distinguish among schools: schools with no black students, schools in which blacks constituted between 1 and 9 percent of the population, and schools where more than 10 percent of the students were black. Their research would not allow for the more fine-grained analysis that one finds in the Jones, et al., study. Two findings warrant consideration. West and his collaborators found a direct relationship between disadvantaged status and courses: the larger the fraction of the student body classified as disadvantaged, the smaller the number of schools offering advanced mathematics --but not science--courses, and the smaller the number of students taking calculus, statistics, chemistry, and physics. Although relatively few of the schools with appreciable numbers of disadvantaged students offered calculus and statistics, those that did had relatively few takers. The researchers also determined that fewer black than white students were inclined to take the most advanced courses (see Table 7).

The studies sketched here hint that the kinds of conditions that promote participation and achievement in mathematics and science for nonminority youth affect outcomes for minority youth as well. It is not assumed, nevertheless, that the models derived from the research on the general student population are flawless. Even the most intricate of these models account usually for small proportions of the variance in outcomes, whether the outcomes covered are those for minority or nonminority students. An analysis of college careers makes the point. Using information from NLS/HSB, Wagenaar (1984) looked for the circumstances that led students to plan for certain majors and to receive degrees in those majors. For both outcomes--intended field and actual field--he examined an array of background factors: parents' education, father's occupation, and the presence of such items in the home as a newspaper, encyclopedia, and typewriter. He considered, in addition, variables related to the school. Although some of the variables emerged as more important than others, the regression models that Wagenaar derived were not powerful predictors of the plans that students made or of their final fields of study.

The models that seek to elucidate performance and participation patterns do so only partially; hence, it cannot be concluded that the extant analyses lay bare all of the conditions that affect mathematics and science education. For at least two other reasons, it would be premature to conclude that no further conceptual work is needed. First, the models have used a limited set of outcomes: performance on standardized tests, enrollment in advanced courses, persistence beyond the high school years, and course grades are the usual ones. But poor performance on a standardized test need not mean inadequate understanding of the subject area; it may indicate instead nonexposure to the topics in the test, or limited motivation to perform well on the test. Likewise, participation in advanced courses can mean little if the course is "advanced" in name only. Courses with similar titles do not always cover the same content. Second, there possibly are ways in which race or ethnicity might be important. The next section considers these ways.

Portraying the Unique Experiences of Minority Students

Most of the research and many of the intervention efforts build on the notion that if minority students have the chance to learn the content that is transmitted to nonminority students, differences in performance will disappear. But exposure will not mean convergence, if some students bring to that content perspectives that render it questionable or irrelevant. Such may be the case for students who do not share fully in the larger culture.

Several studies highlight the possible role that culture might play in the performance one finds on standardized tests among Native Americans. Cohen (1985), for example, studied spatial orientation and mathematics achievement for Navajo children. He administered a battery of tests to a small group of Navajos (22) and non-Navajos (34) who were in the sixth and tenth grades. According to Navajo culture, the world is composed of two dishlike structures: the earth and heaven. It is a closed world--nothing substantial can be added--and everything within it is interrelated. Cohen wanted to know if these cultural notions led Navajo students to have ideas about spatial relationships that differed from the ones held by non-Navajos. He found no evidence of differences, on the measures he used.

Others have, in fact, discovered cultural effects. Garbe (1985) used a sample of fourth-, fifth-, and sixth-graders, some of whom were Navajo (255) and the others Anglo (135), to determine if language differences might affect performance. He first asked students to define or draw a picture to represent such terms as "quotient," "angle," and "greater than." He distributed the responses and asked the students to choose the ones they thought the best approximations to or representations of the term. As the next step, he developed two scales. One scale had two definitions for each term: the correct one, and one that contained a word that sounded much like the term being defined. The word, "sum," appeared twice, as follows:

Sum
- (a) part of something
- (b) the answer in addition

Sum
- (a) the total of money
- (b) 

The second scale used terms and symbols to make comparisons:

Greater than
- (a) 6 is greater than 8
- (b) $4 > 2$

Navajo students had difficulty with similarly sounding terms. They were more likely than the Anglo students to choose the response that contained what seemed to be a homonym. These students were also more inclined than the Anglo students to reject the answer that contained a symbol to express a relationship.

The Garbe research stresses the fact that, for many Navajo youth, English is a second language. Lack of facility in that language can affect performance. Other analysts suggest that the language problem has deep roots: the answer does not lie simply in having students learn the right words. Moore (1982) notes that the Navajo language has no words for such concepts as multiply, divide, and cosine. He discovered that Navajo college students had found creative ways to express the idea of "if," an idea for which no expression exists in Navajo. Moore implies that the world within the school may constitute a very different setting from the world without. The concepts that the school advances can be distinct from or even in conflict with those that the student encounters outside the classroom. One critic maintains that all too often "objective" tests assume a reality that does not exist for many. The critic reached this conclusion after he watched a group of Navajo children in Los Angeles struggle with a test on vocabulary and one on concepts. The students, particularly the least acculturated ones, had difficulty not just with the material, but also with the test situation itself (Guilmet, 1983).

One might acknowledge culture by informing students that the approaches to science found in the Western world are not the only ones. More likely, those who see culture as important will look for ways through which cultural experiences can be incorporated into mathematics and science education. Bradley (1984), for example, has used loom beadwork to illustrate mathematics concepts in Euclidean geometry and measurement for Navajo children.

For many minority students, social rather than cultural conditions set the school apart from the spheres they know. If, as cognitive scientists tell us, children bring to the science classroom conceptions about the working of things, undoubtedly more should be known about how students from barrios, from households with few economic resources, from segregated communities conceive of the world. Potentially, greater attention to the cultural and social experiences of minority children could produce models of mathematics and science education that accent determinants and outcomes different from the ones that now predominate.

Research Needs

Research on blacks and Native Americans is far from extensive or exhaustive. The field would profit greatly from analyses of forces that have produced--or might produce--gains in the grasp of mathematics and science. It would help, too, if the research addressed concerns that could lead to programs and policies on the education of minority youth.

Understanding Minority Gains

Undoubtedly, the changes brought about in education by the expansion of federal programs in the 1960s have had ramifications for the gains that minority students have made. Until the 1960s, the federal government generally had provided aid to state and local districts for broad categorical programs, such as vocational education. But with the passage of the Elementary and Secondary Education Act (ESEA) in 1965, the federal government moved to shape particular activities. That act earmarked funds for specific kinds of curriculum projects and services. By the late 1970s at least 70 different agencies administered programs that totaled over 400 (Halperin, 1976). Title I of the act required that local districts distribute funds equally for all students. The expansion of funds designed to compensate for inequities in educational systems made possible any number of initiatives in schools that contained large numbers of minority students. Although there is no extensive research literature that links the history of ESEA to minority advances in mathematics and science, there is reason to assume that ESEA and associated programs set the stage for those advances.

The effective schools movement is another candidate for designation, "stage-builder." A handful of districts with sizable minority and low-income populations began in the 1970s to attempt to stem the tide toward poorer and poorer levels of performance by emphasizing the teaching and learning of basic skills. By the end of the decade, a full-scale movement was under way, a movement centered on the theme that specific strategies and structures could improve the educational outcomes of the most disadvantaged pupil. If, as the achievement data indicate, minority students have made more rapid advances on lower-order than on higher-order skills, this may signal the success of the widespread attempts made to teach the fundamentals.

Efforts to reduce differences in the experiences and opportunities available to minority students have not been limited to those launched by school personnel, however. Professional associations, businesses, parent groups, and others have contributed sizable resources to programs created to interest minority students in and prepare them for mathematics and science. One of these programs, MESA (Mathematics, Engineering, and Science Achievement), has become a model across the nation. Similarly, the Saturday Academy Program that operated as part of the Science Resource Center at Atlanta University has had its emulators.

Education, and especially education in mathematics and science, has moved back into a prominent place on the agenda of the nation. In response to such reports as A Nation at Risk, Educating Americans for the Twentieth Century, and Action for Excellence, one state after another has begun sweeping reforms in its educational programs. More than half have raised their mathematics/science requirements for graduation or have taken steps to do so. Proposals for increasing the quality and quantity of science teachers can be found in nearly every state legislature and Department of Education (Education Commission of the States, 1983).

The current push to improve mathematics and science education almost certainly will have an impact on minority students, given their increased representation in the public schools. But the push will not reduce minority/nonminority differences unless that is made a specific goal. Reducing the differences is not nearly so difficult as might be assumed, for given the point at which minority students are starting, there is substantial room for improvement.

The tracking of actual and possible gains calls for attentiveness to topics that now are underemphasized. There is more work on the individual student than on the settings in which the teaching and learning of mathematics and science occur. Second, one finds similar terms used in different ways. Third, too often the research on minorities in mathematics and science takes place in isolation from other inquiries. Fourth, the search for group properties sometimes downplays the diversity found within a group.

The emphasis on individual-level determinants and outcomes may be the consequence of the theoretical models used to study mathematics and science education. Analysts have used various motivational theories to explain participation and performance. Discussions centered on role modeling attribute the limited participation of minorities in mathematics and science to the absence of role models (see, for example, Sewell and Martin, 1976). Career choice models assume that individuals make rather rational assessments of the tracks they wish to follow. But Spade and her associates have determined that certain contextual forces interact with the composition of the student body to affect mathematics achievement. They found from the HSB data that the structure of the mathematics program mattered more for high-ability students in upper-class schools than it did for low-ability students in lower-class schools (Spade, et al., 1986). This work suggests that the effect of context on outcomes may be complex, but it lends support to the notion in Jones, et al., that the context deserves analysis.

It is not clear how much the measures used are equivalent in the several studies. The studies in mathematics often differentiate between higher- and lower-order skills. But the terms usually are relative rather than absolute: those skills that appear as higher-order ones on a given test would be relegated to a lower category on a more difficult test. The attempt to differentiate among skills represents an advance, however, for much of the earlier work merely reported an overall score in mathematics.

Research on minorities in mathematics and science might benefit from research taking place on other subjects. It is not evident, for example, that programs designed to attract and educate minority students draw on the extensive work centered on cognition. The theories centered on group effects and the success some experimenters have had with using group-based instruction in mathematics could be worth the attention of those who want to study and improve minority student education.

Finally, relatively little is known about the differences that exist among students within the same group. The category, "Native American," is not at all homogeneous. In fact, Native American students can be found in urban centers and in small towns, as well as on reservations, participating fully in some instances and only marginally in others in the life of the community that surrounds them. The research usually draws socioeconomic distinctions within and between categories, often without discussing the implications of those distinctions. Class membership may be a descriptive variable, but it is an explanatory variable only when the analyst shows how and why it is linked to a given outcome in mathematics or science.

On Policies and Programs

To an extent, the narrowing of the gap has taken place because of downturns in white student achievement, attitudes, or participation. It would be unwise social policy to propose such changes as the way to attain equity. Mathematics and science education does not constitute a zero-sum game, in which gains for some mean losses for others. Policies must develop, therefore, that encourage high quality involvement and achievement among all students.

Policies and programs for enhancing minority achievement in mathematics and science need not be limited to student-oriented ones. It is possible to interpret the scores on basic skills as indicating that students learn what they are taught. The teaching of higher-order skills is difficult for many current teachers. Thus, programs designed to upgrade teachers may be an essential step toward improved performance by students.

Nor must the policies and programs be confined to the sphere of mathematics and science. It is not clear that problem-solving skills can be transferred easily from one subject to another; it is clear that reading skills transfer. The difficulties many minority students face in reading should not be overlooked, therefore, by those who would improve the mathematics and science education of these students.

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PRECOLLEGIATE DEVELOPMENT OF MINORITY SCIENTISTS AND ENGINEERS

Michael T. Nettles

Introduction

Among the professional occupations in America, minorities are least represented in the scientific and engineering professions. Although blacks, for example, represent more than 10 percent of the U.S. work force, they constitute only 2.4 percent of the engineers, 5.4 percent of the mathematical and computer scientists, 3.2 percent of the natural scientists, 5 percent of the physicians, and nine-tenths of 1 percent of the dentists (U.S. Bureau of the Census, 1986). The representation of Native Americans in the scientific fields, which is one-half of 1 percent, is estimated to be equivalent to their representation in the U.S. labor force (National Science Foundation, 1986; hereafter, NSF). The underrepresentation of blacks, however, which is often indicative of other ethnic minority groups except Asians, reveals several challenges:

- The challenge for American corporations and industries to achieve racial equality at the highest levels of the workplace,
- The challenge for minority population groups to more aggressively pursue scientific professions in order to benefit equally from the societal and professional rewards of working in the most prestigious professions, and
- The challenge for American society to eliminate racial inequality that continues to plague our nation.

The underrepresentation of minorities is also symptomatic of the continuing inequality of educational opportunities for ethnic minority groups, even after several years of effort to eliminate legal exclusion. The major leverage points for addressing these inequalities in the long term appear to be with improving precollegiate education of minority youth and in addressing the special problems of low socioeconomic population groups. This paper both elaborates upon several issues raised by Dr. Cora Marrett and introduces some additional insights into the precollegiate development and special problems of minorities in pursuit of scientific and engineering careers.

Precollegiate Preparation

Observers of minority youth in America are witnessing a crisis regarding their education development. Black, Hispanic, and Native American youth from preschool through high school demonstrate educational deficiencies through their school performance and their performance on intellectual assessments. Researchers frequently demonstrate the poor performance of minority youth compared to white youth on the reading, writing, math, and science components of the National Assessment of Educational Progress (NAEP) (Holmes, 1980; Helgeson, et al., 1977; Plisko and Stern, 1986; NAEP, 1985). They also report a greater tendency for minority youth to be enrolled in vocational educational tracks in high school rather than the general or academic curricula (Oakes, 1985; Hurd, 1982) and the relatively low tendency for minority youth to be enrolled in more challenging high school courses that prepare them for college curricula and, ultimately, careers in professional scientific fields (Chessnut, undated; Thomas, 1986; Hurd, 1982; Miller and Remick, 1978; Bayer, 1973). Approximately one-third of black students enroll in the academic high school programs compared to two-fifths of white high school students. For example, 20 percent of Asian high school students take calculus (which is considered an advanced high school math course) compared to 8 percent of whites and only 4 percent of blacks and Native Americans. Table 1, which illustrates mathematics and science course-taking by race in 1985, shows that blacks and Native Americans are also less likely than whites to take Algebra I, Algebra II, geometry, or trigonometry.

It is widely proclaimed that the low performance of minorities on various math and science achievement indicators is due to (1) lack of exposure and proper introduction to science at early ages--i.e., preschool and primary grades (Maccoby and Jacklin, 1974; Tsai and Walberg, 1983); (2) failure of adults to cultivate minority students who have strong interests in and positive attitudes towards math and science at early ages; and (3) lack of participation in math and science extracurricular activities during elementary and high school. Based upon studies of the background of present scientists and engineers, it appears that the educational process for successful scientists begins at very early ages and continues throughout the adolescent and young adult stages of development (Thomas, 1986). High achievement motivation, high achievement in school, high performance on intellectual assessments, and active participation in scientific curricula and extracurricular activities throughout early childhood and adolescence are important ingredients for future success in scientific professions (Thomas, 1986).

Despite numerous court orders over the past two decades requiring the desegregation of public schools, many minority students still attend segregated schools with fewer resources than predominantly white schools. In the 1978 NAEP Science Assessment, approximately 30 percent of the black 9-year-olds, 39 percent of the black 13-year-olds, and 47 percent of the black 17-year-olds attended schools that were predominantly white. In the Northeast, even fewer (20-30 percent) attended predominantly white schools (Kahle, 1979). The problem with these segregated schools in terms of preparing students to become sci-

TABLE 1: Mathematics and Science Course-Taking by Race, 1985 (in percent)*

Coursework	White	Black	Hispanic	Asian	Native American
Mathematics					
Algebra I	71	64	60	66	57
Geometry	60	46	40	68	34
Algebra II	38	29	26	39	22
Trigonometry	26	16	15	43	14
Calculus	8	4	4	19	4
Science					
Physical Science	67	71	70	52	67
Biology	79	80	78	79	71
Advanced Biology	20	16	15	25	71
Chemistry	39	30	26	58	24
Chemistry II	5	3	3	9	3
Physics	20	12	9	36	9
Physics II	2	1	1	7	0

*Represents individuals who were sophomores in 1980.
SOURCE: National Science Foundation, Women and Minorities in Science and Engineering, Washington, D.C.: U.S. Government Printing Office, 1986, Appendix Table 35.

entists is neither the school facilities nor the textbooks--but rather the limited opportunity for serious science students to learn with fellow students who share their interest and enthusiasm about science, the low level of investment in science instructional materials and equipment, and the low quality of training and experience of science teachers (Stake and Easley, 1978). Hurd (1982) recently documented the national crisis of low quality science instruction in elementary and secondary education in the United States compared to that in the Soviet Union, Japan, and most of Europe. He notes that in elementary and secondary schools in these foreign nations, students are taught by faculty with the equivalent of a master's degree in a science specialty area and students take more science courses than students in the U.S. For example, students in the Soviet Union take the equivalent of six years in each of geometry, physics, and chemistry. In contrast, American elementary and secondary students take only one year of geometry, which is far too little to provide any depth in the subject. The crisis for minority students is even more severe than for the general population. Minorities are less likely to take even one algebra, geometry, physics, or chemistry course (Table 1). In addition, science instructors at segregated minority schools are often not the most qualified science instructors.

Even for cases in which schools are integrated, courses within the school are most often segregated. In these cases, as in the case of segregated schools, minority youth are found disproportionately in the least academically demanding courses taught by less qualified instructors while majority students have higher-quality courses and instructors. This segregation within integrated schools occurs when minorities are counseled away from college preparatory tracks (Ekstrom and Lee, 1986) and/or do not have prerequisite math or science preparation to participate in higher level high school science courses (Hall, 1981; Kenschaft, 1981; Stake and Easley, 1978; Helgeson, et al., 1977; Oates, 1985). Researchers also consistently report that teachers have lower expectations of minority students than of majority students. These lower expectations are manifested through teachers' tolerance for incomplete homework, allowing students longer time on tasks, and tolerance of inattentiveness in classroom activities. These lowered expectations result in a reduction of minority students' ambitions, self-confidence, and performance in school and a loss of interest and determination for higher academic pursuits (Adenika and Berry, 1972; Dusek, 1975).

Socioeconomic Status Influences

Regardless of racial/ethnic identification, scientists are likely to have family backgrounds of middle to high socioeconomic status (SES) (Pearson, forthcoming). Children from lower SES family backgrounds are more likely to attend lower quality schools, experience lower family values toward educational and occupational achievement, and have a greater probability to experience a lifestyle that is antithetical to educational achievement. Minority children, of course, are overrepresented among the lower SES children in America: 34 percent of black families in the U.S. have incomes of less than $10,000 compared to 11.9 percent of white families, and 50 percent of blacks have annual family incomes of less than $15,000 compared to 22 percent of whites (U.S. Bureau of the Census, 1984). McCloskey (1976) estimates that 80 percent of the black population in large Northern cities have lower SES. Children from lower SES families have fewer extracurricular educational opportunities, limited exposure to such cultural and educational experiences as museums or major scientific expositions, and fewer opportunities to participate in simulated or actual scientific experiments. Kahle (1979) and McCloskey (1976) characterize lower SES children as having constricted experiences and the imposition of such burdens as abstinence, negation, and humiliation placed upon them throughout their whole existence.

Intervention Strategies Are Needed

Efforts to improve the opportunities for minorities to succeed in engineering and to enter scientific professions must compensate for the effects of inferior schooling and lower socioeconomic status. Therefore, both within and in addition to school programs efforts should be initiated to:

- Provide support and encouragement to promote positive attitudes among minorities toward scientific careers,
- Supply minority schools with teachers and/or mentors who have high expectations of minority students' performance in intellectual activities and academic courses,
- Eliminate the racially discriminatory practices of differentially tracking in segregated schools and courses,
- Provide practical experiences wherein minority children can participate in scientific experiments and be exposed to scientific expositions,
- Provide greater exposure for the parents and teachers of minorities to the science and engineering career opportunities, and
- Provide better training for teachers of minority students in order to expose minority students to higher quality instruction during their elementary and secondary school experiences.

Several intervention programs are under way in major urban cities throughout the United States. However, to date, only limited attempts have been made to (1) account for all these programs, (2) describe their goals, (3) compare their activities, and (4) evaluate their effectiveness. My colleagues, Beatriz Clewell and Bernice Anderson at Educational Testing Service, are in the process of developing a comprehensive inventory of science and math intervention programs for women and minorities that focus upon math and science achievement. This is an important first step. The experience of these efforts over the past decade can provide valuable insight about the ingredients of successful programs that can be replicated in more areas where low SES minority youth are concentrated.

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UNDERGRADUATE SCIENCE AND ENGINEERING EDUCATION FOR BLACKS AND NATIVE AMERICANS*

Howard H. Garrison

Introduction

This paper reviews recent studies related to the undergraduate science and engineering education of blacks and Native Americans.[1] The first section contains a general overview of educational trends. The second (and largest) section of the paper focuses on studies that suggest explanations of the underrepresentation of minorities in science and engineering at the undergraduate level. A third and final section examines programs designed to alleviate the underrepresentation of minorities.

At the college level, the representation of minorities in science and engineering fields can be viewed as the product of two separate rates: (1) the rate of participation of minorities in higher education regardless of field and (2) the propensity of minorities to select and persist in certain academic fields when attending college (Berryman, 1983:4; Chipman and Thomas, 1984:3). The separate analysis of persistence in college and field choice facilitates the understanding of causal processes and will be employed as an organizational scheme throughout this review.

Trends in the Higher Education of Blacks and Native Americans

During the past two decades there have been major changes in American higher education. A rapid expansion in the size of the college and university population has occurred as a result of the maturation of the "baby boom" cohort and rising rates of college attendance. The

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*The author wishes to thank Arthur C. Evans for his help in locating many of the studies reviewed in this paper.

[1]There were far more studies of blacks than of Native Americans and the emphasis in this review reflects the availability of material. A separate paper examines the undergraduate science and engineering education of Hispanic students.

civil rights movement also left its mark on U.S. higher education, and in the 1970s minority students began to attend predominantly white schools in increasing numbers.

Minority Participation in Higher Education

Enrollment figures document the dramatic increase in minority participation in higher education during the 1970s. In 1968, the black enrollment in higher education was 287,000. By 1978, this figure more than doubled, reaching 601,000 individuals or 10.6 percent of all persons enrolled in higher education (Willie and Cunnigen, 1981:86). During the mid-1970s, the percentage of black high school graduates going to college was almost at the level of the white population, although the black high school graduation rate continued to be lower than that of whites (Lee, et al., 1985:8). Since 1975, however, progress toward racial equality has slowed and a counter trend may have begun. While the number of black students in college increased from 1975 to 1981, the percentage of college-eligible blacks enrolled in college declined slightly from the 1975 levels (Lee, et al., 1985:5). More recent changes are harder to assess. Regrettably, the U.S. Department of Education has not published data on minority enrollments for the period since 1981.

While the racial gap in enrollment rates was reduced during the 1970s, the racial disparity in degree attainment rates remained (Berryman, 1983:34). Using data from the 1972 National Longitudinal Study (NLS) of High School Seniors, Dunteman, et al., (1979:34) found that blacks had higher college withdrawal rates than whites. Of the males in the sample who went to college, the withdrawal rate as of October 1976 was 30.3 percent for whites and 35.7 percent for blacks. Among the female college entrants from the same high school graduating class, the withdrawal rates were 30.5 percent for whites and 42.0 percent for blacks.[2] (The NLS sample size was too small to estimate withdrawal rates for Native Americans.) A study of a more recent cohort, 1975 college freshmen, found that 65 percent of the whites and 60 percent of the blacks were able to persist in college full-time through the beginning of their junior year (Cross and Astin, 1981:79).

Participation in Science and Engineering Curricula

The underrepresentation of minorities in science and engineering is partly a matter of persistence in higher education and partly due to the choice of fields by minority students in higher education. In this section, the field choices of those students persisting in the educational pipeline are examined.

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[2]Thomas (1981b) found that when the college graduation rate for members of the 1972 high school graduates was measured in 1979 (as opposed to 1976), some of the disparity between races was reduced. Part of what initially appeared to be attrition was actually delayed graduation.

For college-bound high school seniors, there is very little difference across racial or ethnic groups in terms of intended field of study.[3] In 1984, 27.5 percent of the white college-bound high school seniors intended to major in one of the sciences (excluding the social and behavioral sciences). The percentages for blacks and Native Americans were 30.9 percent and 29.7 percent, respectively (National Science Foundation, 1986:161; hereafter, NSF).

However, there is a continual shift in the distribution of major fields from precollege aspiration through college graduation. Dunteman, et al., (1979:34) found that 38 percent of all entering college freshman reported a science major (including the social sciences). Only 26.0 percent had earned science degrees or were still students in science programs 4 years later.

There is an increase in the racial disparities along with the general movement out of science and engineering fields. College-bound blacks and Native Americans left high school intending to major in science at the same rate as whites. But, as entering freshmen, blacks

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[3]Comparisons of science and engineering education studies are complicated by different classifications of academic fields. The National Science Foundation uses the broadest definition of science and engineering (NSF, 1986). Psychology and the social sciences (sociology, anthropology, and "other" social sciences) are included in NSF's typology of scientific fields. The inclusion of psychology and the social sciences with the physical and life sciences has important implications for this paper. First, as Dunteman, et al., (1979:102) have demonstrated, there are important differences in the academic attributes of "hard" science majors and social science majors. Discriminant analyses indicated that nonscience and social science majors were similar to one another and could be differentiated from the "hard" science majors on the basis of 18 ability, interest, schooling, and SES characteristics. A second important outcome of the inclusion of the behavioral and social sciences with the other science fields is the fact that minority students at all education levels tend to be much more highly represented in the social and behavioral sciences than in the "hard" science fields (Astin, 1982:68). Calculations from tabulations presented by NSF (1986:175-177) show that at every education level (bachelor's, master's, and doctorate), the social sciences comprise a larger fraction of the minority science students than they do for white students. By combining the social and behavioral sciences with the other science fields, the degree of minority underrepresentation in science is reduced.

Berryman (1983:15) adopted a different, but extremely useful typology in her work. Rather than focusing on all science fields or on the "hard" sciences, she examined the "quantitatively based disciplines" (biological sciences, physical sciences, computer sciences, mathematics, engineering, and economics). While similar to the "hard" science typology, this classification included economics and used as its defining criterion the prerequisite of mathematics training.

were less likely than whites to be majoring in the physical sciences, mathematics, biological sciences, and engineering. Native Americans were less likely than their white classmates to declare majors in the physical sciences and engineering (Astin, 1982:64-65). Dunteman, et al., (1979:36) found that in their freshman year of college, 47.5 percent of the white males and only 37.1 percent of the black males from the 1972 high school graduating class chose a science major. Black males had a consistently lower probability of entering each field of science than whites (Dunteman, et al., 1979:101). In the fall of 1982, 4.8 percent of all white undergraduates (full- and part-time) were enrolled in engineering programs and 1.3 percent were enrolled as physical science majors. The enrollment rates for blacks and Native Americans were one half of those for whites. Smaller differences were found for mathematics and life sciences majors (Vetter and Babco, 1984:Table 1-21).

The gaps between the racial groups increase because blacks have a higher rate of attrition in the science and engineering fields than whites. A study of 30 engineering colleges conducted by the Sloan Task Force on Minorities in Engineering found that minority students in the 1970 and 1971 freshman classes had a lower than average rate of persistence in engineering programs (Lusterman, 1979:46). This pattern continues to be found in more recent cohorts. Blacks comprised 6.1 percent of the first year engineering students in 1981. This figure fell to 4.9 percent of the second year students in 1982, 3.8 percent of the third year students in 1983, and 3.2 percent of the fourth and fifth year students in 1984 (Vetter and Babco, 1986:Table 7-21).

At graduation, there is a wide gap in the distribution of racial groups across science and engineering fields. Examining the achievements of the 1972 NLS cohort, Dunteman, et al., (1979) found that white males were twice as likely as black males to have earned a physical science degree, three times as likely to have obtained a life science degree, and over ten times as likely to have obtained an engineering degree. These disparities were much greater than those pertaining to majors in the freshman year. Other studies, using other data sources, reported similar racial differences. Astin (1982:58-59) found that blacks comprised 6.1 percent of the 1971 freshmen majors in the physical sciences and mathematics, but only 4.0 percent of the baccalaureate recipients earning degrees in those fields. This pattern of attrition was also detected in the biological sciences and engineering.

The degree of underrepresentation, however, was not constant across fields. Chipman and Thomas (1984:Table 2) constructed representation ratios for the 1980-81 degree recipients. For each ethnic group (and all groups combined), a representation ratio was created by dividing the proportion in a field by the proportion among the bachelor's degree recipients. Black men were the most underrepresented (relative to all men) in the physical sciences, computer sciences, and engineering. American Indian men were most underrepresented in computer sciences and mathematics. While females were highly underrepresented relative to men, Chipman and Thomas (like Dunteman, et al., 1979:101) found fewer and smaller racial differences among females.

Data on the racial identity of degree earners have only been available since the mid-1970s and the most recently published degree data with racial breakdowns were for the 1980-81 school year. Garrison and Brown (1985:56) found that the percentage of black bachelor's degree recipients in the biological sciences remained fairly stable between 1976 and 1981. The most substantial change was a drop in the percentage of white bachelor's degree recipients majoring in these fields. This reduced the difference between racial groups. Using data for the same time periods, Trent (1984:292-93) found small increases in the percentage of black degree earners majoring in computer science and the physical sciences and a large increase in the percentage majoring in engineering. In two of the fields (engineering and computer science) increases by white males were larger than those of black males and resulted in larger racial disparities in 1981 than in 1976.

Correlates of Educational Outcomes for Blacks and Native Americans

In this section, studies attempting to explain the underrepresentation of minorities are examined. The determinants of minority persistence in higher education are examined first and are followed by an examination of the determinants of minority participation in science curricula. Research findings in both areas are important for understanding the origins of racial disparities in science and engineering fields.

Determinants of Persistence in Higher Education

There is an extensive body of social science research on the determinants of persistence in higher education. Studies have examined precollege background factors, college experiences, and institutional characteristics. These studies, and especially those focusing on racial differences in persistence, are reviewed below. Emphasis is given to those studies that used multivariate methods to examine the contribution of different factors to persistence in the pursuit of a baccalaureate degree.

Within this body of research there are a number of important methodological variations that inhibit the direct comparison of findings and complicate generalizations about relationships. First, there are differences in dependent (outcome) measures. Some studies examined the completion of a 4-year degree (Astin, 1982; Dunteman, et al., 1979; Munro, 1981; Thomas, 1981a,b; and Velez, 1985). Other studies examined the persistence from freshman to sophomore year, justifying this procedure on the grounds that the freshman year is a crucial attrition point (Aitken, 1982; Anderson, 1981; Bean, 1980; and Pascarella and Terenzini, 1979). Astin and Cross (1981) examined persistence after 2 years, while Peng and Fetters (1978) analyzed both short- and long-term persistence. While persistence is the most common outcome measure, some studies (e.g., Nettles, et al., 1986) have focused on the determinants of college grade-point average (GPA), itself an important determinant of persistence (see Aitken, 1982: 39-40; Peng and Fetters, 1978:368-369; and Suen 1983:119). Still other studies have focused on attitudinal outcomes, such as the intent to leave (e.g., Bennett and Bean, 1984).

A second important methodological variation involves the sample of students used in the analyses. Those studies using a national sample (typically the 1972 NLS cohort) are able to generalize about the broadest population. However, many researchers have measured persistence using the enrollment records of a single institution. In these studies, students who transfer to other schools cannot be distinguished from those who leave higher education. The advantage of these samples is that they are not limited to a single cohort and can include a larger battery of social and psychological measures than the 1972 NLS.

A third source of methodological divergence is the difference in causal models used by the investigators. Regression coefficients vary according to the nature and number of other variables in the model. For example, studies of the direct relationship between freshman GPA and persistence will report different coefficients if attitudinal variables (institutional satisfaction, intention to withdraw) are included as intermediate factors in a causal model. Modeling variations abound in the research literature on educational persistence.

These fundamental methodological differences complicate the derivation of definitive conclusions from the research literature. As a result, this review will emphasize those findings that are common across a wide range of measurements, models, and samples.

Socioeconomic Background and Persistence in Higher Education. A number of family background characteristics are correlated with persistence in the pursuit of a baccalaureate degree. Peng and Fetters (1978:367) reported that socioeconomic status (a composite index of parental education and income, father's occupation, and a household items scale) had a significant negative relationship with college withdrawal when other predictor variables were controlled. They attributed this relationship to the effects of parental expectations and pressure rather than to financial conditions because they found that scholarship aid and student loans did not have significant relationships to college withdrawal. Allen (1981:133) found that mother's education was the strongest predicator of students' aspiration in his study of black students at the University of North Carolina. However, in contrast to Peng and Fetter's interpretation of the causal dynamics, Astin (1982:94-95) reported that family income and parental education were still significantly related to educational achievement in higher education when other academic characteristics, including student educational aspirations, were statistically controlled.

Given the strong relationship between family socioeconomic background and college persistence, it is important to be cognizant of the socioeconomic differences between white and minority families. On one particularly relevant dimension of socioeconomic background, parental education, there are sizable racial differences even within the population of college-bound high school seniors. The median number of years of schooling for the parents of white students exceeds that of the parents of black students and Native Americans by one full year (American Council on Education, 1984:14). College completion rates showed even greater differences. Nearly 46 percent of the white fathers and 29.8 percent of the white mothers finished college. For black fathers and mothers, the college completion rates were 19.5 and 21.1 percent, respectively. The parents of college-bound American Indian students also had lower rates of college completion than the parents of the white students: only 29.5 percent of the fathers and 21.5 percent of the mothers completed college.

Academic Background and Persistence in Higher Education. Cross and Astin (1981:87) found that high school grade point average (GPA) had the strongest relationship to full-time persistence in college of any individual-level attribute. Aitken (1982:41), Bennett and Bean (1984:185), Nettles, *et al.*, (1986:309) and Bean (1980:180) also reported that precollege academic performance was one of the most important predictors of dropping out. Peng and Fetters (1978:368-69) found that high school curriculum and percentile rank were significantly related to persistence in college even after the effect of college GPA was controlled. Astin (1982:92-93) concluded that students' academic preparation at the time of college entry (high school grades, test scores, study habits, high school curriculum, and perceived need for tutoring) had more frequent and stronger relationships with college outcome measures than any other category of variables.

There are important differences in the average educational background of college students from different racial groups. In 1984, white college-bound high school seniors were much more likely than blacks and Native Americans to have reported an academic curriculum in high school. About four-fifths of the whites and two-thirds of the blacks and Native Americans had been in academic programs in high school (NSF, 1986:28). Other differences in academic preparation (e.g., level and quality of instruction) are harder to measure, but may play a large part in producing the observed differences in persistence. In a survey of black alumni from the Massachusetts Institute of Technology (MIT), 53 percent reported feeling less well prepared than their classmates. Some were dismayed when they learned that their classmates had used some of the textbooks being used at MIT in high school. Others reported that the students from private high schools were more prepared for the pace at MIT (McBay, *et al.*, 1986:8).

There are sizable racial differences in performance on standardized achievement tests taken before college entry. In the National Assessment of Educational Progress (NAEP), the average scores for blacks were lower than those of whites, and average scores for both blacks and Native Americans were lower than those of whites on the Scholastic Aptitude Tests (SAT)[4] (NSF, 1986:29). It is important to

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[4]Due to insufficient sample size, the National Assessment of Educational Progress does not report separate data for Native Americans.

point out, however, that racial disparities in these and other achievement tests have been declining in recent years (Congressional Budget Office, 1986:xviii).

The importance of these racial differences in family and academic backgrounds as determinants of the racial disparities in college achievement can be seen when family background and academic background are statistically controlled in multivariate analyses. In these comparisons of students with "equal" family and academic backgrounds, the racial differences in educational outcomes disappear (Anderson, 1981: 12; Cross and Astin, 1981:82-83; Munro, 1981:139; Nettles, et al., 1985:136; Pascarella and Terenzini, 1978:204; Pascarella, et al., 1983:94; Peng and Fetters, 1978:367; and Velez, 1985:195).

Financial Aid, Student Employment, and Persistence in Higher Education. There is a very complex relationship between student financial need, financial aid, and employment. The strong interrelationship among these variables has made it difficult to delineate the unique contribution of each factor to academic outcomes. Further complicating matters is the tendency for students to receive several types of financial aid. Newman (1985:187) noted that this widespread use of "aid packages" introduces the problem of multicolinearity to the statistical analyses.

Given these problems, it is not surprising that the reviews of the research literature report conflicting results from analyses using different data sets and different measures (see Astin, 1982:107-109). Nettles, et al., (1985:140) found that low financial need was related to both college GPA and academic progress. Fuller, et al., (1982:477) concluded that financial aid can be an important determinant of post-secondary school attendance. However, Peng and Fetters (1978:367) found no significant effects of scholarships or loans on persistence once other student attributes were included in the regression analysis. One review of the literature concluded that scholarships and grants had small positive effects on retention, while loans generally were reported to have negative effects (Jensen, 1983:300).

This finding is important because, in recent years, there has been a shift in the amount and form of student financial aid. After adjusting for inflation, the amount of aid available in the fall of 1983 was 15.5 percent less than that available in 1978 (Lee, et al., 1985:14). During the same time period, grant monies declined by one-half while the amount of loan money nearly doubled. Recent studies have documented a continuation of these trends (Hansen, 1986:46-51).

According to Hansen (1986:57), the decline in the size of grant programs and the expansion of loan programs represents a major shift in federal policy. It is a transformation that may have important implications for the disadvantaged students who were the original targets of federal assistance for higher education. Hansen suggested that the emphasis on loans may have discouraged underrepresented groups from participating in higher education. She noted that there is much speculation that the real decline in federal student aid dollars, plus the shift in the balance between grants and loans, contributed to the recent decline in black college enrollments.

There is much greater consensus on the effects of student employment than there is for student aid. Peng and Fetters (1978:371) found that students who work are more likely to drop out of college. However, subsequent studies have substantially qualified the relationship between work and persistence. Anderson (1981:13) found that holding a work-study job was associated with greater persistence in college, while holding a regular job was associated with a lower probability of persistence. Astin and Cross (1981:84) reported similar findings: on-campus jobs were related to greater persistence in college while working more than 20 hours per week was related to decreased persistence. Velez (1985:198) also found that working on a college campus was related to greater persistence.

Student Adjustment, Integration into Campus Life, and Persistence in Higher Education. Highly influential papers by Spady (1970, 1971) and Tinto (1975) proposed that integration into campus social and academic life were important determinants of persistence in higher education. An extensive research literature has emerged testing and refining these hypotheses (e.g., Aitken, 1982; Bean, 1980; Munro, 1981; Pascarella and Terenzini, 1979, 1980; Pascarella, *et al.*, 1983). Nearly all of the studies confirmed the general hypotheses of Spady and Tinto and found that integration into the academic and social systems of the college campus was positively related to persistence.

Several researchers have demonstrated that student-faculty contact, a component of academic integration, reduced the likelihood of attrition. Nettles, *et al.*, (1986:307-8) found that an index measuring the quantity and quality of faculty contact was positively related to college GPA. Pascarella and Terenzini (1979:204-5) reported that the frequency and the quality of student-faculty relationships were significantly and positively related to persistence in college for male students.[5] Furthermore, there was a compensatory interaction pattern. Some of the measures of faculty contact had their largest positive effects on those freshmen whose parents had relatively low levels of education.

There is some indication that the effects of social and academic integration may be particularly important for black students on predominantly white campuses. In a study conducted at one predominantly white school, Suen (1983:119) found that black students were more alienated than white students and that alienation was a significant predictor of attrition for blacks but not for whites. Nettles, *et*

[5]It is important to note that the *correlation* between faculty contact and student achievement does not necessarily mean that faculty contact *causes* better scholarship. While this is one possible interpretation, other explanations are also possible. The students' achievement may facilitate relationships with faculty members. The more successful students may be more likely to seek out their teachers and faculty members may feel more comfortable or more gratified when interacting with these students.

al., (1986:303) also found that black students reported lower levels of faculty contact, greater perceptions of university discrimination, and lower overall satisfaction than white students. All of these variables were significantly related to college GPA. Nettles, et al., found racial interactions between some measures of academic integration and GPA. In their study of students in 30 southern and border state colleges and universities, the relationship between faculty contact and GPA was stronger for blacks than for whites. Pascarella and Terenzini (1979:70-71), however, found no racial interactions in their study of the effects of academic integration on persistence conducted at Syracuse University.

Adjusting to college life and college coursework can be difficult, as the high freshman dropout rate attests. Beyond these "normal" pressures, minority students often have to confront an alien and inhospitable campus environment. Over 82 percent of the black MIT alumni interviewed in a recent telephone survey reported that they had to adjust to the pace, pressure and workload of college life. Almost 45 percent mentioned that they had to make additional adjustments as black students. Both social and academic situations were cited. Over 40 percent noted cultural barriers or a sense of racial isolation in MIT's living environment. Racial incidents involving other MIT students were mentioned by 15 percent of the respondents. Relationships with white faculty members were often characterized by poor or inadequate support and negative expectations for black student achievement. Black faculty members (2 percent of the total faculty) accounted for 40 percent of the positive faculty relationships mentioned (McBay, et al., 1986:8-13).

A study conducted by the National Research Council (1977:5) found that the retention of minority engineering students at predominantly white colleges was improved when a "critical mass" of minority students was reached on each campus. These students provided peer support and role models for newer minority students. Positive relationships with faculty members were also seen as reducing the alienation of the minority engineering students and consequently reducing their likelihood of attrition. Similar views were expressed in the survey of black MIT alumni. Nearly 40 percent of the respondents volunteered the opinion that MIT needed more blacks (on all levels) to serve as comrades and role models (McBay, et al., 1986:15).

In addition to faculty contact, contact with administrative units of the college can have an impact on students' academic decisions. Willie and Cunnigen (1981:190) reviewed several studies of support services for black students on white campuses and found that black students were most likely to seek help from black administrators, black faculty, and black students. Burrell and Trombley (1983:123-24) also reported that minority students were much more likely to seek help for academic problems from advisers and other students who were minority group members than from their white advisers.

Institutional Characteristics and Persistence in Higher Education. There is a large body of research on the impact of school characteristics on student performance. In a review of these studies, Berryman

(1983:107-114) concluded that (1) individual differences underlie most of the apparent relationships; (2) the effects of the institutions should, in most cases, be small; and (3) the institutional effects should be smaller at the postsecondary level than at earlier levels of education. Concurring with her evaluation, the review of institutional characteristics in this section is limited to two factors that may distinguish the minority experience in higher education from that of the majority: enrollment in predominantly minority institutions and enrollment in 2-year colleges.

The desegregation of U.S. colleges and universities had a profound effect on the distribution of black college students across types of schools. In the early 1960s, an estimated 65 to 70 percent of all black college students were enrolled at traditionally black colleges. By 1968, the figure had dropped to 36 percent. In the 1975-76 school year, black colleges enrolled 17.8 percent of all black college students (Willie and Cunnigen, 1981:181). The most current data (1982) indicated that 16.1 percent of all black college students were enrolled at black colleges (American Council on Education, 1985:12).

While the percentage of black students enrolled in black colleges declined, these institutions continued to award a substantial proportion of all baccalaureate degrees earned by blacks. In the 1975-76 school year, black institutions awarded 40.2 percent of all bachelor's degrees earned by blacks (Trent, 1984:296). In the 1980-81 school year, 33.7 percent of all bachelor's degrees earned by blacks were awarded by black institutions. These figures suggest that there is a higher rate of persistence among black students at black institutions than at white institutions.

The differences in persistence could be due to differences in the characteristics of the students enrolled at each type of institution. In their 1976 survey data, Astin and Cross (1981:30-36) found that black students at black colleges tended to come from families with higher levels of parental education than blacks attending predominantly white institutions, but that black students in white institutions had higher average GPAs and test scores.

Several studies have estimated the impact of attending a predominantly minority institution while controlling for student background characteristics. Astin and Cross (1981:87) found a strong positive effect of minority institutions on persistance after statistically controlling for individual background factors and financial aid. Thomas (1981a:343) also found that attendance at a black institution was positively related to prompt 4-year graduation when academic and family backgrounds were statistically controlled. However, the impact of the black institutions was largely mediated by GPA and other institutional characteristics. When these measures were included in the regression model, there was no direct effect of attendance at a black college. In contrast to these studies and in contrast to his own earlier research on 1968 freshmen, a recent study by Astin (1982:101) reported that attending a predominantly white institution increased a black student's chance of earning a bachelor's degree. He suggested that white institutions may have become more sensitive to the needs of black students in recent years.

In the same study, Astin found that students who began their education at 2-year colleges were also less likely to earn bachelor's degrees. The differences remained when the characteristics of the students attending each type of institution were controlled (1982:99). Similar results were reported by Anderson (1981:13). Velez (1985:197) found that after other determinants of persistence were controlled, students who started their college education at 4-year institutions had a 19 percent higher probability of earning a bachelor's degree than students who began their higher education at 2-year institutions.

These relationships are important because minority students are more likely than white students to attend 2-year colleges. Of the college students enrolled in the fall of 1982, over 41 percent of the blacks, compared to 35.3 percent of the whites, were enrolled in 2-year public schools (Lee, et al., 1985:i). Native Americans were also more likely than whites to be enrolled at 2-year institutions (American Council on Education, 1985:7).

Determinants of Participation in Science and Engineering Curricula

The number of minority students earning science and engineering degrees is a function of both their persistence in higher education and their choice of science and engineering majors. In this section, the factors associated with participation in science and engineering curricula are examined. A number of factors have been suggested as correlates of the low rate of minority participation in science and engineering curricula and the high rate of attrition among those minority students who initially enter those fields (see National Research Council, 1977:21-22). Some of these factors (family background, academic preparation, and college characteristics) were also related to persistence in higher education, while others (cultural factors, career information, and interpersonal influences) have not been identified as important correlates of persistence in higher education.

Socioeconomic and Academic Background and Participation in Science and Engineering Curricula. Many observers have recognized deficiencies in academic preparation as crucial determinants of minority underrepresentation in science and engineering curricula (see McBay, 1978:217). Two separate panels of educational experts identified the lack of academic preparation as one of the most important factors deterring minorities from participating in science and engineering curricula (National Research Council, 1977:21-22; Office of Technology Assessment, 1985:141).

Findings from quantitative assessments support the assessments of these educators. Dunteman, et al., (1979:102) found that differences in ability and academic background distinguished the science majors from nonscience majors. Astin (1982:73-74) reported that students with the highest SAT scores tended to prefer majors in the sciences, and he suggested that the underrepresentation of minorities in the sciences was in part due to poor academic preparation at the secondary school level. Berryman (1983:84) also found that the students who planned to major in the sciences had higher scores on the quantitative portion of the SAT than students planning to major in other fields.

Astin (1982:106) reported that minority students in the natural sciences and engineering received lower grades than would be expected from their academic background characteristics, while minority students majoring in the arts, humanities, social sciences, or education received higher grades. Low grades in college courses may "push" many students out of the science curriculum.

When it comes to training for the quantitative fields, there are large differences in the preparation of minority and nonminority students. Among the 1983 college freshmen with probable majors in mathematics, 80.2 percent of the white students had 4 or more years of high school mathematics. Only 60.8 percent of the blacks and 57.5 percent of the Native Americans planning college majors in mathematics had four or more years of high school mathematics (NSF, 1986:154). There were also large disparities in mathematics preparation among the physical science majors.

Dunteman, et al., (1979:102) demonstrated the importance of these background differences in the choice of college major. When racial groups were statistically equated on four key intervening variables (mathematics ability, orientation to things, perception of mothers' educational aspiration for children, and number of high school science semesters), there was a substantial positive effect of being black on the choice of science majors. The intervening factors accounted for the negative relationship between being black and being a science major.

Most of the research and commentary on precollege factors has focused on academic background. However, researchers have also reported an important relationship between socioeconomic background and the choice of a science major in college. Dunteman, et al., (1979:102) found differences between the socioeconomic status of the families of science majors and other majors. Berryman (1983:89-93) found that having a college-educated parent not only increased the likelihood of choosing a quantitative major, but equalized the rate of choice across white, black, American Indian, and Hispanic subgroups. At least part of the relationship between parental education and college major was due to the effects of parental education on students' high school performance and postsecondary education plans. Berryman hypothesized that parents with college experience were more likely to assume that their children would attend college and also knew more about the early training investments that their children needed to make. She also postulated that the second-generation college students were more likely to have grown up with knowledge of wider occupational horizons than first-generation college students.

Mentors and Minority Participation in Science and Engineering Curricula. Several studies have stressed the importance of role models for increasing the number of minority scientists and professionals (Murphy and McNair, 1981; National Research Council, 1977:21-22; New York State, 1984:4; Office of Technology Assessment, 1985:141). Minority science students have acknowledged the importance of mentors and role models in their field choice (Green and Brown, 1976; Perry, et al., 1976:178) and their persistence in science careers (Garrison and Brown, 1984:25; Malcom, et al., 1976).

Thomas (1984:24) found that both black and white students majoring in the sciences were more likely to have had childhood exposure to scientists than were students majoring in other fields. The race of the role model was also very important. When asked about the person who most influenced their choice of major in college, approximately 90 percent of the black respondents and nearly 98 percent of the white respondents reported a person of the same race (Thomas, 1984:Table 3). Spencer, et al., (1975) found that the occupational aspirations of Choctaw youth tended to mirror the occupational achievements of older tribal members.

While the relationship between mentors and field choice is well documented, less is known about the underlying dynamics of the association. The role models may serve as sources of occupational information. McBay (1978:217) listed inadequate career information as one of the major causes of minority underrepresentation in college science programs.

Identification with the field through identification with the mentor may also be an important process of choosing a scientific career. Minority students participating in an honors training program reported that the opportunity to see members of their own ethnic group working as scientists was a very important factor in the decision to pursue a science career (Garrison and Brown, 1985:25). The experience helped to demystify the life of the researcher and helped students to envision themselves in research careers.

However, part of the mentors' impact on the careers of their students may involve more than psychological dynamics. Blackwell (1981:291-93) noted that the importance of personal references in academia (the "old boy network") tends to work against minority students, especially those from minority institutions.

Cultural Factors and Minority Participation in Science and Engineering Curricula. A common theme in several early studies of minority underrepresentation in science was the idea that cultural barriers deterred many minority students (especially Hispanics and Native Americans) from the pursuit of careers in science and engineering. Maestas (1977) listed four culturally based factors that prevented American Indian and Mexican American students from pursuing careers in science: English as a second language; rejection by members of the majority culture; differences in philosophy (e.g., mastery and control of nature versus life in harmony with nature); and the differences in orientation toward science (minority students seeking to aid their communities resented the deprecation of applied science).

It has also been suggested that cultural orientations toward competition and success differed across cultures and that "success" in white educational institutions forced Native American students into conflict with certain traditional values (Planning Commission, 1974:57). Emphasis on collective rather than individual achievement in Indian cultures has often been viewed as conflicting with the demands of the non-Indian education system. However, one study of this hypothesis using a sample of Oklahoma college students found no significant differences between whites and Native Americans on the acceptance or rejection of individual competition. Furthermore, the four survey items used to measure the presence/absence of values rejecting individual competition were not significantly related to college GPA for either whites or Native Americans (Kerbo, 1981:1278).

It is easier to attribute group differences to the effects of "culture" than to demonstrate the actual cultural basis of an observed difference between groups. Alternative hypotheses explaining the difference need to be ruled out. Factors external to the culture (including negative stereotyping and lack of opportunity) may be sources of the observed differences between groups. In a study based on interviews with Native American students, educators, and program developers, Green (1978a:2) concluded that mathematics anxiety and mathematics avoidance were important barriers to Native American entrance into science. Some of these fears may have been produced by the attitudes held by teachers and counselors. At a meeting devoted to issues in Native American mathematics education, conferees suggested that the most important factor preventing Native American students from obtaining a sound mathematics education was the widespread belief on the part of teachers and counselors that mathematics competence is beyond or irrelevant to Native American needs (Green, 1978b:3). In a statement before the Subcommittee on Science of the House Committee on Science and Technology, the executive director of the American Indian Science and Engineering Society also expressed the view that inadequate counseling and negative stereotypes were important factors limiting Native American achievement in the sciences (Anderson, 1982:15-16).

The limited achievements of Native American students in science and mathematics have also been attributed to the poor quality of their education. One panel of experts felt that the most crucial factor was inadequate preparation in public schools rather than the characteristics of tribal cultures (Green, 1978b:2-3). Until the questions of educational access and quality are resolved, the role of cultural factors remains indeterminate.

Institutional Characteristics and Participation in Science Curricula. While the effects of institutional characteristics on general persistence in higher education were neither large nor uniform across studies, there are important reasons to reexamine their effects on field choice. Schools vary in their ability to offer certain technical curricula (e.g., engineering), and departmental strengths and weaknesses may effect field choice in much more direct ways than other institutional characteristics influence general persistence in higher education.

A number of observers have pointed out the historically important role that traditionally black institutions have played in the careers of black scientists (see Fisher, 1977:173-76; Jay 1977:4). Griffo (1977:156) reported that 62 percent of all black M.D.s and 72 percent of all black Ph.D.s in science received their undergraduate education at black institutions.[6] Jay (1977:4) found that the traditionally black institutions employed between 65 and 75 percent of the academically employed black science doctorates.

While they were important in the production and employment of minority scientists, traditionally black institutions have received only a small fraction of the federal support for research and development activities, and this fraction has declined in recent years. In 1973, federal research and development support at black institutions was $19.5 million, 1 percent of the total support at all institutions. The sum for black institutions rose to $36.5 million in 1980, but the support for other institutions grew more rapidly. In 1980, the black institutions received only 0.9 percent of all federal research and development support (NSF, 1982:2). The relative decline in federal research and development support was particularly important for the black institutions because they are more dependent than the other institutions on federal funds for research and development activities (NSF, 1982:4).

Comparing black students at black institutions and at white institutions, Cross and Astin (1981:41) found only small differences in the percentages choosing science fields as probable majors. Berryman (1983:95) reports similar findings for the selection of "quantitative" majors by black freshmen. However, when earned degrees were considered, much larger differences were found. Garrison and Brown (1985:56) found that a larger percentage of black bachelor's degree recipients were biological science majors at black institutions than at white institutions. Trent (1984:302) found that in a number of science and engineering fields (biological sciences, computer science, engineering, mathematics, and physical sciences), predominantly black colleges produce a greater share of the black bachelor's degrees than their share of all degrees would predict. From 1976 to 1981, the position of black institutions improved relative to the white institutions in terms of the percentage of black degree earners with majors in these science and engineering fields. These findings, however, must be considered tentative because the analyses were not able to control for differences in the characteristics of the students attending each type of school.

The Transition to Graduate School

In the quantitatively based fields, blacks and Native Americans are underrepresented at all degree levels. Their underrepresentation

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[6] These figures, in part, represent the high degree of segregation that existed in American higher education. Until recently, most black students attended black colleges and universities. The absence of historical data on black graduates of white institutions, however, prevents the direct comparison of the rate at which black scientists were produced from the black graduates of each type of institution.

is greater at the master's and doctorate level than at the bachelor's level (Berryman, 1983:21). Some of this increased disparity is the result of lower rates of matriculation in graduate school. In 1983, blacks earned 5.5 percent of the bachelor's degrees in science and engineering (NSF, 1986:32-37). However, blacks made up only 3.7 percent of the U.S. citizens enrolled as full-time students in science and engineering (NSF, 1985a:70).

Aspirations for advanced degrees are important precursors to graduate enrollments, and measures of ability and achievement are highly correlated with graduate degree aspirations. Among a sample of Graduate Records Examination (GRE) takers, Centra (1980:476) found that the important predictors of aspiration for a doctorate rather than a master's degree were GRE scores and college GPA. Being male and black were associated with higher aspirations once the other measures were controlled.

The type of undergraduate institution attended was also correlated with graduate school plans. Astin and Cross (1981:38-40) reported that blacks in black undergraduate institutions tended to aspire to Ph.D. and Ed.D. degrees more often than black students at white undergraduate institutions. (Black students at white institutions, however, were more likely to aspire to professional degrees.) Centra (1980:473) found that when race, sex, GPA, and GRE scores were controlled, undergraduates from black institutions and women's colleges had slightly lower graduate degree aspirations. However, the attributes of individuals were much stronger predictors of graduate school plans than the institutional characteristics. Astin (1982:104) found that measures of undergraduate institution quality were related to graduate enrollment or degree attainment after students' individual attributes were statistically controlled. He suggested that these relationships could be a function of the intellectual climate at certain schools that fostered the motivation for advanced training, or else that prestigious undergraduate institutions had better connections to graduate and professional schools.

Programs to recruit minority students exist at many universities. However, a recent survey of major research universities found that professional programs (e.g., law, engineering, and medicine) were much more likely than graduate school science departments to have minority recruitment and admissions programs. All of the law schools, 93.3 percent of the medical schools, and 82.6 percent of the engineering schools had special minority recruitment and admissions efforts. In the biological sciences, physical sciences, and mathematics, the percentage of departments with such programs was between 50 and 60 percent (Council of Graduate Schools, 1984:14).

As was the case at other educational levels, minority underrepresentation in postbaccalaureate science education was affected by field choice as well as by persistence in higher education. In a study of 1984-85 GRE takers, Pearson and Powers (undated:11) found that blacks with undergraduate degrees in science fields were more likely than whites or Asians to migrate to nonscience fields (especially education) at the graduate level.

Special Programs for Minorities in Science and Engineering

Engineering was the first of the scientific fields to acknowledge the problem of minority underrepresentation and to mount an effort to correct it. Goals were set and organizational structures were established at a symposium held under the auspices of the National Academy of Engineering in 1973 (Kauffman, 1980:331). Over the years, a number of special programs for minority engineering students were created on college and university campuses. Minority students rose from 4.5 percent of the total undergraduate engineering student population in 1973 to 7.5 percent 5 years later (Kauffman, 1980:331-32).

Positive results have been demonstrated in a number of campus training programs for minority students. There were high rates of enrollment in graduate school and professional school among the alumni of the Harvard University Health Career Summer Program (Jackson, 1972:623; Wallace, 1977:234), the Meharry Biomedical Science Program (Birch and Wolf, 1975:1059-60; Murphy and McNair, 1981:196), the University of North Carolina Summer Program in Health Sciences (Lea and Farias, 1972), the Baylor University Work and Study Program (Tristan, et al., 1981:53), and the University of Texas Medical Branch at Galveston Summer Program (Levine, et al., 1976:741). A summer program at the Oak Ridge National Laboratory achieved results similar to those of the college and university campus programs (Hamilton, 1977:229).

Despite numerous local programs, federal support for minority student science training programs at the undergraduate level is very limited. A recent catalog of federal programs designed to attract minoritystudents to science and engineering careers listed 47 programs in 12 agencies (NSF, 1985b). However, 19 of these programs were funded by one agency, the U.S. Department of Health and Human Services. Most of the 47 programs were small, multipurpose initiatives. Only the Minority Biomedical Research Support (MBRS) program and the Minority Access to Research Careers (MARC) program provided support for science training at the undergraduate level.

The MBRS program, initiated in 1972, provides research grants to faculty members at institutions with substantial minority student populations. Graduate and undergraduate students are hired as employees on the research grants. Since 1972, nearly 5,500 undergraduates have been supported by MBRS projects (Minority Biomedical Research Support Program, 1985:5). In 1985 there were 1,109 undergraduate students supported on 647 research grants at 96 different institutions (1985:36). While there has not been an attempt to trace the career accomplishments for a representative sample of MBRS-supported students, several lists of doctorate recipients have been searched for MBRS alumni. These efforts identified 118 Ph.D.s, 95 D.D.S.s, and 617 M.D.s (1985:6).

While MBRS funds research activities, the MARC program directly supports training activities. The Honors Undergraduate Research Training (HURT) program is the largest component of the MARC program. The MARC-HURT trainees (junior and senior honors students at schools with substantial minority enrollments) receive tuition, stipends, and a specially structured curriculum. Research in the biomedical sciences is a central component of the training program and students work closely with faculty members on research projects in the biomedical sciences.

The MARC-HURT program began in 1977 with 74 trainees at 12 institutions. In 1984, all of the nearly 800 program alumni were mailed questionnaires asking about their career progress. Almost two-thirds (65 percent) of the former trainees returned the questionnaires. Over three-fourths (76.1 percent) of the survey respondents had enrolled in a graduate or professional program at some point in time since graduation (Garrison and Brown, 1985:33-34). As of November 1984, 17.9 percent of the former trainees were enrolled in Ph.D. programs, and 15.1 percent were seeking master's degrees. Another 29.5 percent had obtained or were studying for professional doctorates (mostly M.D. degrees).

An important part of the MARC-HURT program is a summer research project, usually conducted off-campus at a major research institution. At least 19 institutions have created formal summer research programs for MARC and other biomedical science students. While not supported by the MARC program, these summer programs often work in close cooperation with MARC program directors at minority institutions. One program, the Purdue-MARC Summer Research Program, has kept track of the educational achievements of its trainees. Of the 75 individuals who were no longer working on bachelor's degrees, 43 percent were in grad-school, 18 percent were in medical school, 13 percent were employed, and 25 percent were not located (Purdue University, 1986).

Despite the consistency of their findings, the reports of program achievements need to be viewed cautiously. The program results are usually reported by program administrators and a selection bias is probably in operation. Administrators of unsuccessful or unsatisfying programs are probably less likely than administrators of successful programs to take the time and effort to document and publish their program's record.[7] In addition, few of the program evaluations have used control groups or comparison groups (Jackson, 1972, and Perry, et al., 1976, are notable exceptions). Along with the accomplishments of program participants, training programs should trace the educational achievements of students who could not be accepted.

On the other hand, it is unfair to demand that these small and innovative programs display irrefutable evidence of effectiveness. In most cases, the cost of a complete evaluation is not justified in light of the total program budget. The projected fiscal year 1985 budget for one of the largest programs, the MARC-HURT Program, was only $4.93 million. While evaluation standards should not be abandoned, the survival of these programs should not be contingent upon an unfair

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[7]This is not meant as an aspersion on the character of program administrators. Scientists also tend to underreport negative findings (see Gould, 1986:47).

burden of proof. Administrative restrictions may also limit evaluation efforts.[8]

Perhaps the best use that can be made of these evaluation reports at the present time is to summarize their most successful characteristics. Reviewing elementary and secondary school programs, Malcom, et al., (1984:vii) concluded that the primary feature of successful programs was the involvement of students in the "doing" of science and mathematics. At the college level, participants in the MARC-HURT program reported that research experience was the most beneficial aspect of the program. The importance of research was emphasized in the responses to both multiple choice and open-ended questions (Garrison and Brown, 1985:47-50). Other observers have also emphasized the importance of direct research experience (National Board on Graduate Education, 1976:13; Watson, 1977:100-101).

Direct interaction with faculty members is another important attribute of successful programs. Next to research experience, this was the most frequently praised characteristic of the MARC-HURT program (Garrison and Brown, 1985:47-50). A study collecting data from the staff of minority retention programs at 40 engineering schools also emphasized the importance of faculty interaction with students (Penick and Morning, 1983). Similar findings have been reported for students in the health professions (Murphy and McNair, 1981:196-97; Green and Brown, 1976:6).

While research exposure and faculty contact have important motivational consequences, the academic components of successful programs should not be overlooked. Tutoring and other academic programs were identified as important methods for reducing minority attrition in an early review of successful minority engineering programs (National Research Council, 1977:34). Early diagnosis and close monitoring of student progress were also cited as important factors in a more recent review of engineering retention programs (Penick and Morning, 1983).

Conclusion

The underrepresentation of minorities in college science and engineering programs is the result of racial differences in rates of participation in higher education and racial differences in field choices. During the early 1970s, rates of college enrollment for

[8]For example, the Office of Management and Budget (OMB) refused to approve the survey of a comparison group in the MARC evaluation on the grounds that the comparison group could not be matched exactly with the MARC-HURT trainees. OMB ignored the possibility of statistical adjustment and failed to see the value of comparisons with the "next best group" of students (see Garrison and Brown, 1985:31). Under the standards proposed by OMB, only programs in which participation was determined by random assignment could be evaluated. This would clearly eliminate the possibility of evaluation for most educational programs.

minorities rose and the percentage of black high school graduates attending college approached that of whites. While the gap in enrollment rates was reduced during the 1970s, the racial disparities in graduation rates remained large. Data from the late 1970s also indicated that there was some progress in reducing the degree of minority underrepresentation among science and engineering majors. However, the absence of published data on the educational attainment of racial groups for the period following 1981 seriously limited the assessment of this issue.

The factors associated with persistence in college and participation in science and engineering fields were reviewed. Precollege academic and socioeconomic backgrounds were important correlates of both educational outcomes. Better preparation in primary and secondary schools would probably improve the rate of minority persistence in college as well as the rate of participation in science and engineering programs. Greater socioeconomic opportunity should also increase the rate of persistence in college and the selection of science majors.

Recent data indicate that there has been some small but significant reduction in the racial gap on the standardized achievement test scores of elementary and secondary school students. Progress in the area of socioeconomic opportunity is more difficult to interpret. Due to the rising number of minority students attending college, there will be an increase in the number of minority students raised in families with college experience. This has been viewed as a precursor to higher rates of participation in the quantitative disciplines (Berryman, 1983:106). However, the rising number of minority children being raised in poor and single-parent families may have the opposite effect and could result in a higher precollege dropout rate and lower rates of participation in mathematics and science courses (Vetter, 1985:7).

While the long-term scholastic and socioeconomic trends will probably affect the number of minority science students, the problem is too immediate, however, to be left to the uncertainty of long-range developments. There is much that colleges and universities can do now to remedy the situation. A number of researchers have examined the factors in the postsecondary school experience that mediate the effects of precollege background. Several have documented the correlation between integration into the social and academic milieus of the college and academic achievement. Others have found that minority students participating in work-study and special training programs were very successful in their science and engineering studies. These programs demonstrate an immediate way of increasing the number of minority scientists and professionals and should not be overlooked in the effort to reduce minority underrepresentation in the technical fields. They should be expanded to cover more fields and more campuses.

These programs perform both academic and socialization functions, and high rates of educational achievement have been documented for program alumni. However, these programs are small in scale and can reach only a small, elite group of high-ability students. In order to reach a greater number of students, the colleges and universities should work to establish a campus-wide milieu that emulates that of the training program. Expanded opportunity for the participation of undergraduate students in research would introduce more students to the challenge and excitement of scientific inquiry. A broad range of student services could help to promote the social and academic integration of minority students on nonminority campuses. Faculty members also have a crucial role to play. Both the quantity and quality of faculty-student interaction are correlated with academic achievement. For minority students, this interaction can best be promoted by the presence of minority faculty members. These minority faculty members serve minority students as mentors and role models and, in addition, become visible symbols of the institutions' commitment to racial equality.

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BACCALAUREATE-LEVEL PRODUCTION OF SCIENTISTS AND ENGINEERS

Michael T. Nettles

Introduction

Black Americans are underrepresented in all scientific and engineering professions. Blacks constitute 10 percent of the employed labor force and 6 percent of all professional employees in the United States, but the 90,500 black scientists and engineers represent only slightly more than 2 percent of all U.S. scientists and engineers. Native Americans, on the other hand, represent only four-tenths of one percent of U.S. scientists and engineers, equaling their representation in the U.S. labor force (National Science Foundation, 1986; hereafter, NSF). Howard Garrison, in this report, has demonstrated the need to increase the production of minority scientists and engineers by increasing the number of minority students admitted into college and by improving their performance in college. This paper elaborates upon some important points discussed in the Garrison paper and also recommends needed research for gaining greater understanding of the obstacles to equal participation in undergraduate science and engineering curricula.

Undergraduate Production

Although preparation for science and engineering careers begins during early childhood, the first level of educational specialization is at the undergraduate college level. Undergraduate colleges and universities provide students the opportunity to specialize in the scientific fields in which they will either practice immediately after receiving the baccalaureate degree or continue to study in graduate and professional schools. Undergraduate science programs also serve as a proving ground for entry into scientific professions; and as a result, the relatively rigorous curricula result in rather high dropout rates, particularly for minority undergraduate science majors.

In recent years, the College Board's annual National College-Bound Seniors reports indicate that of college-bound seniors, 41 percent of blacks, 39 percent of Native Americans, 47 percent of Asians, and 39 percent of whites indicate an interest in majoring in science and engineering (The College Board, 1984). Recent reports of college baccalaureate degree recipients, however, indicate a much smaller proportion of minority degree recipients in science and engineering disciplines. Of the 60,673 black baccalaureate degree recipients in 1980-81, only 6,410 (10.5 percent) received their degrees in either biological science (2,269), computer science (786), physical sciences (906), or engineering (2,449). Similarly, of the 3,593 Native American baccalaureate degree recipients, 418 (11.6 percent) were in either biological science (137), computer science (21), physical science (65), or engineering (195). By contrast, about 17 percent of white and 18.5 percent of Asian baccalaureate degree recipients received their degrees in these four fields (National Center for Education Statistics, 1984). Of the baccalaureate degree recipients in 1980-81, blacks and Native Americans represent respectively 6.5 percent and four-tenths of 1 percent of total degrees, 5.1 percent and one-tenth of 1 percent of computer science degrees, 3.8 percent and three-tenths of 1 percent of physical science degrees, and 3.3 percent and three-tenths of 1 percent of the engineering degrees.

While many colleges and universities have made progress in producing larger numbers of minority undergraduate scientists and engineers in recent years, much more progress is needed, particularly at predominantly white universities. Researchers have recently documented the inordinate production of black science and engineering bachelor's degrees by predominantly black colleges. Although black colleges enroll fewer than 30 percent of black undergraduate students, they produce more than 40 percent of black baccalaureates in biological sciences, physical sciences, engineering and mathematical sciences (Berryman, 1983; The College Board, 1985; Hill, 1985). Accolades and recompensation are due black colleges for producing a high proportion of black scientists, especially since the 88 black 4-year universities represent less than 5 percent of American universities and since the vast majority do not offer extensive science programs. At the same time, however, research is needed in order to examine ways to increase the production of minority scientists at predominantly white universities, where the more extensive science curricula are offered. Only five black colleges offer engineering degrees, yet combined they produced over 35 percent of the 2,445 black engineers in 1981.

Research is also needed to determine the contribution of college attrition to the overall low production of minority baccalaureate degrees. Examination of such issues as the racial differences in the attrition rates and the causes for such differences will provide insight into ways to increase the production of minority scientists. Although increasing minority retention may help to improve somewhat the production of minority scientists, determining ways to increase the pool of minorities qualified for college admissions is also very important. Additionally, an examination of the effects of college remediation and other interventions upon the success of underprepared minority science majors will help to identify methods for reducing the gap between the number of students who aspire for science careers and those who actually achieve baccalaureate degrees in science or engineering. Although 4-year colleges and universities are moving away from remediation, such interventions are often necessary to offset the effects of inferior precollegiate opportunities available for low socioeconomic status and minority youth. An important factor to focus on in efforts to increase admissions and persistence of undergraduates is their academic performance. Precollegiate preparation and performance are important determinants of admissions; and college performance is an important determinant not only of persistence but also of college students' postbaccalaureate career and educational opportunities.

A recent survey of black and white college students reveals some important racial differences in college science students' preparation for college and their performance in college (for a complete description of the survey methodology, see Nettles, et al., 1986). Table 1 illustrates the differences in academic performances of black and white sophomores, juniors, and seniors at 30 diverse colleges and universities. Students in three categories of science major (biological science, physical science, and engineering) are compared as well as students in all other major fields combined. As expected, both black and white college science students have higher performance than students in all other college majors combined on all four performance measures. Black science students perform better than black nonscience students, but their performance is significantly lower than their white counterparts within their discipline. In other words, black science majors have significantly lower Scholastic Aptitude Test scores than white science majors; and with the exception of the physical sciences, blacks have significantly lower high school grade-point averages (GPAs), significantly lower college GPAs, and significantly slower progression rates than white science majors.

Although the precollegiate performance measures are important for admission, perhaps the most important of all these performance measures for determining the future development of minority scientific talent is college GPA. While white science majors report college grades of "B-," black college science majors have average grades of "C." The lower college GPAs for black students are important because they foretell lower postbaccalaureate professional and educational experiences for today's minority college students. Both employers and graduate and professional schools consider college GPAs among the most important criteria when making admissions and employment decisions. Therefore, not only is it important to improve minority participation in college science and engineering programs, but improving minority performance in college is equally important.

Finally, a frequently overlooked source of minority scientific talent is community colleges. The nation's 1,200 community colleges enroll nearly half of the minority college students. However, recent reports estimate that fewer than 25 percent transfer to 4-year universities to pursue a baccalaureate degree (Astin, 1982). Efforts to encourage minority community-college students to transfer to 4-year institutions may also contribute to improving the production of minority scientists.

TABLE 1: Weighted Comparisons of Black and White Students' Academic Performance in High School and College, 1982

	White Mean	Standard Deviation	Number	Black Mean	Standard Deviation	Number	F
SAT Score (Combined V and Q)							
Biological science	1141.49	161.49	144	827.01	178.79	42	117.16*
Physical science	1137.39	158.38	158	955.15	135.68	9	11.88*
Engineering	1148.51	148.30	481	846.93	145.43	70	254.56*
All other fields	1051.84	148.77	2617	811.82	125.39	531	1207.68*
High School GPA							
Biological science	2.14(B+)	1.34	144	3.60(B)	1.58	42	35.25*
Physical science	2.76(B)	1.74	158	2.88(B)	1.80	9	.04
Engineering	2.39(B+)	1.54	481	3.46(B-)	1.73	70	27.76*
All other fields	2.92(B)	1.54	2617	3.79(B-)	1.61	531	138.61*
College GPA							
Biological science	3.98(B-)	1.74	144	5.17(C)	1.75	42	15.04*
Physical science	4.37(B-)	2.01	158	4.40(B-)	2.43	9	.002
Engineering	4.46(B-)	2.14	481	5.23(C)	1.81	70	8.12*
All other fields	4.47(B-)	1.88	2617	5.37(C)	1.79	531	102.52*
Progression Rate							
Biological science	16.55	3.95	144	14.87	3.65	42	5.83*
Physical science	16.34	4.22	158	14.61	3.34	9	1.49
Engineering	16.25	3.21	481	14.69	4.82	70	12.17*
All other fields	15.79	4.21	2617	14.02	4.36	531	72.68*

*Significant at the .001 level.

SOURCE: M. T. Nettles, E. J. Gosman, A. R. Thoeny, and B. A. Dandridge, *The Causes and Consequences of College Students' Performance: A Focus on Black and White Students' Attrition Rates, Progression Rates, and Grade-Point Averages*, Nashville: Tennessee Higher Education Commission, 1985.

Conclusion

Efforts to increase the college production of minority scientists should devote attention to examining the following:

- Improving the quality of the pool of minority college-bound students, especially those 40 percent who express an ambition to become scientists and engineers,
- Improving the retention rates of those minorities who actually enter college science curricula but drop out prior to receiving a baccalaureate degree,
- Improving the college GPAs of minority science majors to the point that they are equal to their nonminority counterparts in science disciplines,
- Determining the factors that contribute to maintaining minority students' interest in science and engineering careers,
- Identifying and eliminating the barriers to success of minorities in science disciplines at predominantly white universities, and
- Determining ways to increase the transfer of minority community-college students who have the interest and ability to succeed in science and engineering degree programs at 4-year institutions.

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HISPANICS' PRECOLLEGE AND UNDERGRADUATE EDUCATION: IMPLICATIONS FOR SCIENCE AND ENGINEERING STUDIES

Richard P. Duran

Introduction

Underrepresentation of Hispanics in professional careers involving science and engineering reflects numerous factors. One key factor is the failure of significant numbers of Hispanics to attain a graduate education, and a second key factor is the decision of those Hispanics who do attain a graduate education to elect areas of graduate study outside the natural sciences, engineering, computer science, and mathematics. This paper reviews current data and research on the educational progress of Hispanic students prior to graduate school in order to discuss how Hispanics' propensity to enter graduate study in science and engineering areas is related to earlier educational attainment and achievement patterns.

Four topic areas are reviewed: (1) Hispanics' demographic charteristics, educational attainment, and school persistence, (2) Hispanics' elementary and high school achievement and academic course selection patterns, (3) Hispanics' undergraduate college admissions profile, college achievement, academic areas of B.A. degree attainment, and Graduate Record Examination (GRE) scores, and (4) the need for further research on background, personal, and institutional factors affecting Hispanic students' educational progress in areas relevant to science and engineering study.

At certain points, the review adopts a comparative perspective, comparing educational outcomes (1) among Hispanic subgroups and (2) between Hispanic students and other ethnic groupings of students--primarily white, black, Asian, and American Indian. In several instances, gender is treated as a grouping variable, since the association of this factor with educational outcomes is important to consider for Hispanics as well as for other groups of students.

Going beyond educational survey-based research, the review also covers selected research on the college admissions process for Hispanic students, their academic and cognitive skill development, and ways in which their language and social characteristics might influence educational outcomes. Some attention is also given to institutional services, programs, and practices and related educational policy issues that one may associate with educational outcomes for Hispanic students. These latter concerns have not been subjected to a great deal of research, yet they are critical in the identification of educational interventions that may benefit Hispanic students' preparation for science and engineering careers.

Hispanics' Demographic Characteristics, Educational Attainment, and School Persistence

Population Size, Age, and Income

Data from the 1985 Current Population Survey (CPS) of the U.S. Bureau of the Census and other surveys provide useful information on the size, socioeconomic status, and general educational attainment levels of U.S. Hispanics.[1] The 1985 CPS survey estimate of 16.9 million persons of Spanish origin in the United States amounts to 7.2 percent of the total U.S. population. The subgroup breakdown of this population was as follows: 10.3 million of Mexican origin; 2.6 million, Puerto Rican origin; 1.0 million, Cuban origin; 1.7 million, Central or South American origin; and 1.4 million, "Other Spanish Origin." The March 1985 CPS survey indicated that the U.S. Hispanic population had grown by 16 percent during the 1980-1985 period, compared to a growth rate of a little over 3 percent for the population as a whole.

Other data indicate considerable heterogeneity in the demographic characteristics of U.S. Hispanic subgroups. For example, the median age of U.S. residents of non-Hispanic origin was estimated at 31.9 years. In contrast, the median age of residents of Mexican origin was 23.3 years, and that of residents of Puerto Rican origin was 24.3 years. U.S. residents of Cuban origin, however, had a median age of 39.1 years--older than the non-Hispanic populace--while "Other Spanish Origin" residents had a median age of 28.0 years--more like that of U.S. non-Hispanic residents as a whole.

Variations in income levels are shown both in the U.S. population as a whole and across Hispanic subgroups. Overall, poverty was more than twice as prevalent among Hispanics (25 percent) than it was among non-Hispanics in the general population (11 percent), but Hispanic groups differed considerably from each other in this regard. Forty-two percent of Puerto Rican families earned incomes below the poverty line in contrast to 24 percent of families of Mexican origin and 24 percent of those of Central and South American origin. Families of Cuban origin showed the lowest incidence of poverty (13 percent), followed by "Other Spanish Origin" families (15 percent).

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[1]Throughout this report reference to "Hispanics" will only apply to persons of Hispanic origin residing within the continental United States. Hispanics residing in Puerto Rico are not discussed but merit separate and specialized consideration.

High School and College Attainment. Census and survey data indicate that Hispanics receive less of an education than the general populace. For example, in 1985 the educational attainment of Hispanic adults 25 years or older lagged considerably behind that of the general population at all levels of education (U.S. Bureau of the Census, 1985): 48 percent of Hispanics in this age range had completed high school in contrast to 76 percent of non-Hispanics. In addition, 14 percent of Hispanics had completed 5 years or less of formal education, compared to only 2 percent of non-Hispanics.

The failure of Hispanics to complete high school at rates equal to those of white students is a severe and long-term national problem. The magnitude of the problem is evident by inspecting the trends depicted in Figure 1, which shows the percent of 18- and 19-year-olds completing 12 years of education during the period 1972-1983. As the plots show, Hispanics' high school completion rates for this age range, far below those of whites, have varied from a low of about 45 percent to a high of about 52 percent over the period in question; the completion rates for whites, meanwhile, ranged from about 71 percent to 74 percent. Blacks also showed depressed high school completion rates among 18- and 19-year-olds relative to white students. These rates followed the growth and decline pattern for Hispanics, but overall, the high school completion rates for blacks were slightly higher than for Hispanics.

The difficulty that Hispanics encounter in completing high school has an obvious negative impact on students' subsequent occupational and schooling development. A recent study by the Hispanic Policy Development Project (1986) examined the occupational status and educational pursuits of white, Hispanic, and black students who were high school sophomores in 1980 and who were participants in the 1984 High School and Beyond (HSB) longitudinal survey,[2] which indicated that unemployment rates were noticeably higher among students who had not graduated from high school and among students who were academically at risk while successfully completing high school. Failure to complete high school seemed especially prevalent among females who became pregnant during high school: about 25 percent of all Hispanic females dropping out of high school indicated that they had done so because of pregnancy.

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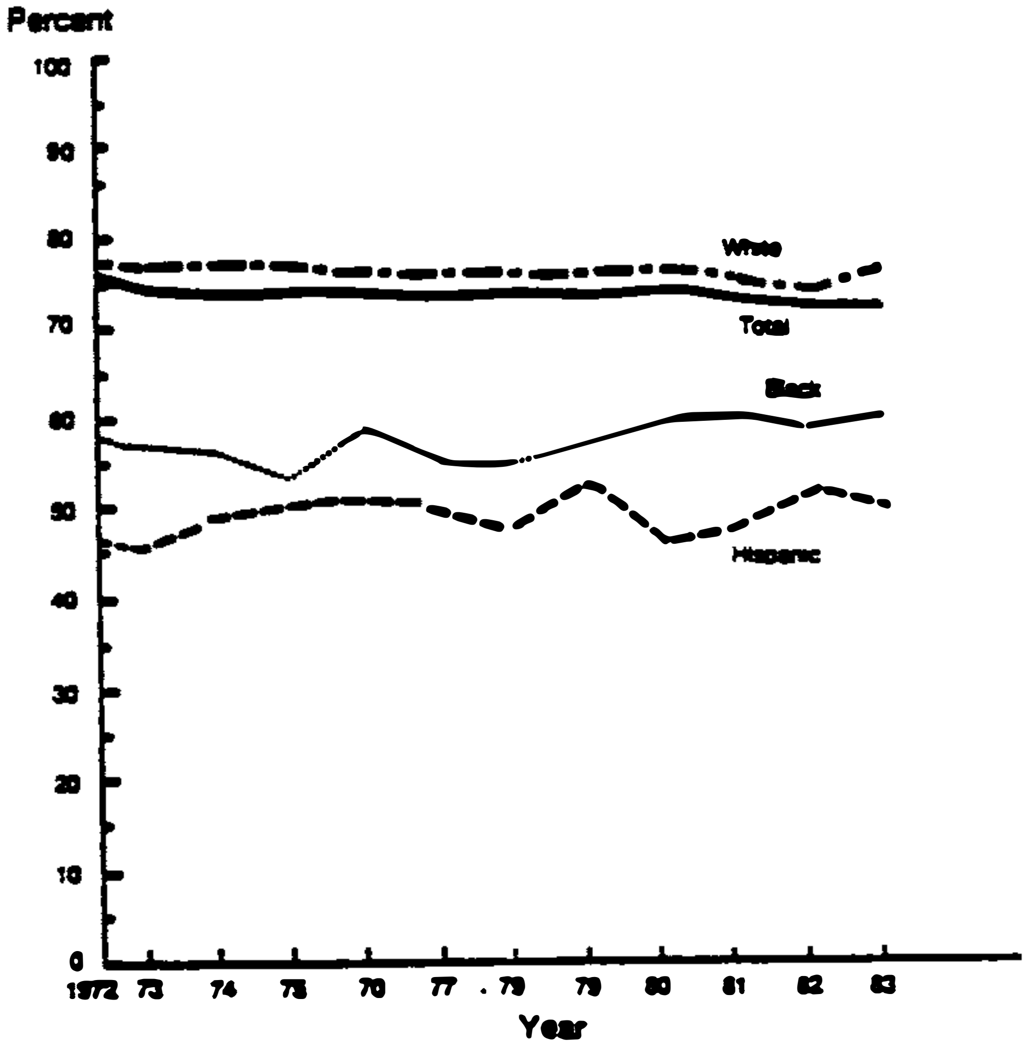
[2]Because of the properties of the High School and Beyond (HSB) sampling procedure in the original 1980 survey and in the 1984 follow-up survey, it is not possible to draw definitive inferences about the national population of Hispanic youth within the sophomore-age range in 1980. The results of the HSB survey, for example, exclude Hispanic students who might have been sophomores in 1980 but who had already dropped out of school (see Hispanic Policy Development Project, 1986:7, for a discussion of these and other sampling limitations).



NOTE: The proportion of 18- and 19-year-olds who have graduated from high school declined from a peak of 74.8 percent in 1972 to 72.0 percent in 1982. The percentages of high school graduates for blacks and Hispanics are several points below whites for each year, but are slightly higher in 1982 than in 1972.
SOURCE: U.S. Department of Education, Indicators of Educational Status and Trends, Washington, D.C.: U.S. Government Printing Office, 1985.

Figure 1 High school graduates, by race/ethnicity, 1972-1983 (in percent).

Growth in Hispanic College Enrollment. The fact that so many Hispanics have a problem attaining a high school education implies that Hispanics would necessarily show lower levels of college attainment than the population as a whole. Indeed, this is the case. Results from the 1985 CPS survey indicated that only 8 percent of Hispanics, as compared to 20 percent of non-Hispanics, had completed at least four years of college. However, recent survey data indicate that small, but steadily increasing, numbers of Hispanics are attending colleges and receiving undergraduate degrees (American Council on Education, 1986). In addition to providing this information, Table 1 also includes enrollment trend statistics for various non-Hispanic groups.

Overall, from 1976 to 1982, Hispanic undergraduate education enrollment increased by roughly 136,000 students, and the percentage of college enrollees of Hispanic origin increased from 3.5 to 4.2 percent. These increases contrasted with trends encountered for white and black students: the enrollment numbers and proportional representation among college enrollees declined for these two groups. More recent statistics indicate that Hispanic enrollment in 2-year and 4-year colleges has grown further: in 1984 Hispanics constituted 4.3 percent of all undergraduate college students, 3.1 percent of all 4-year college students, and 6.4 percent of all 2-year college students. Over the period 1980-1984, the population of Hispanic college students grew by an average of 12 percent: the growth rate was highest for 2-year colleges (13 percent) and lower for 4-year colleges (11.1 percent). In contrast, the number of black college enrollees dropped by 3.3 percent over the period. Very small drops also occurred for white students, the largest occurring for 2-year colleges (1.5 percent).

Growth in Hispanic Bachelor's Degree Recipients. Increased college attainment among Hispanics is also evidenced in survey data concerning undergraduate degrees conferred over the period 1975-76 through 1980-81 (American Council on Education, 1985:17). During this period, the number of Hispanic bachelor's degree recipients increased from 17,964 to 21,731, or 20.4 percent. Blacks also showed an increase in the number of bachelor's degrees received: from 59,122 to 60,533, or 13.9 percent. Virtually no increase occurred for American Indians, and only a slight increase occurred for whites (0.8 percent). Interestingly, Asians showed the most dramatic increase; the number of bachelor's degrees received by this group rose by 67 percent during the period.

Interpretation of Data on College Enrollment and Degrees Earned. The data reviewed above on increases in the number of Hispanics attending college and receiving bachelor's degrees is subject to misinterpretation. On first inspection, the data might be judged to signal unambiguously that a general improvement has occurred in Hispanics' ability to attain a college education. As the data indicate, the number of Hispanic undergraduate students has clearly increased in recent years, the proportion of Hispanics among all undergraduate college students has increased, and the number of Hispanic bachelor's degree recipients was increasing as of 1981. However, it is important to analyze this growth further to clarify whether Hispanics' propensity to enroll in college has indeed changed.

An examination of additional data (U.S. Bureau of the Census, 1984) suggests that the growth rate in Hispanics' college attendance, uneven across 2- and 4-year colleges, largely reflects an increase in the raw size of the Hispanic college-age population. Such data indicate that there is no increased propensity for Hispanic high school

TABLE 1: Trends in Total Enrollment in Institutions of Higher Education, by Level of Institution and Race/Ethnicity, 1976-1984

Race/Ethnicity and Citizenship	Number Enrolled (in thousands)					Percent Enrolled					Percent Change
	1976	1978	1980	1982	1984	1976	1978	1980	1982	1984	1980-1984
TOTAL, 4-year inst	7,090	7,187	7,565	7,648	7,561	100.0	100.0	100.0	100.0	100.0	1.1
White, non-Hispanic	5,984	6,013	6,275	6,306	6,263	84.4	83.7	82.9	82.5	81.6	-0.2
Minority	930	973	1,050	1,073	1,108	13.1	13.5	13.9	14.0	14.5	5.5
Black, non-Hispanic	603	611	634	612	613	8.5	8.5	8.4	8.0	8.0	-3.3
Hispanic	173	190	217	229	241	2.4	2.6	2.9	3.0	3.1	11.1
Asian/Pacific	118	137	162	193	217	1.7	1.9	2.6	2.5	2.8	33.9
Native American	35	35	37	38	37	0.5	0.5	0.5	0.5	0.5	0.0
Non-resident Alien	176	200	241	270	280	2.5	2.8	3.2	3.5	3.6	16.2
TOTAL, 2-year inst	3,880	4,028	4,521	4,740	4,511	100.0	100.0	100.0	100.0	100.0	-0.2
White, non-Hispanic	3,077	3,167	3,558	3,692	3,504	79.3	78.6	78.7	77.9	77.7	-1.5
Minority	761	810	899	987	955	19.6	20.1	19.9	20.8	21.1	6.2
Black, non-Hispanic	429	443	472	489	457	11.1	11.0	10.4	10.3	10.1	-3.2
Hispanic	210	227	255	291	288	5.4	5.6	5.6	6.1	6.4	13.0
Asian/Pacific	79	97	124	158	165	2.0	2.4	2.7	3.3	3.7	33.1
Native American	41	43	47	49	45	1.1	1.1	1.0	1.0	0.9	-4.2
Non-resident Alien	42	52	64	61	52	1.1	1.3	1.4	1.3	1.2	-18.8
TOTAL, all institutions	10,970	11,215	12,087	12,388	12,162	100.0	100.0	100.0	100.0	100.0	0.6
White	9,061	9,180	9,833	9,997	9,767	82.6	81.9	81.3	80.7	80.3	-0.6
Minority	1,691	1,783	1,949	2,059	2,063	15.4	15.9	16.1	16.9	17.0	5.8
Black	1,032	1,054	1,107	1,101	1,070	9.4	9.4	9.1	8.9	8.8	-3.3
Hispanic	383	417	472	519	529	3.5	3.7	3.9	4.2	4.3	12.1
Asian/Pacific	197	234	286	351	382	1.8	2.1	2.4	2.8	3.1	33.6
Native American	76	78	84	88	83	0.7	0.7	0.7	0.7	0.7	-1.2
Non-resident Alien	218	252	305	331	332	2.0	2.2	2.5	2.7	2.7	8.9

NOTE: Excludes enrollment in U.S. Service School.
SOURCES: American Council for Education, Minorities in Higher Education, Fourth Annual Status Report, 1985, and Minorities in Higher Education, Fifth Annual Status Report, 1986.

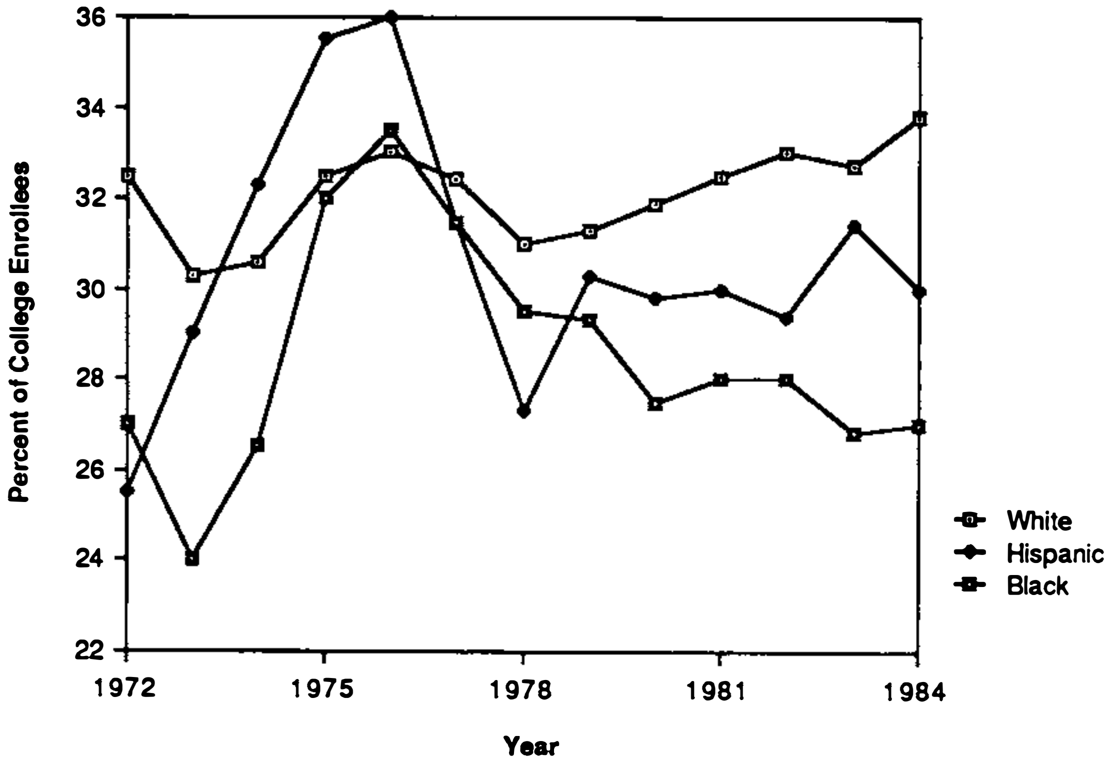
students to elect college study following successful completion of high school: indeed, the proportion of Hispanic high school graduates electing to go to college after high school has declined during the past 10 years.

Growth in 2- and 4-Year College Attendance Rates. Data indicating Hispanics differential enrollment rates in 2-year versus 4-year colleges (see Table 1) indicate that Hispanics are twice as likely to attend 2-year colleges than 4-year colleges and that this trend seems consistent over the period 1976-1982. Hispanics constituted 5.4 percent of the 2-year college population in 1976 and 6.1 percent of this population in 1982. In comparison, their representation among all 4-year college enrollees was 2.4 percent and 3 percent in 1976 and 1982, respectively. The statistics suggest that, in the 18- to 24-year-old group (of which they constituted about 7 percent of the population in 1982), Hispanics are close to approaching an equitable representation in 2-year colleges but remain seriously underrepresented in 4-year colleges.

The fact that Hispanics' enrollment rates in 4-year colleges are not keeping pace with their population growth is important to an analysis of factors contributing to Hispanics' failure to pursue graduate study in science and engineering areas. It is clear that improving Hispanics' participation in graduate school in these areas requires a concomitant growth in their ability to attend 4-year undergraduate colleges and students' subsequent selection of undergraduate majors that will promote pursuit of science and engineering studies in graduate school.

Decline in College Attendance Following High School. A more startling development calling into question unqualified optimism that Hispanics are gaining greater access to college is that the percentage of Hispanic high school graduates, aged 18 to 24, who go on to college has declined over the past 10 years following a period of increasing college enrollment during the period 1972-1976 (American Council on Education, 1985). Figure 2, which graphically displays this trend based on a plot of recent data compiled by the U.S. Bureau of the Census (1984), indicates that in 1984 an estimated 30 percent of Hispanic high school graduates were enrolled in college as compared to 35.8 percent in 1976 and 25.8 percent in 1982. Estimated black college enrollment rates among 18- to 24-year-old high school graduates between 1976 and 1984 show a similar increase, followed by a decline. Since 1972, white high school graduates in the same age range show the least variation in estimated college enrollment rates, from a low of 30.2 percent to a high of 33.7 percent.

Population Growth and Proper Interpretation of Increased Attainment. Given the pattern of college enrollment rates for Hispanics, the growth rate in numbers of Hispanics attending college appears to reflect growth in the raw numbers of Hispanics who do manage to complete high school, rather than an increased propensity for Hispanics either to complete high school itself or to elect college following successful



SOURCE: U.S. Bureau of the Census, School Enrollment--Social and Economic Characteristics of Students: October 1984 (advance report), Washington, D.C.: U.S. Department of Commerce, 1985.

Figure 2 Rate of college attendence of 18- to 24-year-old high school graduates, by racial/ethnic group, 1972-1984 (in percent).

completion of high school. Since 1972 the 18- to 24-year-old Hispanic population has grown from an estimated 1,338,000 persons to an estimated 2,018,000 persons in 1984--an increase of roughly 51 percent. In contrast, the general population of 18- to 24-year-olds has grown from 24,579,000 in 1972 to 28,031,000 persons in 1984--an increase of roughly 14 percent. Thus, the Hispanic population of high school graduation age has been growing far faster than the rest of the population. This fact appears to account for the growth in the number of Hispanics attending college.

The noteworthy growth (20.4 percent) in the number of Hispanic college students successfully earning bachelor's degrees over the period 1975-76 to 1980-81 is likely to be associated with growth in the number of Hispanics attending college during the period, although only indirect evidence supporting this contention has been encountered in preparing this report. In order for the association between growth in bachelor's degree recipients and growth in 4-year college attendance to be examined adequately, it would be necessary to study growth in the pool of Hispanic college students originating 4 or more years prior to receipt of the degree. Unfortunately, data to complete such an analysis appear not to be readily available.

As shown in Table 1, during the period 1976-1980 the number of Hispanics attending 4-year institutions grew from 173,000 to 217,000, an increase of about 25 percent. However, this growth rate can only be partially and indirectly related to growth in the number of Hispanic bachelor's degree recipients, since the growth rate reflects increasing enrollment without consideration of students' level of college advancement. Thus, the data do not directly address the contention that growth in the number of Hispanic bachelor's degrees over the period 1975-76 through 1980-81 can be largely attributed to sheer growth in the number of Hispanics attending 4-year colleges.

School Persistence

College Progress and Persistence. Given that Hispanic students are able to enroll in a 4-year college, a key question is whether they are able to progress through their college education as well as other students. The answer to this question is "no" based on data compiled from a number of survey sources.

Table 2 reveals college completion rates of American Indian, black, Chicano, Puerto Rican, and white students based on data compiled from the National Longitudinal Survey of 1972 (NLS), Current Population Surveys (CPS), and 1980 follow-up data on participants in a 1971 survey conducted by the Higher Education Research Institute on entering full-time college freshmen at 4-year institutions. The data bases for the surveys are different (the NLS and CPS data include 2-year as well as 4-year college students), and the resulting college completion rates show some variability across survey sources. However,

TABLE 2: Two Estimates of Percentage of College Entrants Who Completed College

Group	NLS and CPS*	HERI**
Whites	59.0	55.6
Blacks	42.0	50.9
Chicanos	31.3	39.7
Puerto Ricans	31.3	41.8
American Indians	39.0	38.6

*National Longitudinal Study and Current Population Surveys.
**Higher Education Research Institute Follow-up Study of 1971 Freshmen (conducted in 1980).
SOURCE: Alexander Astin, Minorities in Higher Education, San Francisco: Jossey-Bass, 1982, p. 43.

TABLE 3: College Entrants Who Had Persisted, Transferred, Completed Short-Term Programs, or Withdrawn, by Racial/Ethnic Group: February 1982 (in percent)[a]

Racial/ Ethnic Group	4-Year College			2-Year College		
	Persist	Transfer	Complete/ Withdraw[b]	Persist	Transfer	Complete/ Withdraw[b]
All students	75	15[c]	10	59	16[d]	26
Hispanic	66	17	17	65	11	24
Black	71	14	15	61	15	24
White	75	15	9	57	16	27
Asian American	86[e]	12	2	70	21	9
American Indian	81	11	9	61	21	18

[a]Percentages are based on those individuals who entered college before June 1981.
[b]Students who had completed short-term programs (i.e., completers) and students who had left school without completing programs (i.e., withdrawers) were not differentiated in this table because the information needed for so doing was not available in the HSB first HBA follow-up survey.
[c]Includes 10 percent 4- to 4-year college transfers and 5 percent 4- to 2-year college transfers.
[d]Includes 8 percent 2- to 2-year college transfers and 8 percent 2- to 4-year college transfers.
[e]The apparently higher persistence of Asian Americans is based on a small sample of Asian Americans and does not differ significantly from the rate for whites.
SOURCE: National Center for Education Statistics, Two Years After High School: A Capsule Description of 1980 Seniors, Washington, D.C.: National Center for Education Statistics, 1984.

both sets of results show a similar pattern of college completion rates among the various ethnic groups: well over half of white students were estimated as completing college successfully, as compared to only 30-40 percent of Hispanics; American Indian and black students also were found to be less successful in completing college than white students.

Data from the 1982 follow-up survey to the 1980 HSB Survey suggest more recent trends in Hispanics' progress through college relative to other groups. As Table 3 indicates, Hispanic students showed the lowest persistence in college (66 percent), followed by blacks (71 percent) and whites (75 percent). Asian Americans (86 percent) and American Indians (81 percent) showed the highest persistence rates. The overall rate of college persistence across groups was 75 percent. Thus, as early as 2 years into an undergraduate education, Hispanics' persistence was notably below that of students as a whole, as well as below the persistence rates for all other ethnic classifications of students. Also, 17 percent of Hispanic students either had withdrawn formally from college or had ceased college attendance because of attainment of some short-term college objective. This rate, too, was higher than for all other groups and nearly double the rate for white students.

The data cited above contrast with previously cited data that indicated a growth in the number of Hispanics receiving bachelor's degrees during the period 1975-1981. Again, it is possible that Hispanics earned more degrees because of their sheer growth in the college-age population and not because they were becoming more successful in completing college once they entered it. Other data to be discussed suggest that Hispanic students as a whole enter colleges with less academic preparation than other students and that other personal, background, financial, and institutional factors can impede progress in college for them more than for other students.

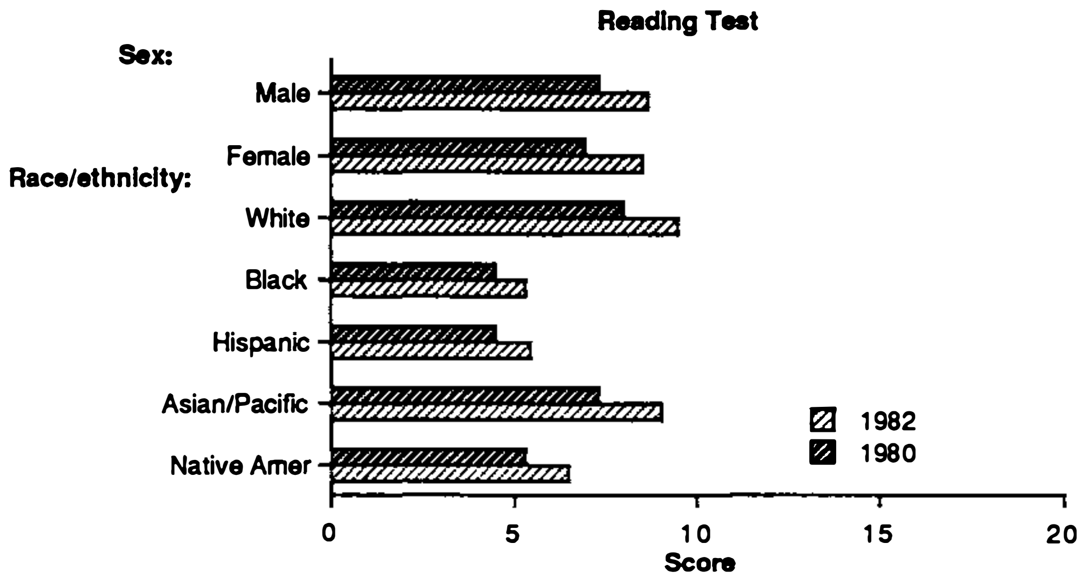
Elementary and High School Achievement and Academic Coursework

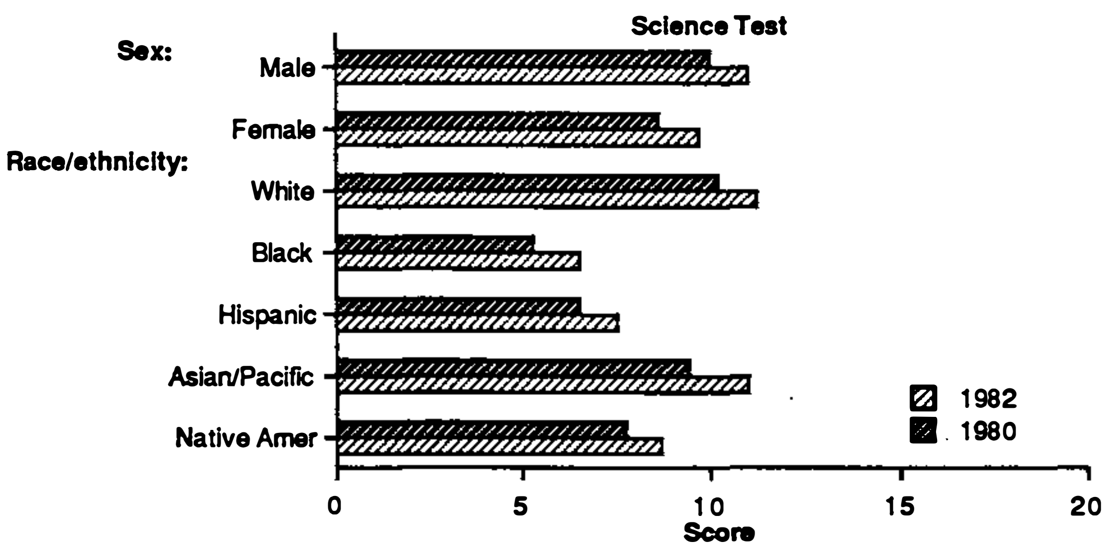
Survey studies indicate that Hispanic students' educational achievement begins to fall behind that of white students during the elementary school grades and that the gap in achievement continues unabated throughout the high school years and across all major academic areas of study. While Hispanics' level of achievement appears to have improved in certain skill areas over the past decade, it still falls below that of students as a whole. By the end of high school, Hispanic students are less well prepared academically to pursue advanced study in mathematics and the natural sciences as compared to other students.

Achievement Data, 1971-1984

NAEP data on the reading achievement trends of black, Hispanic, and white 9-, 13-, and 17-year-olds show a steady rise in the mean reading scores of Hispanics and blacks at all three age levels from 1975 to 1984. Rises have also occurred in the mean reading scores of white students at all three ages, but these rises are very slight in comparison to gains shown by black and Hispanic students. Despite evidence of gains, however, Hispanics in 1984 attained mean reading achievement scores below those of white students of comparable age: for example, Hispanic 17-year-olds were estimated to read only a little better than white students aged 13 years and far below white students aged 17 years.

It is important to note that the NAEP survey excludes students who are judged to be so limited in their English proficiency that they are





SOURCE: Valerie White Plisko and Joyce D. Stern (eds.), The Condition of Education: Statistical Report (1985 ed.), Washington, D.C.: National Center for Education Statistics, 1986, p. 57.

Figure 3 Comparative scores for 1980 sophomores on reading and science tests, by sex and race/ethnicity: 1980 and 1982.

incapable of being tested in the English language. The NAEP results cited above thus suggest that Hispanics' lower reading achievement may not be attributed solely to their severely limited English proficiency, although some of the Hispanics tested by NAEP may show some degree of limited English proficiency.

NAEP data on mathematics achievement trends of 9-, 13-, and 17-year-old white and minority students have been compiled for the period 1978-1982. With one exception, the data suggest gains in the mathematics performance of all those students (Plisko, 1985). However, these gains were found to be statistically significant only for 13-year-olds: the gains in performance among Hispanic and black 13-year-old students were larger than for their white counterparts. Despite this evidence of gains at one age level, Hispanic students' performance fell far below that of white students overall in 1981-82.

The HSB survey of high school sophomores in 1980 and the subsequent follow-up survey of these students in 1982 assessed students' reading and science achievement at both points in time, excluding students who were not enrolled in high school in 1982, two years after the initial assessment (Figure 3). The data indicate that Hispanic sophomores earned lower reading and science test scores than their white and Asian/Pacific Islander counterparts both in 1980 and in 1982. Data for black and American Indian/Native American students show a similar pattern. Further examination of the data indicates that the increased reading and science achievement test scores of Hispanic, black, and American Indian/Native American students during this period were smaller than those attained by white and Asian American/Pacific Islander students. This evidence needs to be examined for statistical significance; it suggests the possibility that Hispanics were falling further behind in reading and science achievement as students approached the completion of high school--despite the exclusion of students who dropped out of school between 1980 and 1982.

Academic Coursework

The HSB Survey also provides data on the average number of Carnegie units earned by students while in high school. Table 4 shows this information for various racial/ethnic groups of students (the same as reported earlier for reading and science achievement test scores) for a number of academic areas: English, foreign language, mathematics, natural science, social science, arts, business, trade and industry, and "other." Overall, Hispanics showed a slightly lower number of total Carnegie study units than white students and about one less Carnegie unit than Asian/Pacific Islander students. The largest differences between Hispanic students and white and Asian/Pacific Islander students in amount of study occurred in pursuit of mathematics and natural science study: in both of these areas, Hispanic students studied almost one-half year less than white students and nearly a year less than Asian/Pacific Islander students.

The evidence also indicates that Hispanics did not earn as high academic grades as white and Asian/Pacific Islander students in mathematics and natural science coursework. A little over 11 percent of

TABLE 4: Average Number of Carnegie Units Earned by High School Sophomores Who Graduated by Fall 1982, by Student Race/Ethnicity*

Race/Ethnic Group	Total	English	Foreign Language	Math	Nat Sci	Soc Sci	Arts	Business	Trade & Industry	Other**
All students	21.0	3.7	1.0	2.5	1.9	2.6	1.4	1.7	0.9	5.4
White, non-Hispanic	21.2	3.7	1.1	2.6	2.0	2.6	1.4	1.8	.8	5.2
Black, non-Hispanic	20.3	3.6	.7	2.4	1.6	2.5	1.2	1.7	.8	5.8
Hispanic	20.7	3.6	.8	2.2	1.5	2.5	1.2	1.6	1.1	6.1
Asian/Pacific Islander	21.7	3.6	1.9	3.1	2.4	2.5	1.2	1.1	.7	5.2
American Indian/ Alaskan Native	20.6	3.5	.4	2.0	1.6	2.7	1.6	1.5	1.6	5.6

NOTE: Each Carnegie Unit represents one year of complete study in an academic area.
*Data are based on student transcripts for the last four years of high school.
**Includes courses in architecture, computer and information sciences, health, home economics, industrial arts, personal and social development, philosophy, physical education, psychology, public affairs, and religion.
SOURCE: V. W. Plisko and J. D. Stern (eds.), The Condition of Education: Statisical Report (1985 ed.), Washington, D.C.: National Center for Education Statistics, p. 48.

Hispanics earned an "A" average in mathematics study in high school as compared to about 18 percent of white students and about 28 percent of Asian/Pacific Islander students. Hispanics were much more likely to earn barely passing or failing grades in mathematics: over 35 percent of Hispanic high school students averaged "D" or "F" grades in mathematics as compared to about 22 percent of white students and 20 percent of Asian students. Hispanic students (more than 34 percent) also were more likely than white or Asian/Pacific Islander students (18 and 16 percent, respectively) to earn "D" or "F" grades in natural science study (Plisko and Stern, 1986:50).

The data cited imply that Hispanic students completing high school are likely to be underprepared in mathematics and science study areas and that efforts to improve their access to graduate training in science and engineering areas in the long run will benefit from improving their educational progress in these areas prior to the completion of high school and as early as possible.

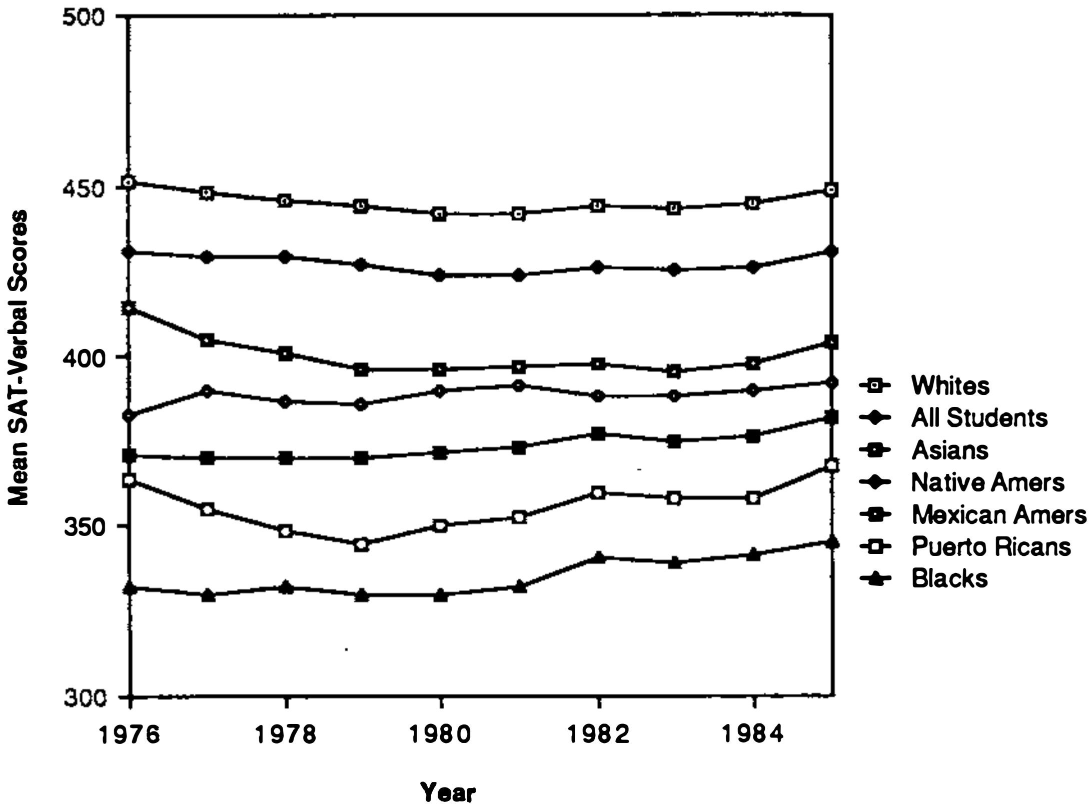
College Admissions Profile, College Achievement, and Degree Areas

Not all students completing high school aspire to attend selective 4-year colleges; some apply to attend 4-year colleges with open admissions, some apply to attend 2-year colleges, and still others decide not to go on to college. This section of the report discusses the academic credentials of Hispanic students who do aspire to attend selective 4-year colleges by virtue of their taking college admissions tests. Data presented compare the college admissions test scores and academic records of Hispanic students with those of students from other backgrounds. Attention is also given to the degree aspirations of Hispanic students and to their plans for college study in science- and engineering-related areas at the point at which they first apply to college. Special attention is given to Hispanic high school students' performance on advanced achievement tests in mathematics and science areas. Additional topics discussed include (1) the prediction of Hispanic students' college grades from their high school grades and admissions test scores and (2) Hispanic male and female students' rate of attainment of degrees related to science and engineering careers.

Scholastic Aptitude Test Admissions Scores of Mexican Americans and Puerto Ricans

Two college admissions tests in national use, the American College Testing (ACT) program and the SAT of the College Entrance Examination Board, are intended to measure students' developed academic ability relevant to pursuing coursework in college. Data from the Admissions Testing Program (ATP) of the College Board are discussed here because more detailed information on Hispanic examinees' performance was readily available for these tests than for the ACT.

Figures 4 and 5 plot the mean SAT-Verbal and SAT-Math scores of various ethnic groups over the period 1976-1985. The mean scores of

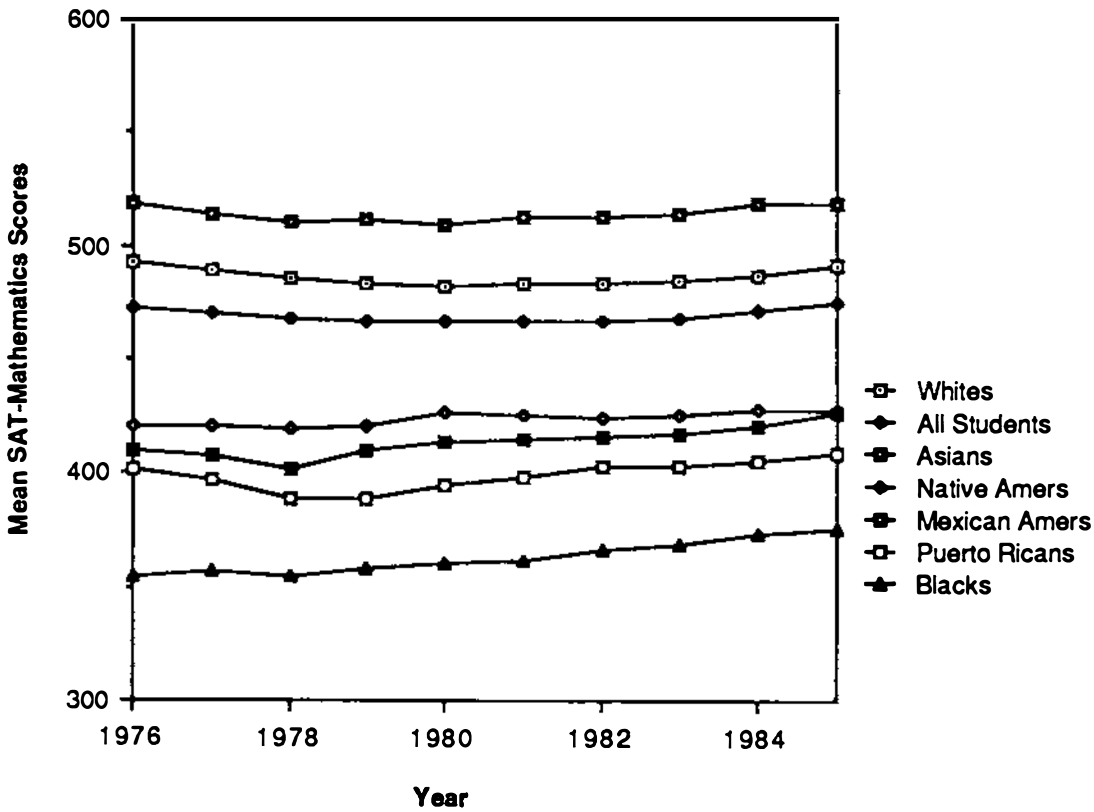


NOTE: The plot of trend data in Scholastic Aptitude Test scores excludes "Others" in order to increase legibility of the graphs.
SOURCES: American Council on Education, Minorities in Higher Education: Fourth Annual Status Report, Washington, D.C.: ACE, 1985; and Chronicle of Higher Education, October 2, 1985, pp. 33, 37.

Figure 4 Trends in SAT-Verbal scores, by ethnic groups: 1976-1985.

Mexican American and Puerto Rican students tended to fall 50-75 points below the mean for all test-takers each year during that period. This difference amounts to about one-half to three-quarters of a standard deviation. In 1985, Mexican American examinees earned slightly higher SAT-Verbal (382) and SAT-Math (426) scores than Puerto Rican examinees (verbal, 368; math, 409), and the mean scores for both of these groups exceeded those earned by blacks (verbal, 346; math, 376). In 1985 American Indian examinees earned higher mean SAT-Verbal (392) and SAT-Math (428) scores than Mexican Americans and Puerto Ricans and so did Asians (verbal, 404; math, 518), who earned the highest mean SAT-Math scores of all the groups considered.

It is interesting to note the degree of stability shown in the relative rankings of groups on SAT-Verbal and SAT-Mathematics scores over the 10-year period. It is also interesting to note that the data



NOTE: The plot of trend data in Scholastic Aptitude Test scores excludes "Others" in order to increase legibility of the graphs.
SOURCES: American Council on Education, Minorities in Higher Education: Fourth Annual Status Report, Washington, D.C.: ACE, 1985; and Chronicle of Higher Education, October 2, 1985, pp. 33, 37.

Figure 5 Trends in SAT-Math scores, by ethnic groups: 1976-1985.

given in Figures 4 and 5 indicate a general rise in SAT-Verbal and SAT-Math scores in recent years for all groups of students following a period of score decline after 1976. In the context of the topic of this paper, it is important to note that the mathematics scores of Mexican American and Puerto Rican students are both below the national average for SAT test-takers as a whole and below the averages shown by Asian and white students.

Prediction of Hispanic Students' College Grades from Admissions Test Scores and High School Grades

While controversies linger about the population validity of SAT scores for Hispanic and other minority students, taken at face value these scores indicate that Hispanics as a group will be judged as less

TABLE 5: Median Correlations Between College Predictor Measures and College Grades*

	Group[a]		
	Breland Review		This Review[b]
Predictor	White	Chicano	Hispanics[c]
High school record (HSR)	.37(32)	.36(8)	.30(14)
Verbal test scores	.37(45)	.25(9)	.25(16)
Quantitative test scores	.33(45)	.17(9)	.23(16)
HSR and admissions test scores	.48(61)	.38(25)	.38(31)

[a]Number of independent analyses over studies is indicated in parentheses.
[b]Includes the same analyses found in Breland (1979), as well as results cited in new studies reviewed here. The review appears in Duran (1983).
[c]Hispanics in the 50 states and District of Columbia only.
SOURCE: R. P. Duran, Hispanics' Education and Background: Predictors of College Achievement, New York: College Entrance Examination Board, 1983.

prepared for college academic work than students overall. It should also be noted that the pattern of depressed SAT scores among Hispanic students is consistent with information that they are less likely to have been enrolled in high school college-preparatory programs; have averaged fewer years of English, mathematics, and science coursework in high school; and have earned average lower grades in high school (Duran, 1986; Ramist and Arbeiter, 1984).

Research studies indicate that high school grade-point average (GPA) or rank in high school class and college admissions test scores are statistically significant predictors of the early college GPA of students regardless of their background. However, some evidence suggests that the accuracy of prediction may be lower for Hispanic students than for nonminority, white students. Table 5 displays median correlations between early college grades and various predictor measures computed on the basis of correlations reported in a number of published research studies involving Hispanic and white college students. The table reports results from two sources--a review by Breland (1979), which also examined prediction of black students' college grades, and a review by Duran (1983) focusing on Hispanic and white students and supplementing the studies of Hispanic students examined by Breland. The predictor measures included high school grades or rank in high school class [labeled "High school record (HSR)" in the table], verbal admissions test score, quantitative admissions test score, and a composite of all of these measures.

As would be expected, the early college grades of Hispanic and white students were predicted best by a combined measure derived from students' high school GPA (or rank in class) and their verbal and quantitative test scores. However, the median correlation of .48 obtained for white students across studies was notably higher than the median correlation of .38 for Hispanics. The difference between the square of these correlation coefficients indicates that about 9 percent more variability could be predicted in white students' college grades than could be predicted in those of Hispanics.

As the tabled correlations show, each individual predictor measure was less associated with college grades than a composite measure developed from a combination of all of them. However, GPA in high school (or rank in high school class) associated more with college GPA than did verbal and quantitative admissions scores for both white and Hispanic students. Interestingly, both this high school achievement information and verbal and mathematics college admissions scores bore a stronger relationship to college grades for white students than for Hispanic students across the studies examined. This disparity was larger for verbal test scores than for quantitative test scores. A follow-up review of the studies in question indicates that the lower correlation occurring for Hispanics could not be explained by restriction in the range of values taken by predictor measures; Hispanic samples tended to show larger variance in predictor measures than was the case for white students sampled from the same institutions.

Another study comparing prediction of Hispanic, white, and black students' early college grades from high school grades and college admissions test scores was conducted by the ACT (Maxey and Sawyer, 1981). Involving only the ACT college admissions test, that study found that white students' college grades could be predicted a little more accurately from high school grades and ACT admissions test scores than could those for black or Hispanic students.

These summaries of predictive validity research suggest that the admissions test scores and high school grades of minority students merit cautious interpretation in college-admissions decision making. In particular, heterogeneity in the background and personal characteristics of Hispanic students may affect interpretation of this information as indicators of potential for college success (Duran, 1983). For example, one's having greater familiarity with Spanish and limited proficiency in English may lead to inaccurate assessment of his/her ability to do college work (Alderman, 1981; Duran, 1985).

Graduate Study and Degree Aspirations of Mexican American and Puerto Rican College Board Examinees

Attention is now turned to data on the higher education aspira-

TABLE 6: Degree Goals Among Admissions Testing Program Examinees in 1984 (in percent)

	Mexican Americans			Puerto Ricans			All Examinees		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Two-year training program	4.2	3.2	3.7	5.3	4.7	4.9	2.9	2.8	2.9
Associate of Arts degree	1.5	2.3	1.9	2.6	4.6	3.7	1.4	2.8	2.2
Bachelor's degree	29.3	29.3	29.3	32.4	30.0	31.1	32.0	33.4	32.7
Master's degree	28.4	25.9	27.1	24.1	22.3	23.1	27.7	25.2	26.4
M.D., Ph.D., other professional degree	20.6	20.2	20.4	17.6	18.2	18.0	19.3	17.7	18.4
Undecided	16.1	19.1	17.7	18.0	20.2	19.2	16.7	18.1	17.5
Two-year program or degree	5.7	5.5	5.6	7.9	9.3	8.7	4.2	5.7	5.0
Graduate study	48.9	46.1	47.4	41.7	40.6	41.1	47.0	42.9	44.8
TOTAL NUMBER	8,440	9,442	17,882	3,727	4,557	8,826	423,931	472,738	896,669

SOURCE: S. Arbeiter, Profiles, College-Bound Seniors, 1984, New York: College Entrance Examination Board, 1985.

tions of Mexican American and Puerto Rican examinees taking admissions and placement tests administered by the College Board as part of the ATP. The fact that Mexican American and Puerto Rican students earn lower college admissions test scores and high school grades than College Board examinees as a whole does not mean that they necessarily have lower graduate study and college degree aspirations than other examinees as a whole. Table 6 reveals that 47.4 percent of Mexican Americans, 41.1 percent of Puerto Ricans, and 44.8 percent of all examinees planned to attend graduate school. The data also indicate no dramatic differences between Mexican American and Puerto Rican male and female students' plans for graduate study, though a slightly larger percentage of males planned graduate study than females. Among students as a whole, slightly more males (47 percent) planned graduate study than females (42.9 percent) than was the case for the two Hispanic groups.

It is quite interesting to note that Mexican American students aspired to obtain M.A. and Ph.D. degrees at rates exceeding those of examinees as a whole. The corresponding rates for Puerto Ricans were slightly below those of examinees as a whole. The fact that Mexican American and Puerto Rican students showed similar and sometimes higher graduate study and degree goals than SAT test-takers as a whole is somewhat surprising. It suggests the exceptional motivation of these students to pursue a graduate education in spite of evidence that they are likely to earn lower SAT scores in comparison to College Board examinees as a whole. Intervention programs aiding Hispanics' development of career goals in science and engineering should capitalize on these aspirations for graduate education.

College Board Mathematics and Science Achievement Test Scores of Mexican Americans and Puerto Ricans

In the context of this paper, findings cited above need to be tempered by examining further data on the College Board achievement test scores earned by these students in areas related to mathematics and science achievement. Table 7 shows the mean test scores earned by various ethnic groups taking College Board achievement tests as part of ATP during 1984 (Arbeiter, 1985). The College Board's achievement test in physics is not considered because data on Hispanics' performance on this test was not available. In addition, Table 7 also inindicates the number of persons from each ethnic group taking an achievement test and the mean SAT-Verbal and SAT-Math scores of these groups.

The incidence of achievement test-taking in mathematics and science appears lower for Hispanic students than for students as a whole. Students who take College Board achievement tests need not take the SAT in the same year; nonetheless, a rough estimate of the incidence of achievement test-taking can be formed by dividing the number of students taking a given achievement test in a year by the total number of SAT-takers in the same year. If this is done, then roughly 15 percent of all SAT-takers in 1984 took the Mathematics Level 1 test, and about 4 percent took each of the remaining tests (Mathematics Level 2,

TABLE 7: 1984 College Board Mean Achievement Test Scores in Mathematics, Biology, and Chemistry, by Ethnic Groups

	Mexican Americans	Puerto Ricans	All Students	Whites	Asians	Blacks	American Indians
Mathematics Level 1	486	510	542	546	566	481	507
(N)	(2,438)	(630)	(146,693)	(102,855)	(10,341)	(5,229)	(397)
Mean SAT-V	441	446	503	514	455	445	470
Mean SAT-M	494	522	560	567	578	482	522
Mathematics Level 2	603	621	659	661	674	577	614
(N)	(390)	(101)	(41,702)	(29,113)	(5,057)	(954)	(101)
Mean SAT-V	498	514	553	568	497	489	524
Mean SAT-M	594	609	650	655	655	563	609
Biology	491	517	550	553	556	481	521
(N)	(279)	(200)	(43,166)	(29,866)	(3,068)	(1,227)	(97)
Mean SAT-V	473	484	531	537	504	467	483
Mean SAT-M	517	524	579	583	609	490	536
Chemistry	524	543	573	575	586	505	524
(N)	(233)	(142)	(36,419)	(25,692)	(3,829)	(1,054)	(74)
Mean SAT-V	498	499	541	552	500	473	502
Mean SAT-M	590	588	629	632	650	535	592

SOURCE: S. Arbeiter, Profiles, College-Bound Seniors, 1984, New York: College Entrance Examination Board, 1985.

Biology, and Chemistry). The incidence of achievement test-taking among Hispanics appears noticeably lower with one exception: only about 8 percent of Puerto Rican examinees took the basic mathematics test, and the incidence of Mexican American and Puerto Rican students taking the remaining achievement tests was between 1 and 2 percent--except for Mexican Americans who took the Mathematics, Level 1 test (about 15 percent).

The foregoing information is important to note because achievement test-takers are a highly select group of examinees; these are likely to be students with the strongest academic credentials, since (1) only the more competitive 4-year colleges are likely to request submission of achievement test scores and (2) many students are likely to elect to take achievement tests in areas in which they feel highly competent. Inspection of the Table 7 data is consistent with such a view. For example, the mean SAT-Verbal and SAT-Math scores earned by Mexican American and Puerto Rican students and by students as a whole were higher than the means for these groups in the general SAT-taking population.

However, the data indicate that mean achievement test scores of Mexican Americans and Puerto Ricans were lower than those of students as a whole and, in particular, in comparison to mean scores earned by Asians and whites. Thus, the self-selection of examinees to take mathematics and science achievement tests did not dramatically reduce the test score advantages shown by students as a whole--and Asians and white students, in particular--over Mexican American and Puerto Rican students. It was clear, however, that these latter students earned much higher SAT-Verbal and SAT-Math scores than students from their overall group.

Intended Undergraduate Majors of Mexican American and Puerto Rican College Board Examinees

College Board data indicate that Mexican American and Puerto Rican students do not differ from students as a whole in their plans to major in mathematics and science while in college (see Tables 8-10). Between 19 and 20 percent of students, regardless of grouping, planned majors in the biological sciences or a related area. Most of this interest lay in the health and medical fields (between 15 and 17 percent of all students), where rates of planned study were about twice as high among females as among males across all three groupings of examinees. Also, Puerto Rican examinees were more likely than both Mexican Americans and examinees as a whole to plan study in health and medical areas. This pattern was most evident for Puerto Rican females; over 22 percent of those examined in 1984 planned academic study in the health and medical area as compared to 19.1 percent of Mexican American examinees and 20.3 percent of examinees as a whole.

Rates of planned study in biological sciences proper were slightly lower among Hispanic examinees than among examinees as a whole; but apart from this difference, there was equal preference for electing study in these areas among males and females within Hispanic groups and within the "All Students" group. Across all groups, students planning concentrated study in the biological sciences earned the high-

TABLE 8: Mexican Americans' Intended Areas of Study, First Choice, 1983-84

				SAT-V Percentile			SAT-M Percentile		
Area of Study	Male	Female	Total	25th	50th	75th	25th	50th	75th
Arts and Humanities	10.1	9.6	9.8	299	366	448	323	393	465
Architec/envir design	4.0	0.9	2.4	289	347	410	342	408	491
Art	2.5	3.7	3.2	293	355	423	306	368	447
English/literature	0.8	1.2	1.0	376	458	524	347	431	507
Foreign languages	0.4	1.6	1.0	293	372	465	325	398	460
Music	1.3	0.8	1.0	306	378	460	322	395	460
Philosophy/religion	0.4	0.2	0.3	334	370	431	333	388	458
Theater arts	0.6	1.2	0.9	300	371	457	318	374	461
Biol Sci/Related Areas	15.9	22.2	19.2	310	376	448	345	413	491
Agriculture	1.2	0.3	0.7	270	329	409	314	374	456
Biological sciences	2.6	2.6	2.6	336	403	480	362	429	512
Forestry/conservation	0.3	0.1	0.2	313	390	456	328	373	461
Health/medical science	11.8	19.1	15.7	308	374	444	343	412	489
Business, Commerce, & Communications	16.4	25.4	21.2	293	354	420	324	389	462
Business and commerce	14.1	22.0	18.3	288	349	412	324	389	461
Communications	2.3	3.4	2.9	328	395	464	324	390	463
Phys Sci/Related Areas	38.6	15.4	26.3	310	378	450	379	457	539
Comp sci/sys analysis	12.9	9.5	11.1	291	356	426	350	425	501
Engineering	23.4	4.6	13.4	325	394	462	405	483	559
Mathematics	1.0	0.7	0.8	326	390	463	428	518	581
Physical sciences	1.4	0.7	1.0	333	410	496	394	471	569
Soc Sci/Related Areas	13.5	22.2	18.1	303	371	447	323	391	467
Education	2.4	7.1	4.9	278	332	402	309	366	433
Ethnic studies	-	-	-						
Geography	-	-	-						
History and cultures	0.4	0.2	0.3	358	440	497	332	395	483
Home economics	0.1	0.5	0.3	243	310	390	285	318	415
Library science	-	-	-						
Military science	1.0	0.1	0.5	343	413	486	378	434	518
Psychology	1.7	5.2	3.6	312	378	451	331	395	473
Social sciences	7.9	9.1	8.5	316	385	463	331	401	480
Miscellaneous	5.5	5.1	5.3	283	341	412	323	385	455
Other	1.0	0.9	1.0	272	323	380	311	371	431
Trade and vocational	0.8	0.8	0.8	243	293	347	293	343	400
Undecided	3.7	3.4	3.5	298	357	432	339	399	470
Number Responding*	8,297	9,324	17,621						

*The number who responded to SDQ Question 61.
SOURCE: S. Arbeiter, Profiles, College-Bound Seniors, 1984, New York: College Entrance Examination Board, 1985.

TABLE 9: Puerto Ricans' Intended Areas of Study, First Choice, 1983-84

				SAT-V Percentile			SAT-M Percentile		
Area of Study	Male	Female	Total	25th	50th	75th	25th	50th	75th
Arts and Humanities	10.2	9.2	9.7	286	362	441	308	368	451
Architec/envir design	2.5	0.6	1.4	268	314	414	323	400	489
Art	3.3	3.7	3.5	282	352	415	302	357	434
English/literature	0.6	0.8	0.7	385	459	568	358	448	505
Foreign languages	0.5	1.5	1.1	295	363	445	302	363	443
Music	1.5	0.9	1.2	283	369	443	308	385	450
Philosophy/religion	0.6	0.1	0.3	311	410	463	338	408	453
Theater arts	1.2	1.5	1.4	278	361	435	292	335	415
Biol Sci/Related Areas	14.3	25.3	20.3	285	360	445	312	386	481
Agriculture	0.5	0.3	0.4	293	340	458	311	375	490
Biological sciences	2.6	2.5	2.5	351	415	499	364	441	524
Forestry/conservation	0.3	0.1	0.2	298	343	393	291	390	459
Health/medical science	10.9	22.4	17.2	281	352	432	307	376	472
Business, Commerce, & Communications	19.1	26.0	22.9	277	343	423	308	368	448
Business and commerce	16.1	23.0	19.9	272	336	414	306	368	449
Communications	3.0	3.0	3.0	316	390	463	317	375	441
Phys Sci/Related Areas	35.0	15.0	24.0	285	362	446	339	424	526
Comp sci/sys analysis	16.1	11.5	13.6	269	333	416	314	384	474
Engineering	17.0	2.3	8.9	319	396	483	388	471	564
Mathematics	0.8	0.5	0.6	328	378	440	414	505	583
Physical sciences	1.2	0.6	0.9	372	453	520	415	498	600
Soc Sci/Related Areas	14.8	18.9	17.1	290	364	441	310	374	451
Education	2.6	5.0	3.9	256	327	403	287	346	416
Ethnic studies	-	-	-						
Geography	-	-	-						
History and cultures	0.3	0.2	0.3	360	535	605	355	455	532
Home economics	0.1	0.6	0.4	235	282	355	265	303	360
Library science	-	-	-						
Military science	1.9	0.2	1.0	340	395	463	320	385	493
Psychology	1.7	4.9	3.4	302	370	441	315	376	448
Social sciences	8.1	8.0	8.1	307	380	459	320	387	466
Miscellaneous	6.6	5.7	6.1	257	326	426	295	357	448
Other	1.4	1.0	1.2	240	293	420	290	348	430
Trade and vocational	1.7	1.6	1.6	238	298	360	279	320	373
Undecided	3.4	3.1	3.2	283	359	455	309	384	486
Number Responding*	3,680	4,474	8,134						

*The number who responded to SDQ Question 61.
SOURCE: S. Arbeiter, Profiles, College-Bound Seniors, 1984, New York: College Entrance Examination Board, 1985.

TABLE 10: Intended Areas of Study, First Choice, of All Students, 1983-84

Area of Study	Male	Female	Total	SAT-V Percentile 25th	SAT-V Percentile 50th	SAT-V Percentile 75th	SAT-M Percentile 25th	SAT-M Percentile 50th	SAT-M Percentile 75th
Arts and Humanities	8.4	11.1	9.8	358	435	517	371	451	533
Architec/envir design	2.6	0.7	1.6	343	410	483	406	484	564
Art	2.1	4.5	3.4	335	403	475	346	414	488
English/literature	0.9	1.7	1.3	442	524	605	411	495	575
Foreign languages	0.3	1.3	0.8	402	484	567	409	484	566
Music	1.5	1.3	1.4	361	437	513	370	451	536
Philosophy/religion	0.5	0.2	0.3	387	461	547	390	481	568
Theater arts	0.6	1.4	1.0	361	437	516	354	432	516
Biol Sci/Related Areas	14.4	24.2	19.6	357	430	507	387	470	559
Agriculture	1.5	0.6	1.0	331	396	462	356	426	499
Biological sciences	3.0	3.1	3.1	400	476	552	431	517	597
Forestry/conservation	0.7	0.1	0.4	353	414	482	371	444	518
Health/medical science	9.2	20.3	15.1	352	424	501	382	465	555
Business, Commerce, & Communications	20.9	24.6	22.9	339	406	477	367	445	526
Business and commerce	17.6	20.5	19.1	334	400	467	367	445	527
Communications	3.2	4.1	3.7	374	446	517	368	443	523
Phys Sci/Related Areas	37.1	13.4	24.6	360	439	517	436	528	615
Comp sci/sys analysis	12.1	7.7	9.7	334	407	483	392	481	572
Engineering	21.4	3.6	12.0	377	455	529	462	550	631
Mathematics	1.2	1.1	1.1	379	456	530	506	584	660
Physical sciences	2.5	1.0	1.7	419	502	583	481	571	656
Soc Sci/Related Areas	13.0	20.7	17.1	359	432	510	371	451	533
Education	2.1	6.8	4.6	329	395	463	349	417	493
Ethnic studies	-	-	-	285	368	455	305	360	430
Geography	-	-	-	353	415	479	397	466	539
History and cultures	0.6	0.3	0.5	407	493	584	393	474	561
Home economics	0.1	0.8	0.5	317	380	451	330	402	474
Library science	-	-	-	375	470	552	361	430	525
Military science	1.4	0.1	0.7	368	437	508	394	473	548
Psychology	1.4	5.3	3.5	366	433	503	373	449	527
Social sciences	7.3	7.4	7.3	381	459	538	391	473	560
Miscellaneous	6.3	6.0	6.1	343	416	498	373	456	545
Other	1.0	0.8	0.9	319	389	461	350	421	503
Trade and vocational	0.9	0.7	0.8	282	341	402	314	371	444
Undecided	4.4	4.5	4.4	363	436	514	397	479	565
Number Responding*	413,781	465 123	878 904						

*The number who responded to SDQ Question 61.

SOURCE: S. Arbeiter, Profiles, College-Bound Seniors, 1984, New York: College Entrance Examination Board, 1985.

est SAT-Verbal and SAT-Math scores among students planning study in all academic areas listed under the larger umbrella category "Biological Sciences and Related Areas."

The academic areas encompassed by the category "Physical Sciences and Related Areas" included computer science/systems analysis, engineering, mathematics, and physical sciences. Mexican American and Puerto Rican students tended to show equal, and sometimes higher, propensity to plan major study in this broad category as compared to students as a whole--in spite of evidence that the Hispanic students earned lower SAT-Verbal and SAT-Math scores within every area of academic study listed under this umbrella category. More than 26 percent of Mexican Americans and 24 percent of Puerto Ricans planned studies in these areas as compared to about 25 percent of students as a whole. However, males, both within Hispanic subgroups and within examinees as a whole, were two to three times more likely than females to plan studies in the "Physical Sciences and Related Areas."

Some interesting similarities and differences emerged in Mexican American, Puerto Rican, and all students' preferences for individual major areas identified under the rubric "Physical Sciences and Related Areas." Mexican Americans showed slightly higher rates than students as a whole in plans to study computer science/systems analysis (11.1 percent versus 9.7 percent) and engineering (13.4 percent versus 12.0 percent). In addition, Puerto Ricans showed a higher rate of planned study of computer science/systems analysis (13.6 percent) than did students as a whole. The propensity of Mexican American, Puerto Rican, and students as a whole to plan study in mathematics and in the physical sciences proper were all under 2 percent. These patterns suggest that it may be easier to attract Hispanic students to academic study in computer science and engineering but much more difficult, and perhaps worth more effort, to attract them to pursue study in mathematics and the physical sciences.

As with plans to study in the biological sciences and related areas, students' gender was strongly related to their plans for study in the physical sciences areas, both for Hispanic groups and for students as a whole. In particular, five to seven times as many men as women planned to study engineering, and about three times as many males as females planned to study either mathematics or the physical sciences. White males were more likely to plan the study of mathematics than females; the rates appeared only a little higher across all groups. Interestingly, while males' plans to study computer science exceeded those of females by almost 3-1 for examinees as a whole, these rates were well under a 2-1 ratio for the two Hispanic subgroups.

The Association of Gender with Bachelor's Degree Area

As the foregoing discussion indicates, there appear to be important associations between gender and undergraduate candidates' plans to study in science and engineering. Chipman and Thomas (1984) extended this concern to degree recipients, examining the associations between receipt of B.A., M.A., and Ph.D. degrees in 1980-81 and degree recipients' academic area, gender, and ethnic group. The entries in

Table 11 give the percentages of men and women from each ethnic group receiving B.A. degrees in given academic areas: biological sciences, computer and information sciences, engineering, mathematics, and physical sciences. These main table entries can be interpreted in a straightforward manner. For example, under Hispanics, the entries 1.1 for women and 1.5 for men in biological sciences mean that in the biological sciences, 1.1 percent of all B.A. degrees were earned by Hispanic women while 1.5 percent were earned by Hispanic men.

The parenthetical entries in Table 11 are an index of the propensity of men or women from a given group to receive a degree in an area, given their representation in the total U.S. population.[3] For example, under Hispanics, the entry (0.34) for Hispanic women means that a little over a third of the degrees expected of Hispanic women in biological sciences are actually received, assuming that Hispanic women should be earning degrees in this area at the same rate they are represented in the U.S. population.

Inspection of Table 11 indicates that Hispanic men were much more likely to earn B.A. degrees than Hispanic women in each of the five areas related to natural science and engineering training. In contrast, Hispanic women were better represented among bachelor's degree recipients in psychology than men, although the reverse pattern held in other social sciences. The data indicate that Hispanic men and women are severely underrepresented as degree recipients in these areas, given their density in the U.S. population. It is also interesting to note that this same pattern holds for other B.A. academic areas outside science and engineering, though the rates of underrepresentation are not quite as severe.

The patterns of bachelor's degrees received by black men and women also reflect underrepresentation, although these patterns show some differences from those encountered by Hispanics. Rates of underrepresentation for American Indians cannot be discussed because they were not computed. Asians show considerable overrepresentation in the number of B.A. degrees received in science and engineering, while they show underrepresentation in nonscience areas such as letters, fine arts, and education.

The data of Table 11 do not provide information about the preferences of successful men and women baccalaureate recipients from different ethnic groups to attain degrees in one area over another. To examine this question, Chipman and Thomas devised a propensity index that used the ratio of two statistics: the numerator is the percentage of B.A. degrees received in an academic area by persons of a given gender and ethnicity relative to the total number of degrees awarded in that academic area; the denominator is the total number of B.A. degrees awarded across all fields of study. As the index value departs

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[3]Chipman and Thomas point out that the propensity index given in parentheses is approximate, since it does not take into account variation in population size according to different age intervals for an ethnic group and gender.

TABLE 11: Percent of B.A. Degrees Earned, by Ethnic Subgroups, 1980-81

Major Field/Sex	All Students	Asians	American Indians	Blacks	Hispanics
Biological Sci					
Women	44.2(0.86)	1.5(1.86)	0.26	3.0(0.48)	1.1(0.34)
Men	55.8(1.15)	1.9(2.71)	0.26	2.2(0.42)	1.5(0.47)
Comput/info sci					
Women	32.6(0.63)	1.7(2.3)	0.03	2.6(0.42)	0.7(0.22)
Men	67.4(1.39)	2.7(3.36)	0.11	2.6(0.50)	1.3(0.41)
Engineering					
Women	10.4(0.20)	0.5(0.63)	0.03	0.6(0.09)	0.2(0.06)
Men	89.6(1.84)	3.6(5.14)	0.23	2.7(0.52)	1.7(0.53)
Mathematics					
Women	43.1(0.84)	1.5(1.88)	0.07	2.8(0.45)	0.7(0.22)
Men	56.9(1.17)	2.0(2.86)	0.08	2.5(0.48)	1.0(0.31)
Physical sci					
Women	24.9(0.48)	0.8(1.00)	0.08	1.2(0.19)	0.5(0.16)
Men	75.1(1.54)	1.7(2.42)	0.19	2.5(0.48)	1.2(0.38)
Psychology					
Women	65.1(1.26)	1.3(1.63)	0.31	5.6(0.09)	2.0(0.62)
Men	34.9(0.31)	0.7(1.00)	0.17	2.5(0.48)	1.2(0.33)
Social sci					
Women	44.3(0.87)	0.8(1.00)	0.23	4.4(0.71)	1.3(0.41)
Men	55.7(1.15)	0.9(1.29)	0.24	3.7(0.71)	1.5(0.47)
Business/mgmt					
Women	36.8(0.72)	0.9(1.13)	0.10	3.4(0.55)	0.8(0.25)
Men	63.2(1.30)	1.1(1.57)	0.20	3.3(0.63)	1.2(0.33)
Education					
Women	75.0(1.46)	0.4(0.50)	0.40	6.3(1.02)	1.9(0.60)
Men	25.0(0.51)	0.3(0.43)	0.10	2.4(0.46)	0.7(0.22)
Fine/appl arts					
Women	63.7(1.24)	1.2(1.50)	0.30	2.5(0.40)	1.1(0.24)
Men	36.3(0.75)	0.8(1.14)	0.20	2.1(0.40)	0.8(0.25)
Letters					
Women	59.3(1.16)	0.7(0.38)	0.20	3.3(0.53)	1.0(0.31)
Men	40.2(0.83)	0.4(0.57)	0.10	1.6(0.31)	0.7(0.22)
TOTAL degrees					
Women	49.9(0.97)	0.9(1.13)	0.20	3.9(0.63)	1.2(0.39)
Men	50.1(1.03)	1.1(1.57)	0.18	2.6(0.50)	1.1(0.34)

NOTE: Numbers in parentheses indicate the representation ratio of the group in certain fields relative to their proportion in the total U.S. population.
SOURCE: S. F. Chipman and V. G. Thomas, The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields (unpublished manuscript), Washington, D.C.: National Research Council, 1984.

from 1.0, it indicates either lower preference for an area (values less than 1.0) or greater preference for an area (values greater than 1.0).

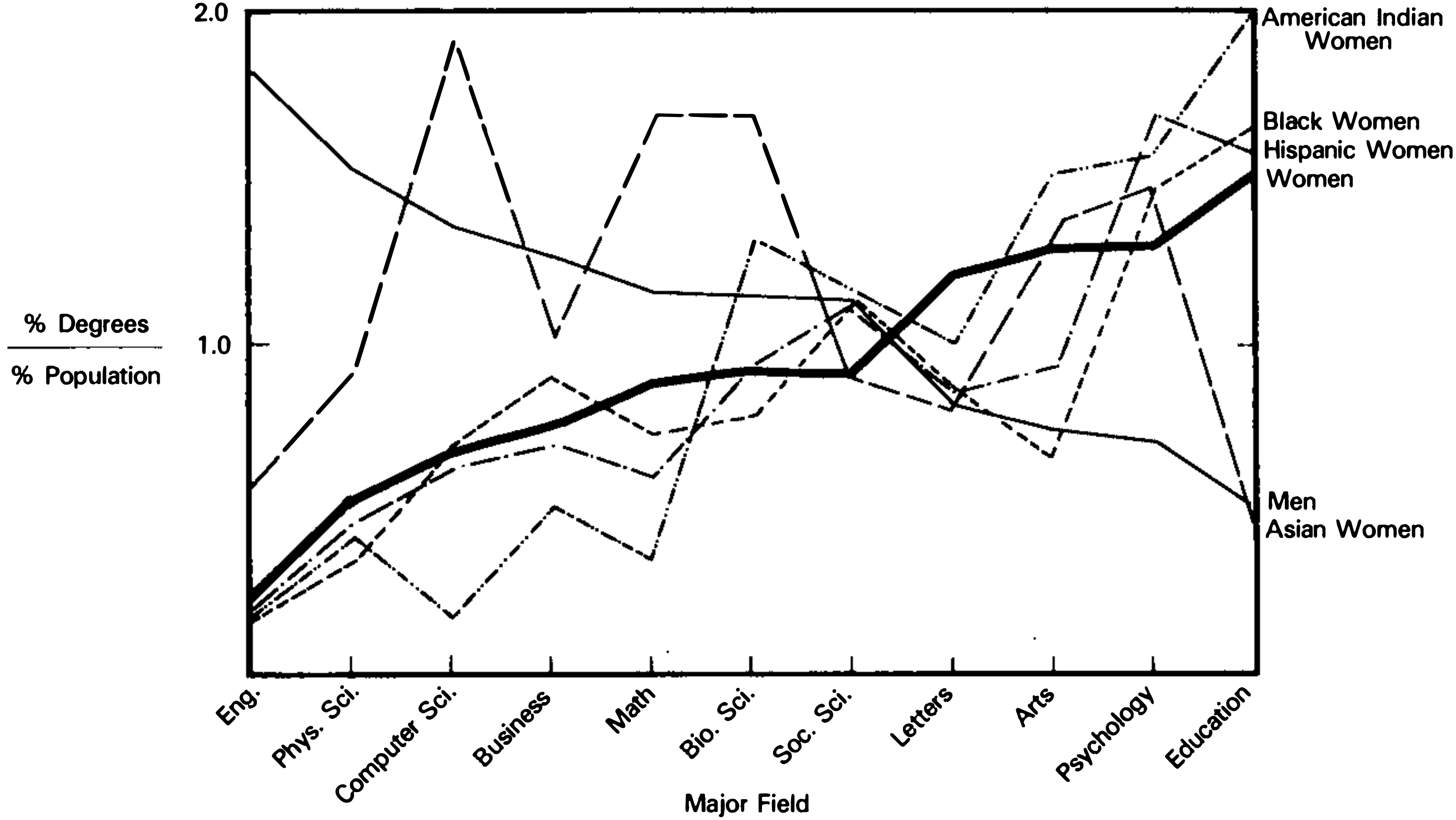
Figures 6-9 are taken from Chipman and Thomas; the figures graphically summarize differences in the propensity index across ethnic groups and gender for various majors. The majors listed for the abscissa axis are ordered according to preference among degree recipients; those to the left tend to be of lower preference for women and higher preference for men, while those that fall to the right tend to be of higher preference for women and lower preference for men. The least-preferred scientific and engineering degree areas for women, from least to most preferred, were engineering, physical sciences, computer/information science, mathematics, biological science, social science, and psychology.

The bold line for women plotted in Figure 6 gives the propensity for women as a whole to receive degrees in the various academic areas, going from areas least preferred to most preferred. Figure 7 shows a bold line plotted for men, showing the converse relationship. The plot of Figure 6 indicates that Hispanic women were less likely than other women as a whole to earn degrees in engineering, physical sciences, and computer science. In the biological sciences, social sciences, and psychology, Hispanic women earned B.A. degrees at the same rate as women as a whole. The plot of Hispanic men's propensity to earn B.A. degrees in different areas (see Figure 7) indicates that Hispanic men were less likely than men as a whole to earn B.A. degrees in science and technical fields--except, as with Hispanic women, in the biological sciences and psychology. While Hispanic men showed a lower propensity overall to earn B.A. degrees in science and technical areas in comparison to men as a whole, they showed a higher propensity to earn B.A. degrees in these areas than women as a whole.

The Chipman and Thomas analyses suggest that there are very strong gender-related differences in students' pursuit of degrees in science- and engineering-related areas and that analyses of degree rates based on ethnicity alone mask these associations. The fact that bachelor's degree rates in engineering and science areas show a relationship to both gender and ethnicity argues for the need to keep both factors in mind in analyzing factors related to students' development of academic skills and aspirations related to science and engineering careers.

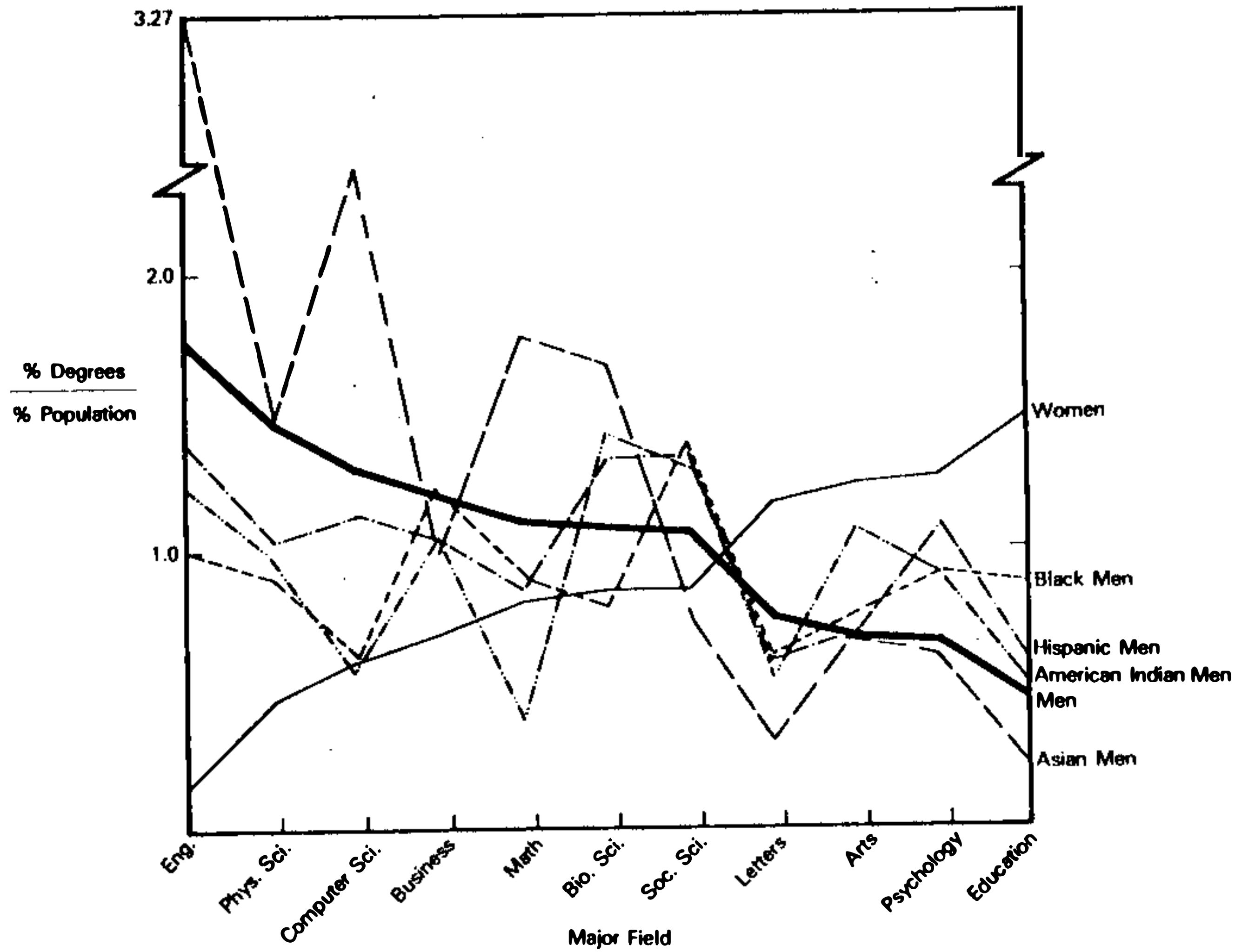
GRE Test Scores of Hispanic and Other Students

Tables 12-14 display the mean GRE verbal, quantitative, and analytical subscores of various ethnic groups of U.S. citizen examinees according to planned area of graduate study. Across all groups, students planning to major in the humanities showed the highest mean GRE verbal subscores. Interestingly, across all groups, students planning to major in the physical sciences tended to earn higher GRE verbal scores than those earned by students planning majors in the social sciences and in the biological sciences. One exception to this pattern occurred in the case of Asian examinees; their mean GRE verbal subscores were higher for students planning majors in the social sciences



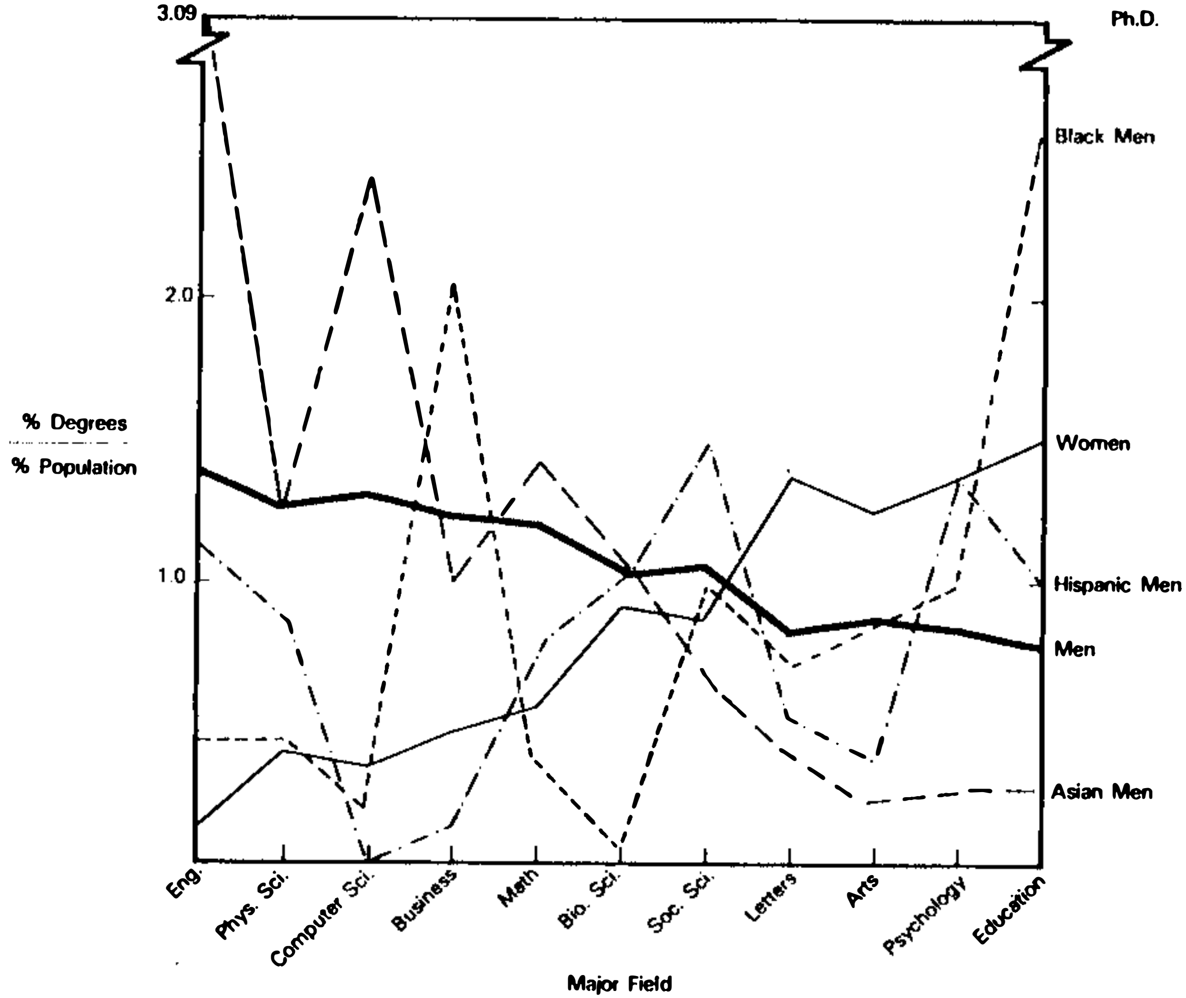
SOURCE: S. F. Chipman and V. G. Thomas, The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields (unpublished manuscript commissioned by the Committee on Research in Mathematics, Science, Technology and Education), Washington, D.C.:National Research Council, 1984.

Figure 6 Propensity to select major fields: Men, women, minority women at B.A. level.



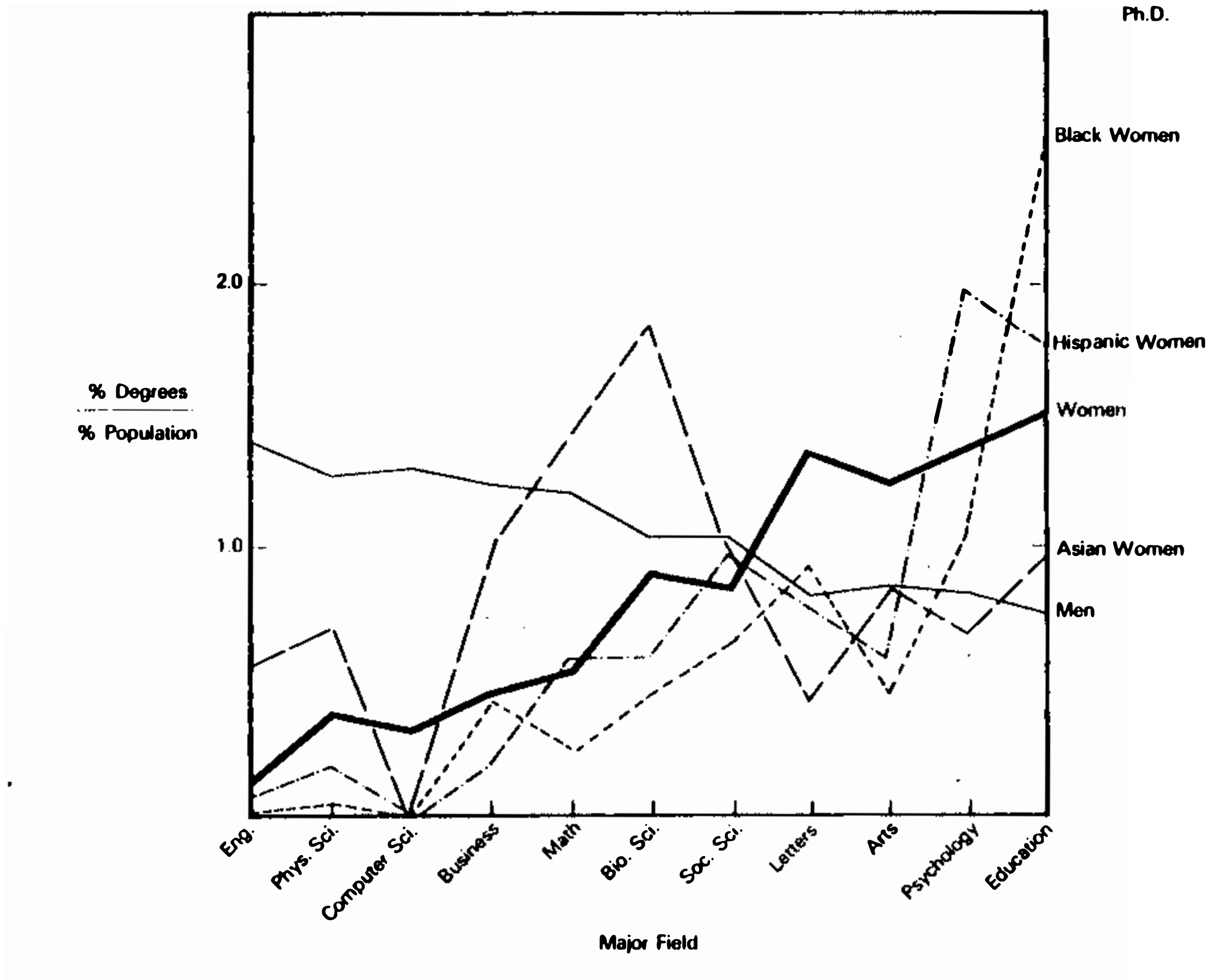
SOURCE: S. F. Chipman and V. G. Thomas, The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields (Unpublished manuscript commissioned by the Committee on Research in Mathematics, Science, Technology and Education), Washington, D.C.: National Research Council, 1984.

Figure 7 Propensity to select major fields: Men, women, minority men at B.A. level.



SOURCE: S. F. Chipman and V. G. Thomas, The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields (unpublished manuscript commissioned by the Committee on Research in Mathematics, Science, Technology and Education), Washington, D.C.: National Research Council, 1984.

Figure 8 Propensity to select major fields: Men, women, minority men at Ph.D. level.



SOURCE: S. F. Chipman and V. G. Thomas, The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields (unpublished manuscript commissioned by the Committee on Research in Mathematics, Science, Technology and Education), Washington, D.C.: National Research Council, 1984.

Figure 9 Propensity to select major fields: Men, women, minority women at Ph.D. level.

and the biological sciences than for Asian students planning graduate majors in the physical sciences and mathematics. Interestingly, the GRE verbal scores of psychology majors were similar to those of biological and physical science majors, regardless of ethnic group.

Regardless of planned graduate area of study, Mexican American, Puerto Rican, and other Hispanic examinees earned lower mean GRE verbal subscores than white examinees. Also among students planning graduate study in the humanities, social sciences, and biological sciences, Hispanic examinees also earned lower mean GRE verbal subscores than Asian examinees.

As would be expected, regardless of ethnic group, students planning graduate study in the physical sciences and mathematics earned the highest mean GRE quantitative subscores, followed by students who planned to study in the biological sciences. Surprisingly, students planning graduate study in the humanities earned higher or equivalent mean GRE quantitative scores, in general, as students planning graduate study in the social sciences. Behavioral science majors, however, earned higher quantitative scores than humanities majors. The results are somewhat surprising, given that quantitative methods are typically thought of as an important area of graduate training for both social science and behavioral science majors.

As with GRE verbal subscores, within any planned area of graduate study, Hispanic and non-Asian minority group examinees earned lower mean GRE quantitative subscores than white or Asian examinees. Asian examinees earned higher mean quantitative subscores than white examinees within every graduate major area.

The mean GRE analytical subscores of students from all ethnic subgroups were highest for students planning a graduate major in the physical sciences and mathematics. Examinees planning graduate majors in the biological sciences earned noticeably lower mean GRE analytical subscores than students in these two highest groups. In turn, the mean GRE analytical subscores of examinees planning graduate majors in the biological sciences were slightly higher than those earned by students planning graduate study in the humanities. This pattern, too, was consistent across ethnic groups. Finally, the lowest mean GRE analytical subscores among students planning graduate science majors were earned by those pursuing study in the social and behavioral sciences. This pattern was consistent across ethnic groups. Across all planned graduate areas, Asian and white examinees earned higher mean analytical subscores than examinees from Hispanic, black, and American Indian backgrounds, replicating the finding for the verbal and quantitative subscores. Thus, regardless of planned area of graduate study, examinees who were Mexican American, Puerto Rican, "other Hispanic," American Indian, and black earned lower GRE subscores than Asian and white examinees.

TABLE 12: GRE-V Mean, S.D., and Number of Test-Takers, by Graduate Major and Ethnic Group, 1982-83 (U.S. citizens only)

Graduate Major		Amer Indian	Black/ AfroAmer	Mexican American	Oriental or Asian	Puerto Rican	Other Hisp Latin Amer	White	Other	No Response	Total
	N	18	162	34	43	15	25	3501	71	97	3966
Arts	Mean	531	367	451	488	341	470	507	516	509	500
	S.D.	97	103	116	133	85	145	108	113	113	112
Other	N	71	353	111	174	92	130	9868	256	298	11353
Humanities	Mean	508	416	463	511	418	485	560	583	570	553
	S.D.	116	123	121	134	114	134	115	115	125	121
	N	179	1563	436	155	140	192	17366	191	344	20566
Education	Mean	413	335	372	449	364	412	463	460	458	450
	S.D.	99	87	97	108	90	104	103	112	120	109
	N	96	1548	257	187	130	125	10810	199	256	13608
Social Sci	Mean	452	364	412	481	382	454	509	508	491	488
	S.D.	108	99	98	122	98	112	109	119	122	118
	N	167	1449	265	357	252	258	17692	452	505	21397
Behavior Sci	Mean	497	395	467	516	402	483	535	542	542	522
	S.D.	113	105	108	124	114	111	108	110	122	115
	N	39	291	60	200	151	61	6575	128	180	7685
Biolog Sci	Mean	479	397	463	520	378	496	529	536	564	521
	S.D.	99	96	99	112	90	122	100	111	117	106
	N	103	938	134	275	139	112	12774	160	254	14889
Health	Mean	456	376	423	461	374	461	491	491	492	481
	S.D.	88	89	90	103	103	112	98	107	105	103

Applied Bio	N	25	99	20	41	50	30	3809	44	78	4196
	Mean	450	351	438	485	354	463	493	503	517	488
	S.D.	86	94	100	105	87	106	101	123	111	104
	N	39	263	87	502	96	114	7238	129	184	8652
Engineering	Mean	531	436	468	462	419	466	533	549	540	524
	S.D.	90	99	91	121	102	87	99	131	104	105
	N	26	333	56	254	77	45	5306	94	156	6347
Math Science	Mean	503	379	483	454	406	493	548	552	571	533
	S.D.	97	110	113	141	101	126	111	120	127	121
	N	31	142	54	140	75	55	6479	118	162	7256
Physical Sci	Mean	507	409	487	519	389	518	534	542	551	530
	S.D.	109	99	103	133	101	130	104	115	119	108
	N	22	196	25	52	25	18	2458	58	73	2927
Not in Above	Mean	434	341	410	422	354	441	490	525	495	477
	S.D.	118	93	96	96	88	113	110	125	102	116
	N	71	859	149	275	90	94	11075	245	304	13162
Undecided	Mean	465	648	435	499	403	459	518	536	532	505
	S.D.	99	102	113	119	94	115	112	129	129	120
	N	35	174	26	60	27	29	2735	60	2315	5461
No Response	Mean	476	350	401	480	384	487	516	584	518	511
	S.D.	136	100	87	137	102	105	114	118	121	121
	N	922	8370	1714	2715	1359	1288	117686	2205	5206	141465
Total	Mean	468	670	427	483	389	466	514	532	522	503
	S.D.	111	102	110	125	103	117	110	121	123	117

SOURCE: H. R. Smith,, A Summary of Data Collected for Graduate Record Examinations Test-Takers During 1982-83, Data Summary Report #8, 1984.

TABLE 13: GRE-Q Mean, S.D., and Number of Test-Takers, by Graduate Major and Ethnic Group, 1982-83 (U.S. citizens only)

Graduate Major		Amer Indian	Black/ AfroAmer	Mexican American	Oriental or Asian	Puerto Rican	Other Hisp Latin Amer	White	Other	No Response	Total
	N	18	162	34	43	15	25	3501	71	97	3966
Arts	Mean	492	350	450	554	291	428	495	505	476	488
	S.D.	118	104	117	123	74	114	115	114	129	120
Other	N	71	353	111	174	92	130	9868	256	298	11353
Humanities	Mean	455	371	437	550	400	467	529	535	524	521
	S.D.	135	124	122	123	119	122	117	129	122	122
	N	179	1563	436	155	140	192	17366	191	344	20566
Education	Mean	405	321	373	501	347	389	471	446	433	455
	S.D.	109	94	405	126	104	113	111	123	124	119
	N	96	1548	257	187	130	125	10810	199	256	13608
Social Sci	Mean	432	345	412	524	389	439	504	497	463	481
	S.D.	115	104	115	130	103	128	115	128	131	126
	N	167	1449	265	357	252	258	17692	452	505	21397
Behavoir Sci	Mean	471	378	445	553	404	464	530	524	522	516
	S.D.	121	113	117	125	111	118	115	117	132	123
	N	39	291	60	200	151	61	6575	128	180	7685
Biolog Sci	Mean	542	434	526	623	443	557	589	587	592	580
	S.D.	102	108	106	97	105	115	98	98	113	106
	N	103	938	134	275	139	112	12774	160	254	14889
Health	Mean	464	376	437	545	411	467	508	506	494	498
	S.D.	110	103	108	122	108	123	109	112	118	115

Applied Bio	N	25	99	20	41	50	30	3809	44	78	4196
	Mean	531	371	432	585	449	523	561	572	563	554
	S.D.	117	119	94	105	110	106	105	103	129	111
	N	39	263	87	502	96	114	7238	129	184	8652
Engineering	Mean	658	559	632	679	590	619	681	666	675	675
	S.D.	85	117	77	80	104	91	78	95	88	84
	N	26	333	56	254	77	45	5306	94	156	6347
Math Science	Mean	612	468	596	653	545	588	662	651	667	649
	S.D.	95	127	110	94	104	102	94	106	106	107
	N	31	142	54	140	75	55	6479	118	162	7256
Physical Sci	Mean	597	476	594	659	527	600	631	621	626	626
	S.D.	118	108	112	105	97	116	96	110	109	100
	N	22	196	25	52	25	18	2458	58	73	2927
Not in Above	Mean	460	332	436	541	400	449	518	535	493	503
	S.D.	122	97	142	108	105	149	123	141	116	131
	N	71	859	149	275	90	94	11075	245	304	13162
Undecided	Mean	474	350	460	603	416	473	548	542	554	534
	S.D.	135	114	152	124	121	132	122	137	141	133
	N	35	174	26	60	27	29	2735	60	2315	5461
No Response	Mean	523	359	400	571	398	457	529	587	532	524
	S.D.	127	109	121	146	110	108	127	132	131	133
	N	922	8370	1714	2715	1359	1288	117686	2205	5206	141465
Total	Mean	475	368	443	596	430	480	542	542	542	533
	S.D.	111	102	110	125	103	117	110	121	123	117

SOURCE: H. R. Smith, A Summary of Data Collected for Graduate Record Examinations Test-Takers During 1982-83, Data Summary Report #8, 1984.

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TABLE 14: GRE-A Mean, S.D., and Number of Test-Takers, by Graduate Major and Ethnic Group, 1982-83 (U.S. citizens only)

Graduate Major		Amer Indian	Black/ AfroAmer	Mexican American	Oriental or Asian	Puerto Rican	Other Hisp Latin Amer	White	Other	No Response	Total
	N	18	162	34	43	15	25	3501	71	97	3966
Arts	Mean	498	303	476	533	335	475	527	508	504	518
	S.D.	97	95	122	122	72	132	117	126	127	121
Other	N	71	353	111	174	92	130	9868	256	298	11353
Humanities	Mean	480	405	439	509	394	458	545	549	539	536
	S.D.	118	111	110	121	87	115	119	123	127	122
	N	179	1563	436	155	140	192	17366	191	344	20566
Education	Mean	430	352	379	474	368	418	486	460	451	470
	S.D.	104	81	92	115	94	109	111	114	116	116
	N	96	1548	257	187	130	125	10810	199	256	13608
Social Sci	Mean	458	381	415	489	395	452	521	503	489	500
	S.D.	101	96	99	116	103	116	114	121	130	122
	N	167	1449	265	357	252	258	17692	452	505	21397
Behavoir Sci	Mean	489	407	462	533	401	482	544	529	532	530
	S.D.	111	100	113	124	103	112	116	117	128	121
	N	39	291	60	200	151	61	6575	128	180	7685
Biolog Sci	Mean	519	418	488	565	404	512	574	553	575	563
	S.D.	101	100	90	113	106	135	110	118	117	117
	N	103	938	134	275	139	112	12774	160	254	14889
Health	Mean	468	397	442	503	393	482	524	507	504	512
	S.D.	107	93	105	113	107	112	109	110	119	114

Applied Bio	N	25	99	20	41	50	30	3809	44	78	4196
	Mean	521	378	439	532	402	477	552	560	554	545
	S.D.	132	88	91	111	84	104	112	130	115	116
	N	39	263	87	502	96	114	7238	129	184	8652
Engineering	Mean	560	470	539	557	481	519	606	597	592	595
	S.D.	115	107	103	126	122	119	112	131	123	118
	N	26	333	56	254	77	45	5306	94	156	6347
Math Science	Mean	567	425	528	536	465	510	613	596	616	597
	S.D.	103	119	136	135	111	114	115	124	122	126
	N	31	142	54	140	75	55	6479	118	162	7256
Physical Sci	Mean	563	439	532	580	428	525	582	553	591	576
	S.D.	132	94	108	136	114	136	115	116	129	118
	N	22	196	25	52	25	18	2458	58	73	2927
Not In Above	Mean	471	368	416	464	393	430	518	535	506	504
	S.D.	109	88	128	112	107	117	117	126	122	123
	N	71	859	149	275	90	94	11075	245	304	13152
Undecided	Mean	484	378	471	556	420	481	552	547	551	538
	S.D.	107	98	127	127	107	119	119	136	138	127
	N	35	174	26	60	27	29	2735	60	2315	5461
No Response	Mean	508	369	406	528	410	436	536	576	525	524
	S.D.	144	90	102	143	114	87	120	125	124	125
	N	922	8370	1714	2715	1359	1288	117686	2205	5206	141465
Total	Mean	481	389	439	532	407	473	542	534	529	528
	S.D.	117	99	116	127	108	120	119	127	129	125

SOURCE: H. R. Smith, A Summary of Data Collected for Graduate Record Examinations Test-Takers During 1982-83, Data Summary Report #8, 1984.

Association of Hispanics' School Achievement with Other Factors: Existing and Needed Research

Analyses of factors underlying Hispanics' educational attainment and academic progress toward advanced study of engineering and science can proceed on many grounds. The influence of three broad classes of factors on Hispanics' educational outcomes has been studied: (1) the background of students' families, (2) the characteristics of individual students, and (3) the characteristics of educational institutions and their ability to meet Hispanic students' needs. Studies of the associations of these factors with educational outcomes vary in their theoretical orientation, the number of variables they examine simultaneously, their methods, and their units of behavioral and social analysis. An exhaustive review of studies is not presented here, but those studies reviewed exemplify recurrent issues and findings of importance. This section first summarizes some of the important findings emanating from survey-based studies and large sample studies that have investigated connections between Hispanic students' educational outcomes and multiple predictor variables. Next is a discussion of anthropological and ethnographic research on Hispanics' learning and the importance of educationally supportive connections between families, communities, and schools. The final portion of the section reviews psychological research on the cognitive and linguistic skills of Hispanic students and the need for research on areas related to the academic motivation of Hispanic students.

Explaining Achievement of Hispanic Students: High School and Beyond Survey Studies

A number of studies have been undertaken involving Hispanic students participating in the 1980 HSB survey and its 1982 follow-up survey. Three studies are cited here. In one of the first major studies on the HSB 1980 data base, Nielsen and Fernandez (1981) investigated the prediction of school delay, educational aspirations, and mathematics, reading, and vocabulary achievement test scores of sophomore and senior Hispanic high school students based on information about personal and background characteristics of students. The predictor variables used in regression analyses included measures of self-judged Spanish proficiency, self-judged English proficiency, judgments of frequency of Spanish use, socioeconomic status (SES), gender, and Hispanic subgroup membership (Mexican American, Puerto Rican, or other Latin American). Use of regression analysis procedures permitted calculation of the unique contribution that each independent variable made in predicting each criterion measure for the sample in question. The findings of the Nielsen and Fernandez study typify the findings of other survey studies on factors predicting Hispanic students' elementary and high school educational outcomes. Hence, some of the major findings are discussed below with regard to each outcome variable.

The school delay outcome measure was based on the difference between a student's age and the modal age of all students in the same grade. The results of regression analysis indicated that school delay was significantly less for females with higher SES status, English language proficiency, and Spanish language proficiency. On the other hand, more frequent oral use of Spanish and less length of residence in the United States was allied with greater school delay. Membership in a particular Hispanic subgroup exerted no significant influence on school delay, controlling for the effects of the other predictor variables on school delay.

The educational aspirations of students, measured by the number of years of schooling that they expected to get, were significantly predicted by higher Spanish language proficiency, less oral use of Spanish, and higher SES status for both sophomores and seniors. English language proficiency was a significant predictor of sophomores' educational aspirations but not of seniors' aspirations. Interestingly, in contrast to the findings for prediction of schooling delay, longer length of U.S. residence predicted significantly lower educational aspirations among sophomores and seniors. This point is worth reiterating: the longer that Hispanic students had lived in the United States, the more likely they judged that they would not get as far in their schooling. Some differences emerged in the educational aspirations of Hispanic subgroups. Cuban American sophomores and seniors had significantly higher educational aspirations than their Mexican American counterparts after controlling for the influence of other predictor measures on aspirations. And among seniors, Puerto Rican students also had significantly higher educational aspirations than their Mexican American peers. It is thus interesting to note that while school delay was not significantly predictable from subgroup membership after controlling for other predictor variables, educational aspirations were influenced by Hispanic subgroup membership.

Prediction of students' mathematics, reading, and vocabulary achievement test scores followed similar, but not identical, patterns for sophomores and seniors. Higher Spanish language proficiency, English language proficiency, and SES level were significant positive predictors of mathematics achievement for both sophomores and seniors, while greater oral use of Spanish was a significant negative predictor of mathematics scores for sophomores and seniors. In addition, males earned significantly higher mathematics scores than did females for both grade levels. Another finding was that length of U.S. residence was a significant negative predictor of sophomores' mathematics scores, while this influence was not statistically significant for seniors. Two additional findings were that Mexican American sophomores earned significantly higher mathematics scores than Puerto Rican sophomores, while Cuban American seniors earned significantly higher mathematics scores than Mexican American seniors. The results obtained for prediction of mathematics scores are important because they suggest that indicators of language, gender, and social background can contribute unique information associated with students' mathematics achievement and, further, that the same predictor variables account for verbal achievement test scores in a manner resembling the pattern of prediction of mathematics achievement test scores.

Additional analyses of 1980 HSB data have compared prediction of educational outcome variables for Hispanic students, language minority students, and nonminority white students (Fernandez and Nielsen, 1986). One important finding of this work was that SES contributed less to the prediction of Hispanic students' and linguistic minority students' educational outcome than was the case for nonminority white students who were not language minority students.

One important stream of follow-up research in the HSB survey is investigating the academic growth of Hispanic sophomores participating in the initial wave of the 1980 survey (O'Malley, 1984). Among other things, the research is investigating gains in achievement test scores from 1980 to 1982 and connections between these gains, students' background and personal characteristics, and their intervening coursework. A preliminary oral report of findings presented to the National Center for Education Statistics in July 1985 indicated that Hispanic students' gains in achievement test scores were very similar to those shown by non-Hispanic white and black students. While Hispanic students' achievement grew, the relative difference between achievement levels of Hispanic and non-Hispanic white students remained the same at the end of the 2-year period. Other analyses indicated that achievement test scores earned by students in 1980 uniquely accounted for about one-third of the gain in students' test scores from 1980 to 1982. Less than 2 percent of the gain in students' achievement test scores from 1980 to 1982 could be uniquely attributed to influences stemming from individual variables (SES, home language, educational aspirations, gender, race/ethnicity, and high school academic credits). However, variance shared in common by these latter predictor variables accounted for about 48 percent of the variance in the gains shown by students' achievement test scores.

The foregoing findings indicate the difficulty in attempting to use regression analysis procedures in order to identify individual personal and background variables that can be shown to have a significant and meaningful impact on educational outcomes. Intercorrelation among predictor variables makes it very difficult to isolate the important influences asserted by individual variables on outcomes. Yet the results support strongly the hypothesis that the strongest individual predictor of students' current achievement is previous achievement in the same academic content domain. This latter contention has important implications for interventions aimed at improving students' academic development in areas relating to science and engineering, suggesting that effective interventions should include academic skill development if they are to maximize their impact on students' academic growth.

Another stream of follow-up research in the HSB survey examined, in 1982, persistence in high school, entry into college, and the labor force experience of Hispanic students who had been sophomores and seniors in high school in 1980 (Fernandez and Hirano-Nakanishi, unpublished manuscript). The study found that Hispanic students had the highest dropout rate from school (18.3 percent), followed by blacks (17.1 percent) and whites (12.5 percent) and that these dropout rates were also associated with the income of students' families--the lower the income, the higher the dropout rate. Pregnancy of Hispanic females was associated with a propensity to drop out of high school. Another finding was that Hispanic students' self-judged English proficiency and self-judged Spanish proficiency were not significantly related to dropping out of high school.

The high school dropout rate was highest among Hispanic students who were the most recent immigrants to the United States (30 percent among students with less than 5 years of United States residence). Surprisingly, however, among other immigrant Hispanics, except those in the "Other Latin American" grouping, the dropout rate tended to be higher among students who had spent almost all of their lives in the United States (17.8 percent) than among those who had lived 10 or more years in the United States (15.1 percent). However, in spite of these trends for immigrants, Hispanic students who were at least second-generation United States citizens tended to be less likely to drop out of high school than first-generation Hispanics.

Data on the college attendance rates in 1982 of students who were high school seniors in 1980 indicated that Hispanic males (23.9 percent) were less likely to be enrolled in 4-year colleges than non-Hispanic males (34.9 percent). Only 19.1 percent of Hispanic females who were high school seniors in 1980 attended 4-year colleges in 1982, in contrast to 36.4 percent of non-Hispanic females. The 2-year college attendance rates of Hispanics and non-Hispanics who were high school seniors in 1980 were similar across ethnic groups and gender; these rates varied between 22 and 28 percent. The pattern of college attendance findings described here appears consistent with the finding described in the first part of this report: Hispanics who are successful in completing high school are entering 4-year colleges at rates below those shown for nonminority white students.

Linguistic and Cognitive Factors Affecting Mathematics and Science Learning

While Hispanic students' school achievement is related to background measures such as family socioeconomic status, achievement is associated even more with students' linguistic and cognitive characteristics. In recent years a number of research studies investigating connections between Hispanic students' mathematics and science learning ability and their ability to think and reason in either Spanish or English have emerged. These investigations have included studies examining correlations between measures of students' English language proficiency and their college aptitude test scores and also studies of Hispanics' problem-solving ability, drawing on cognitive psychology approaches.

Findings from each of these approaches will be discussed in turn. Table 15 shows correlations between (1) SAT-Verbal, SAT-Math, and Test of Standard Written English (TSWE) scores and (2) self-ratings of English and Spanish proficiency for a large sample of Hispanic college freshmen in the academic year 1982-83 (Duran, et al., 1985). The rating scale for proficiency assigns low numbers for high self-ratings of language proficiency; hence, negative correlations with SAT-Verbal, SAT-Math, and TSWE scores indicate a positive association between

TABLE 15: Correlations Between Self-Ratings of Global Language Proficiency and SAT and TSWE Scores

	Extremely well	Well	Moderately well	Not very well	Not at all	Correlations Verbal	Math	TWSE
SDQ 38: Is English your best language?						-.19	-.09	-.25
6. With regard to English, how well do you do the following?								
a. Understand English when people speak it?	( )	( )	( )	( )	( )	-.29	-.13	-.31
b. Speak in English?	( )	( )	( )	( )	( )	-.35	-.15	-.36
c. Read in English?	( )	( )	( )	( )	( )	-.35	-.10	-.31
d. Write in English?	( )	( )	( )	( )	( )	-.34	-.15	-.39

NOTE: SAT = Scholastic Aptitude Test; TSWE = Test of Standard Written English.
SOURCE: R. P. Duran, M. K. Enright, and D. A. Rock, Language Factors and Hispanic Freshmen's Student Profile (College Board Report No. 85-3), New York: College Entrance Examination Board, 1985.

language proficiency and academic aptitude test scores. Conversely, positive correlations indicate a negative relationship between self-ratings of language proficiency and test scores. The correlations in Table 15 indicate that the SAT-Math scores had a smaller positive association with self-ratings of English proficiency than did SAT-Verbal and TSWE scores. The pattern of correlations thus suggests that the mathematics aptitude of students was less dependent on English proficiency skills than their verbal and writing skills were.

Nonetheless, research has found that the mathematics aptitude of Hispanic students may not be assessed accurately in English if students show limited English proficiency and an education predominantly in Spanish. Table 16 summarizes the results of regression analyses predicting the SAT-Verbal and SAT-Math scores of 361 Puerto Rican students from scores on the Prueba de Aptitud Academica (PAA) and various English language proficiency tests (Alderman, 1981). The PAA test is a Spanish language version of the SAT developed for use in Latin America. Like the SAT, the PAA assesses students' verbal and mathematics aptitude for college work. The English proficiency utilized included the English as a Second Language Achievement Test (ESLAT), TSWE, and the Test of English as a Foreign Language (TOEFL). Of particular interest in Table 16 is the bottom half: the three regression analyses summarized involved prediction of SAT-Math scores from PAA-Mathscores and each of the three English proficiency measures separately. The regression analyses included an interaction term between PAA-Math scores and a proficiency measure. In the case of each analysis, the interaction term attained statistical significance ($p < .01$). These results indicate that students' SAT-Math scores were affected by their English language proficiency, given the assumption that their PAA-Math scores reflected their true mathematics ability. As students' English language proficiency increased, their SAT-Mathscores bore a closer relation to their PAA-Math scores--suggesting that the English language requirements of mathematics problems can limit the display of mathematics skills by Hispanic students with limited English proficiency.

Cognitive research studies of students' verbal problem-solving skills have verified that Hispanics may encounter difficulties in properly comprehending verbal mathematics problems (Mestre, 1986; Morales, et al., 1985; Spanos[4]). The studies suggest that difficulties in properly interpreting verbal mathematics problems may arise because of limited development of the underlying conceptual knowledge required to solve problems as well as difficulties in understanding the English statement of problems. Both of these factors constraining verbal mathematics problemsolving need to be considered in designing interventions aiding the development of Hispanic students' mathematics skills (Cuevas, et al., 1986).

Research on the deductive reasoning skills and cognitive task performance of Hispanic bilinguals indicates that students solve problems more slowly in their less familiar language (either English

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[4] Personal communication.

TABLE 16: Regressions of Aptitude Test Scores in Second Language (SAT) on Aptitude Test Scores in First Language (PAA) and Measures of Second Language Proficiency

Multiple Correlations R	R^2	Independent Variables	Regression b	Coefficients B	seg	Statistical Test of Moderator Effect
.6655	.4429	PAA-V	-.8303	-.97	.10	
.8568	.7341	TOEFL	-.8329	-.94	.14	
.8934	.7982	TOEFL x PAA-V	.0025	2.57	.00	F(1,357)=113.39*
		(constant)	490.8048			
.6655	.4429	PAA-V	-.7913	-.92	.09	
.8022	.6436	ESLAT	-.7916	-1.21	.10	
.8615	.7423	ESLAT x PAA-V	.0021	2.75	.00	F(1,357)=136.70*
		(constant)	508.1330			
.6655	.4429	PAA-V	.0952	.11	.08	
.8790	.7727	TSWE	2.2814	.23	2.26	
.8805	.7754	TSWE x PAA-V	.0071	.58	.00	F(1,357)= 4.216
		(constant)	68.4927			
.7955	.6328	PAA-M	-.6207	-.70	.11	
.8514	.7248	TOEFL	-1.2147	-1.17	.16	
.8871	.7870	TOEFL x PAA-M	.0026	2.56	.00	F(1,357)=104.26*
		(constant)	558.7010			
.7955	.6328	PAA-M	-.5502	-.62	.10	
.8259	.6821	ESLAT	-1.0554	-1.39	.11	
.8777	.7703	ESLAT x PAA-M	.0022	2.66	.00	F(1,357)=137.16*
		(constant)	540.7829			
.7955	.6328	PAA-M	.0664	.07	.09	
.8615	.7422	TSWE	-9.0486	-.77	2.69	
.8718	.7601	TSWE x PAA-M	.0200	1.51	.00	F(1,357)= 26.69*
		(constant)	236.5505			

*Indicates statistical significance, $p < .050$
SOURCE: D. Alderman, Language proficiency as a moderator variable in testing academic aptitude, Journal of Educational Psychology 74(4):580-587.

or Spanish). However, for simple problems, the rate of correct solution of problems in English and Spanish is very similar (Mestre, 1985; Duran, 1985). The research suggests that as students became more proficient in English or Spanish, they are able to concentrate their attention on understanding the principles needed to interpret and solve problems, rather than on decoding the linguistic statement of problems.

Attitudes Toward Science and Mathematics Learning

Walker and Rakow (1985) reviewed previous studies of minority students' attitudes toward science and mathematics learning, and they also analyzed data on 9-, 13-, and 17-year-old black, Hispanic, and white students' attitudes toward science. They concluded that (1) lack of representation of minority students in academic science courses could not be adequately explained by inferring that black and Hispanic students simply show less preference than white and Asian students for the study of science courses and the pursuit of science careers and (2) the causes underlying these different preferences need investigation. The data reported by Walker and Rakaw indicated that while the positive attitudes of black, Hispanic, and white students toward the value of scientific research increased among older students their attitudes toward science teachers and perceptions about science careers varied by ethnic group and age. They also found that male students showed more positive attitudes toward science classes than did female students but that this positive attitude declined between the ages of 13 and 17 among white students.

A study by Mestre and Robinson (1983) found that Hispanic and Anglo college students enrolled in engineering and technical courses reported similar motivations for pursuit of these studies: both groups reported that their choice of study area was influenced by having friends or relatives employed in technical fields and that their decision to pursue technical studies in college emerged between the ages of 14 and 18. Anglo students, however, were more likely to have parents employed in technical fields, and they were found to have received more encouragement to pursue science careers than Hispanic students.

Psychological studies investigating differences in the motivation of minority male and female students for science and mathematics study have just begun to emerge. Lockheed, et al., (1985) report that students in grades 4 to 8 indicate very little evidence of gender differences in mathematics achievement but clear evidence that Asian and white students have higher mathematics achievement than black and Hispanic students. In science, however, without concern for ethnicity as a factor, evidence has emerged that boys outperformed girls on tasks that require manipulation of science task materials and objects that were more familiar to boys than to girls. The possible interaction of gender with ethnicity in science achievement has yet to be investigated in depth.

Hackett (1985) has proposed that self-efficacy (i.e., self-assessed ability) in mathematics problem solving is a critical intervening variable affecting differences in the pursuit of mathematics majors by college women and men. Hackett's research has found that previous mathematics achievement is important in the development of women's and men's mathematics self-efficacy. In addition, however, gender-related socialization practices may contribute significantly to attitudes constraining women's pursuit of coursework requiring mathematics. Research on the mathematics self-efficacy of male and female students from minority backgrounds has not been conducted but seems valuable to pursue in order to learn ways in which interventions might be designated to stimulate aspirations for science and engineering careers.

Anthropological and Sociolinguistic Research

Research on the educational performance and educational outcomes of Hispanic students from anthropological and sociolinguistic perspectives has indicated that students' ability to learn is very much affected by the social and cultural climate of the school and by the degree of compatibility between home, community, and school environments and experiences. This body of research has yet to probe either the mathematics and science achievements of Hispanic students or the development of aspirations for study in specific science- and engineering-related areas. Nonetheless, important and relevant findings do indicate the promise of such research for identifying interventions aiding Hispanic students' aspirations for careers in science and engineering.

Ogbu and Matute-Bianchi (1986) surveyed, from an anthropological perspective, an international collection of research on the academic attainment of minority-group members within countries and communities. Based on their research synthesis, they theorized that many U.S. Hispanic students fail to develop aspirations for higher education because there does not exist a social support system for the development of these aspirations. They claim that Hispanic students from lower socioeconomic backgrounds may develop perceptions that higher education will not lead to jobs and economic rewards equal to those obtained by nonminority persons with similar education. Ogbu[5] has suggested that innovative partnerships between ethnic minority community members, universities, and scientific and technical businesses could be used to foster programs promoting Hispanic and other minority students' development of higher education aspirations in science and engineering.

Sociolinguistic research on classroom communication has found evidence that Hispanic school children may perform poorly on academic tasks because of lack of familiarity with norms for communication in the classroom. Teachers, as well, may not be sensitive to the cultural values and communication norms of Hispanic students, and this may lead to behavior of both students and teachers that blocks students from demonstrating their academic competence (Carrasco, et al., 1981; Moll, et al., 1980). This same research has also found that peer tutoring and design of experientially relevant classroom tasks can promote Hispanic students' learning. Moll, et al., found, for example, that Hispanic students' display of literacy skills was very much affected by teachers' choice of classroom tasks: when teachers concentrated on

[5]Personal communication.

basic skills development, such as the proper pronunciation of words in isolation, Hispanic students did not get a chance to exercise high-level reasoning skills in their reading and writing. The same students displayed these skills when assignments required them. The foregoing research findings suggest that research should be conducted on the quality and meaningfulness of the mathematics and science learning activities and how these activities build on students' communication skills, cultural and social knowledge, and higher-level reasoning skills.

Cognitive Intervention Programs To Enhance Science and Mathematics Learning of Hispanic Students

Research on intervention programs drawing on cognitive theory has begun to emerge. Cuevas, et al., (1986) reported implementation of a program, known as the Language Process Approach to Mathematics Teaching, for teaching early grade-school children methods for solving verbal mathematics problems. The program combines second-language teaching techniques with the teaching of mathematics content. Drawing on cognitive psychology research on metacognition, the program helps students develop skills in planning problem solving and in checking their work as they solve problems. Teachers help students systematically learn vocabulary and syntactic structures occurring in verbal mathematics problems. As part of mathematics lessions, Cuevas, et al., (1986) have formally evaluated the effectiveness of this program with Cuban, Mexican American, and Haitian students. They found that students exposed to the program in grades 3 and 5 earned higher California Test of Basic Skills (CTBS) mathematics scores than comparison groups of students in the same grades, after controlling for the influence of prior CTBS mathematics scores earned by students.

DeAvila (in press) reported the evaluation of a science and mathematics intervention program that he and others developed for use with Hispanic 2nd-, 3rd-, and 4th-graders enrolled in bilingual education programs. Known as "Finding Out/Descubrimiento," the intervention program consists of 150 small-group activities designed to train students in measuring, counting, estimating, grouping, hypothesizing, analyzing, and reporting results of experiments. Once given the problem-solving tasks, students are permitted to interact freely with other students in the same group and to use either Spanish or English versions of task materials. Drawing on cognitive psychology research, activities for a given skill area are structured so that the tasks presented in current activities focus on problem-solving skills and principles mastered at an earlier point by students. New problem-solving tasks vary in well-defined, but limited, ways, enabling students to discover how skills that they have already mastered can be used and further augmented to solve novel problems.

An evaluation of the "Finding Out/Descubrimiento" program by DeAvila found that participants in the program showed higher mathematics application and conceptual problem-solving score gains than the comparison group of bilingual students who did not participate in the program.

Institutional Strategies for Mathematics and Science Interventions

Rendon (1985) provided a detailed analysis of mathematics and science learning programs involving Hispanic and other minority group students. She noted four organizational arrangements that were especially successful: (1) collaboration between a school district, college or university, and industry, (2) a formal consortium arrangement among colleges, (3) cluster programs within colleges targeting the mathematics and science training of minority students, and (4) student/faculty mentorship programs. Rendon also discussed in detail features of programs that were judged to contribute to their success.

Resta and Rendon (1985), Berriozabal (1985), Murgia (1985), and Turnbull (1985) in Border College Consortium (1985) described the implementation of a series of mathematics and science intervention programs aimed at students enrolled in elementary school, high school, and college. One important characteristic of these programs conducted by colleges in Arizona, Texas, and California was that many of them involved tutoring in mathematics while students were still enrolled in elementary or secondary school. These programs thus emphasized development of mathematics and science skills and of aspirations for college study in these areas prior to the student's entry into college. Another important characteristic of the programs was that some of them included attention to developing specific higher mathematics skills of students, such as vector algebra and calculus appropriate for college-level science and engineering coursework.

Rendon (1986) has demonstrated in her own research how basic research both on the attitudes of Hispanic students toward science and mathematics learning and on the diagnoses of science and mathematics learning can be made useful in the context of a community college program to aid students' learning. She advocates an analysis of institutional resources that might be made available to aid mathematics learning of students, given their attitudes and learning characteristics. She also emphasizes the importance of developing formal documentation and evaluations of interventions for dissemination to practitioners and educational policymakers.

A useful compendium of programs facilitating mathematics and science learning of females and minority students is provided by Malcom (1984). Her compendium identifies additional programs, such as MESA (Mathematics, Engineering, and Science Achievement), which served Hispanic students as of 1983.

Suggestions for Further Research

While the review of Hispanic students' progress toward careers in science and engineering has not been exhaustive, several important directions for research emerge. First, continued and more extensive educational survey research is needed. This research should include (1) longitudinal survey studies of Hispanic students' progress through school and (2) investigation of factors promoting mathematics and science coursework. It is especially important that major educational survey data bases maintained by the U.S. Department of Education and other federal and state agencies readily make available information on the ethnic identity of students. This is critical, given projected increases in the size of the U.S. Hispanic population and the emergence of trends suggesting that Hispanic, black, and American Indian academic development and education achievement continue to lag seriously behind that of white and Asian students.

A second suggestion for needed research concerns gender as a factor associated with minority students' success. Research investigating how socialization processes and societal values constrain the access of Hispanic and other minority female students to science and engineering careers is needed. While evidence suggests that men and women show equal achievement in mathematics in the early school years, the absence of minority women in college training areas involving mathematics and the sciences needs careful investigation in order to devise effective intervention programs.

A third area of needed research concerns the development of aspirations for careers in science and mathematics. We need to understand better how students' aspirations for these careers develop and how interventions might be designed to stimulate such aspirations among Hispanic and other minority students. Community- and family-based approaches seem especially promising, given research findings suggesting that educational aspirations are related to familial socialization of children. This third area of research is connected to a fourth broad area--research on designing and evaluating interventions aiding Hispanic and other minority students in their science and mathematics career aspirations, mathematics and science skill development, and persistence in college. Development of proficiency and high-level literacy skills in English should also be a target for research, given findings that suggest that mathematics and science problem solving involves verbal as well as quantitative skills. Bilingual language training should be investigated as a medium for aiding the development of mathematics and high-level reasoning skills as students acquire greater proficiency in English. Related to this is the need for an investigation of institutional strategies for implementing and evaluating intervention programs. Work such as suggested by Rendon (1985) on effective interventions and institutional arrangements cutting across college and other schooling systems and community and home seems especially important to pursue.

Finally, cognitive and linguistic research is needed on the acquisition of science and engineering content by related learning skills of Hispanic and other minority students. The programs of research by Mestre (1985), DeAvila (in press), and Cuevas, et al., (1986) exemplify ways in which such research can or could lead to the design of training interventions that promote development of high-level reasoning and mathematics skills, which subsequently help students advance toward college-level study in engineering and science areas. The approaches mentioned appear especially promising, since they use experimental and quasi-experimental techniques to evaluate scientifically the effectiveness of intervention programs.

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CASUAL RELATIONSHIPS OF FACTORS UNDERLYING SCIENCE EDUCATION OF HISPANICS

Amaury Nora

In reviewing Richard Duran's paper, "Hispanics' Precollege and Undergraduate Education," one cannot help but be awed by the thoroughness of the study. The findings are very specific in identifying trends of Hispanic participation in higher education and provocative in their implications regarding access, retention, academic performance, and degree attainment of Hispanic students. However, although there is total agreement with the findings, the report is almost solely descriptive in nature. While it is necessary to begin research on the underrepresentation of Hispanics in certain areas of higher education by pointing out the differences in degree attainment, retention rates, test scores, academic performance and many other factors between different groups of student populations, studies should also focus on the causal relationships among the factors identified in earlier descriptive studies and the underlying structural patterns among the different groups. Moreover, confirmatory research enhances the capacity of institutions to understand student academic and attitudinal factors associated with student underrepresentation and underachievement. The lack of an empirical base of information often gives rise to the misunderstanding of problems and the misdirection of solutions to problems and can limit the extent to which colleges are able to develop appropriate policies and intervention strategies to improve student preparation, achievement, and attitudes.

The presence of Hispanics in higher education and the cohort's corresponding underrepresentation in quantitative and scientific fields of study make confirmatory research on preparation, attitudes, achievement, and participation among Hispanics a necessity for educational planning and policy. The findings in the Duran paper are alarming, but not unexpected. That Hispanics are underrepresented in higher education is not, and should not be, a surprise. That Hispanics have not made substantial gains in numbers and representation in recent years is interesting but, again, not surprising. That confirmatory studies on Hispanic students are almost nonexistent is distressing.

If we are to begin to test the causal relationships of factors associated with Hispanic underrepresentation in various areas of higher education, one must first examine the appropriateness of available data sets. Depending on the data set one chooses to study, different paradigms inherent in different data sets could result in different conclusions based on different findings. For instance, the National Longitudinal Survey of 1972 is not only outdated, but also extremely nonrepresentative and uncharacteristic of Hispanic students. Even the High School and Beyond Survey of 1980 and the follow-up survey of 1982 represent students surveyed in their sophomore year, well after many Hispanic students have already dropped out. Studies that examine Hispanic student characteristics and subject the data to different analyses may be misleading in any generalization that may come from their findings.

The problem with inappropriate data sets lies mostly in their representation of reality for Hispanic students. Examining factors associated with Hispanic students, be they retention or academic performance, from data sets that exclude Hispanics in community and junior colleges distorts reality: most Hispanic college students are enrolled in 2-year institutions. On the other hand, studies that report attrition rates for Hispanics in higher education from data sets that are inclusive of Hispanics in 2-year institutions may not be representative of true attrition rates because of different paradigms operating in Hispanic student populations in 2- and 4-year institutions. The reasons that students attend community colleges are very different than those reasons for students enrolled in a 4-year institution. Attaining an undergraduate degree may not be the goal of this specific Hispanic population.

Although attrition rates remain high in any case, the deletion or separation of these two Hispanic student subgroups would be crucial in (1) operationally defining variables in studies that appropriately reflect characteristics and paradigms that are operating in these subgroups and (2) identifying parameter estimates that truly are representative of these subgroups. More appropriate samples that represent true group reality may exist in surveying students at the institutional level. Only by examining data sets collected at similar institutions with similar Hispanic student characteristics can we rely on parameter estimates identified in the findings. The acceptability of these indices becomes even more critical when they are tied in with the intervention strategies and policies for these subgroups.

The only major concern in Duran's study arises with the validity of the findings of the three studies reported. Although Duran cites that "[i]ntercorrelation among predictor variables makes it very difficult to isolate the important influences asserted by individual variables on outcomes," other problems need to be addressed. In experimental research, the experimenter manipulates the variables of interest and observes the effect on the dependent variable. However, in nonexperimental (educational) research, the situation is more complex and more ambiguous because manipulation of the variables and randomization is not possible (Pedhazur, 1982). While it is possible to resort to statistical controls when randomization is not achieved, other conditions must be considered: the correlated causes between the variables, the order of entry in the equations, and the common variance with other variables.

Multiple regression analysis has been used almost exclusively in attempts at analyzing data collected from different student populations. Multiple regression is a method by which the variability of a dependent variable is analyzed by regressing the dependent variable on one or more independent (predictor) variables. Studies in education, however, employ variables that are intercorrelated. The intercorrelations between most, if not all, variables examined in educational research frequently preclude the use of multiple regression analysis to determine the relative importance of the variables in any hypothesized model.

Moreover, the order of entry of the variables in the equation is critical and should be based on theoretical considerations. Variables that appear not to have any predictive validity would prove to be statistically significant had the order of entry for the variable in the equation been different. Even after appropriate partialling of variables (which result in R^2 changes reflecting the proportion of variance accounted for by the unique partialled predictor variable), the residualized variable is not reflective of the original variable.

At most, multiple regression makes implicit assumptions about the direct and causal relationships among the variables. Underlying structural equations among the variables cannot be examined. Because the following research conditions exist in educational research, causal modeling appears to be the most appropriate form of data analysis: (1) the intercorrelations between the independent (predictor) variables, (2) intact (nonrandom) groups that comprise the samples to be used, (3) nonmanipulation of the variables, and (4) the inability to determine the relative importance of predictor variables.

When certain assumptions cannot be met by the researcher (e.g., uncorrelated residuals, single indicators or indices for observed variables in the model), the use of structural equation models (Linear Structural Relations, Version 6, or LISREL VI) can accommodate for a variety of research conditions (Joreskog and Sorbom, 1984). Structural equation models take into account the correlations found between the residuals and adjust accordingly. Multiple indicators (indices) may be used to measure constructs in the theoretical model by forming latent variables. In addition, when variables are collected through the use of survey instruments, often it is at the nominal or ordinal level. Structural equation models can handle the use of coding schemes for endogenous and exogenous variables.

In sum, quantitative studies on Hispanic underrepresentation in higher education should begin to expand from noteworthy descriptive studies by focusing on theory building and testing related to Hispanic student populations. Why are Hispanic students underrepresented in undergraduate degree attainment in all areas of higher education? Is this problem a matter of aspirations, high school features, institutional factors, or all of these? Are aspirations affected by institutions? These questions must now be addressed by researchers. Moreover, research on Hispanic students that expand from current studies must be a collective effort by educational practitioners and researchers and must involve faculty from different disciplines. The latter has already begun; Duran's report is evidence of this interdisciplinary effort. However, this is only a beginning; further confirmatory studies on Hispanic students must now be conducted by researchers.

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THE GRADUATE EDUCATION AND CAREERS OF UNDERREPRESENTED MINORITIES IN SCIENCE AND ENGINEERING*

Willie Pearson, Jr.

Introduction

That disproportionately few blacks, Hispanics, and Native Americans, relative to Asians and whites, are found in science and engineering has been well documented (Cole and Cole, 1973; Hill, 1984; Jay, 1971; National Science Board, 1985; Young and Young, 1974). Beyond this fact, however, scant knowledge exists on the causes of this underrepresentation and the experiences of these groups in the American scientific community. This paper describes recent trends in the participation of blacks, Hispanics, and Native Americans in science and engineering graduate education and careers. Data are derived from a review of relevant literature. Both published and unpublished materials are derived from a number of sources, including a thorough computerized search and additional searches in those journals yet to be indexed by electronic sources. Unpublished reports were solicited from various scholars conducting research in the topical area.

Because the principal assignment is to review the literature on the participation of blacks, Hispanics, and Native Americans in science and engineering graduate education and careers, relative to that of whites (and Asians), the chapter is necessarily highly descriptive. Due to space and time limitations, a discussion of the status of minority women in science and engineering is not included (see Leggon's discussion, this volume). Additionally, the chapter concludes with an assessment of the current state of the literature on underrepresented racial/ethnic minorities in American science and engineering.

Limitations

A number of caveats are in order. To avoid repetition, these caveats will not be repeated in the chapter. First, ultimate assess-

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ments of equality are difficult to reach because previous studies generally fail to include performance variables. Second, the comparability of many studies is hampered by the inclusion of both foreign and native minorities. The social backgrounds of foreign minorities may be very different from those of American minorities, and their treatment within this society may be different. Third, the terms "race," "ethnic," and "minority" are often used interchangeably in the literature, but they are not synonymous. While these categories overlap somewhat, they are analytically distinct.

Wirth (1985) argued that the primary driving force behind minority status is that the group, whether racial or ethnic, is excluded from full participation in the life of the society in which they live.

Graduate Education

Despite more than a century's presence in American graduate education, remarkably little systematic research has been generated on the minority graduate educational experience and training. In fact, most of what has been done is limited to summary statistics (Duncan, 1976). In addition, after two decades of affirmative action and desegregation efforts, only minimal progress has been made by blacks and Hispanics in their quest for graduate school access and attainment (Loury, 1986; Thomas, 1986). A number of reasons have been suggested for the low levels of participation of certain minorities, especially blacks and Hispanics, in graduate education. For instance, immediate employment opportunity upon graduation from college may appear more rewarding to some minorities than advanced study given (1) the prospect of further financial difficulties, (2) the academic risk of graduate study, and (3) labor market uncertainties (Office of Technology Assessment, 1985).

Thomas (1986) reported that a major reason that blacks and Hispanics give for not pursuing higher education is lack of financial support. She argues that grant awards, as opposed to loans, tend to have a more positive influence on blacks' and Hispanics' graduate school retention and access. In short, Thomas believes that both the amount and the type of funding are important. Arbeiter (1986) argued that the amount of financial aid available to minorities declined modestly between 1978 and 1983. The increasing shift in the financial aid package from grants to loans--along with the limited incomes of some minorities, particularly blacks--may further limit the pursuit of advanced study. There is some evidence that minorities are less likely than whites to borrow money to support their education (Arbeiter, 1986).

In addition to financial aid, Thomas (1986) believes that standardized test performance, lower college grades, and institutional recruitment and selection practices also have impacts on the access and retention of blacks and Hispanics in graduate education. In the case of blacks, Blackwell (1981) asserted that improper counseling and a general lack of interest may be additional inhibiting factors. He argued that the lack of interest may result from the fact that many black students are first-generation college students to whom the pursuit of studies beyond the bachelor's degree may not have occurred. In sum, the confluence of the above factors may deter or delay the pursuit of graduate studies by qualified minority students.

The generally lower graduate education participation rates of some minorities is even more pronounced in certain academic disciplines, especially science and engineering. These low participation rates of some minorities, particularly blacks and Hispanics, may well reflect individual preferences. Such preferences, however, have significance in terms of prospective employment opportunities (National Board on Graduate Education, 1976). Ultimately, this situation may serve as social and cultural barriers to equal opportunity (Office of Technology Assessment, 1985; Pearson, forthcoming).

Current data reveal significant differences among racial/ethnic minorities with respect to rate of participation and preparedness in science and engineering graduate education. In general, the data show that blacks and Hispanics tend to be severely underrepresented while Native Americans are proportionately represented and Asian Americans are overrepresented. Regarding master's degrees, Berryman (1983; 1985) noted striking differences among racial/ethnic groups. As evidence, she revealed that in 1978-79, relative to a randomly selected black from the appropriate age group, a randomly selected white and Asian American were, respectively, five and thirteen times as likely to have earned a quantitatively based master's degree. Berryman attributed these differences to a number of factors: specifically, pipeline attrition, along with major field choices, accounts for most of the variations of science and engineering participation at the graduate level. For example, among blacks, attrition appears to be dispersed across the education pipeline. Yet, among Native Americans, attrition seems to be somewhat minimal after the bachelor's degree; as for Hispanics, attrition tends to be concentrated at high school graduation and college entry.

Berryman pointed out that at the master's degree level, blacks chose quantitatively based majors at roughly two-fifths of the national average; whites and Native Americans, at the national rate; Hispanics, at about four-fifths; and Asian Americans, at roughly twice the national average. She also contended that the driving force behind the Asians' overrepresentation in quantitatively based fields appears to be their major field choice, where they are considerably more likely than others to choose such a major. In 1983, approximately one-half of Asian Americans earning master's degrees received them in the field of engineering. In sharp contrast, blacks and Hispanics earned most of their master's degrees in the social sciences or psychology; Native Americans earned most of their master's degrees in the life sciences or psychology (NSF, 1986).

Overall, the patterns of minority participation evidenced at the master's degree level continue at the doctoral level. For example, engineering continued to be the most popular field choice for Asian Americans: in 1983, nearly one-third of the Asian Americans earning science and engineering degrees did so in the field of engineering. Slightly less than one-third of the science and engineering doctorates received by whites were in the life sciences, while a similar proportion of blacks earned doctorates in psychology. An equal proportion (one-third) of both Hispanics and Native Americans earned doctorates in the field of psychology (NSF, 1986).

With respect to major field choice, Berryman (1983; 1985) showed that in 1979-80, 30 percent of the Ph.D.s earned by U.S. citizens were in quantitatively based fields. However, Asian Americans' approximate degree attainment was twice the national average; whites', about equal; Hispanics' and Native Americans', two-thirds; and blacks', one-third.

Racial/ethnic minorities, except for Asian Americans, continue to be severely underrepresented among science and engineering Ph.D.s. For example, among doctoral science and engineering degree recipients in 1979, blacks (2.3 percent) and Hispanics (1.7 percent) were severely underrepresented; whites (89 percent) and Asian Americans (6.5 percent) were overrepresented; and Native Americans (0.2 percent) were about proportionately represented. By 1983, the proportional representation for each of the groups remained relatively unchanged (NSF, 1986). Jackson (1984) has estimated that to achieve parity with whites in science, the percentage of black doctorates would have to increase tenfold.

Striking differences also emerged among the groups under discussion within the science and engineering doctoral degree recipient pool. For example, in 1979, whites accounted for nearly 91 percent and 77 percent of all scientists and engineers, respectively. These representational levels were essentially identical in 1983. For blacks earning doctorates, proportional representations among scientists in 1979 (2.4 percent) and in 1983 (2.3 percent) were unchanged. Blacks, while still severely underrepresented among engineers, experienced gains, however, from 1979 (1.3 percent) to 1983 (2.0 percent). Similarly, Hispanics accounted for roughly 1.7 percent and 1.9 percent of the science doctorates in 1979 and 1983, respectively. Comparable figures for Hispanic degree recipients in engineering were 1.6 percent and 2.0 percent. The pattern for Native Americans remained constant at 0.2 percent among scientists in both 1979 and 1983, while their representation among engineers declined from 0.2 percent to 0.1 percent. Asian Americans evidenced the most striking representational change during the period in question: for instance, while their proportional representation in science was similar in both 1979 and 1983 (4.7 percent and 4.3 percent, respectively), the pattern in engineering was considerably more conspicuous. In 1979, Asian Americans received nearly 20 percent of engineering doctorates awarded. By 1983, however, the figure had declined slightly. Nevertheless, they continued to be overrepresented, especially among engineering doctorate recipients (NSF, 1986). These findings are consistent with previous findings (Astin, 1982; Berryman, 1983, 1985; and Maxfield, 1985).

Graduate Support Status

Among 1984 science and engineering doctorate recipients, universities were most frequently cited as the major source of support. Racial/ethnic disparities did arise with respect to both level and type of support received for graduate education. For example, more than one-half of whites and Asian Americans reported receiving university assistance. Comparable figures for blacks and Native Americans were less than 40 and 25 percent, respectively. Hispanics (45 percent) were least likely of all to report that universities were their main source of support. Other frequently cited sources of support were "federal" government and "self." Slightly more than one-half of Native Americans cited "self" support, compared to 30 percent of the whites and blacks, and 25 percent of the Asian Americans and Hispanics (NSF, 1986).

Most of those receiving university support, blacks being the exception, reported holding research assistantships rather than teaching assistantships. Racial/ethnic variations, however, did emerge. For example, slightly more than one-half of the Asian Americans and whites and about two-fifths of the Native Americans held research assistantships in 1984. In sharp contrast, slightly more than one-fourth of blacks held these positions--a pattern that may be explained, in part, by field distributions. Blacks, in comparison with other groups, were more highly concentrated in the fields of social science and psychology, where teaching assistantships are more often awarded (Blackwell, 1981; NSF, 1986; Pearson, forthcoming). Hispanics were least likely of all to hold research assistantships.

Postdoctoral Appointments

Although the numbers of racial/ethnic minorities holding postdoctoral appointments in science and engineering increased dramatically in the decade ending in 1983, this continues to be miniscule. Between 1973 and 1983, there was a sevenfold (from 28 to 215) increase in the number of black science and engineering postdoctorates. Comparable figures for Asians were 658 and 1,175. During the same period, the number of postdoctoral appointments held by Native Americans and Hispanics jumped from 0 to 11 and from 69 to 270, respectively (NSF, 1986).

In 1983, almost all postdoctoral holders, except Asian Americans, were in the sciences. For whites, almost two-thirds and one-fifth were in the life and physical sciences, respectively. Blacks were equally (one-third) distributed among the social and physical sciences. Nearly 60 percent of the Asian Americans were in the life sciences, while slightly less than 20 percent were in engineering. For Hispanics, more than one-half were in the life sciences, and one-fifth were in engineering. The few Native Americans tended to hold postdoctoral appointments in the life sciences (NSF, 1986).

The primary reasons given by minority graduates for declining to pursue postdoctoral appointments are similar to those given by other Ph.D. recipients: more promising career opportunities were available; the appointment was perceived as being of little or no benefit in terms of career aspirations; and the stipend was considered financially unattractive compared with alternative salary offers. It is speculated that the increasing uncertainty about careers in academic research may have had a greater influence on the career decisions of minority scientists than of other scientists. Minority graduates tended to be older and have more dependents at receipt of the doctorate (Coggeshall, 1981).

In their study of postdoctoral training in the biosciences, McGinnis, et al., (1982), reported several interesting findings:

- Postdoctoral trainees are more likely than others to take academic positions,
- Prestige of postdoctoral institution replaces doctoral prestige as the strongest predictor of the prestige of first academic position,
- Postdoctoral training has a positive effect on subsequent publication rates (due primarily to the fact that postdoctorals are usually concentrated in research-oriented sectors), and
- Postdoctorals get over 30 percent more citations to their publications than non-postdoctorals.

They believe that one of the major functions of postdoctoral training is that it facilitates intellectual mobility (the time to explore new areas of inquiry).

Some researchers (Coggeshall, 1981) express concern that the lack of postdoctoral experience may restrict the ultimate career achievement of minority scientists, especially in fields such as the biosciences, physics, and chemistry. In these fields, postdoctoral experience is generally regarded as valuable to careers, particularly in academic research. It is equally important for the scientific community and young minority scientists that they gain greater postdoctoral education.

Field Switching

The uneven distribution of racial/ethnic groups across various science and engineering fields is partly accounted for by field migration or switching. For example, some of the underrepresentation of blacks among science and engineering majors relative to the representation of other racial/ethnic groups is due to the fact that blacks tend to switch disciplines, especially to nonscience fields, as they ascend the educational ladder. Of the 1973-74 black Ph.D.s who had an undergraduate major in the life sciences, only 52 percent (versus 80 percent of whites) continued in that field for doctoral study. Similarly, in the physical sciences, slightly more than 40 percent of black doctorates who earned bachelor's degrees (compared to more than two-thirds of their white counterparts) continued in those fields for doctoral work while one-third switched to education (compared to slightly less than one-tenth of whites). Further, while roughly one-third of black doctorates earned bachelor's degrees in education, about 60 percent earned their doctorates in that field. Although this pattern of disciplinary migration is also evident for whites, it is considerably less pronounced (National Board on Graduate Education, 1976).

In a recent pilot study of the graduate enrollment decisions of undergraduate science majors who were Graduate Record Examination

(GRE) test-takers, Pearson and Powers (1986) confirm that blacks are more likely than whites (and Asian Americans) to report intentions to switch to a nonscience field, especially education, for graduate study. Overall, white test-takers were slightly more likely than Asian Americans to report intentions to migrate to another field, usually another science field. Unfortunately, the numbers of Hispanics and Native Americans in the sample were too small to make any definitive statements.

Summary

The underrepresentation of blacks and Hispanics (and to a lesser extent, Native Americans) in science and engineering graduate education is partly attributable to their overall low participation rates in graduate education. But the confluence of several factors appears to account for their representation, relative to that of other groups, in science and engineering graduate education. Because of differential retention patterns among the racial/ethnic groups, dissimilar strategies are needed to address their particular needs (Berryman, 1983; Wilson and Melendez, 1984).

Of the racial/ethnic groups covered in this review, blacks and Hispanics are most underrepresented in every phase of the science and engineering graduate education pipeline. While field choice and field retention play a large role in the underrepresentation of the two groups, precollege experiences seem to be at the heart of the problem. Perhaps a more fundamental issue to be gleaned from the low participation of some racial/ethnic groups in science and engineering graduate education is its potential to create barriers to equal opportunity.

Career Patterns

Transition from School to Work

Of recent science and engineering graduates who gained employment, not all were employed in the science and engineering work force. There is some evidence that the ability of young science and engineering graduates to secure science and engineering employment is significantly influenced by both degree level and field. For example, of those graduating in 1978, about one-half of the bachelor's degree recipients, but four-fifths of the master's degree recipients, had found degree-related employment by 1979. Employment patterns also varied significantly by field. In general, the data reflect a strong market demand for computer specialists and engineers, while physical science and mathematics degree holders were in somewhat lower demand (NSF, 1982).

Generally, an advanced degree is considered necessary for postdoctoral employment in the mathematical and physical sciences. To some extent, the increased demand for mathematical science degree recipients is associated with the increasing demand for computer specialists, the principal reason being that many of these with degrees in mathematics have found employment in computer specialties (NSF, 1982). These findings have obvious implications for some racial/ethnic groups given their generally lower representation, relative to that of Asians and whites, among doctorate holders in quantitatively based fields.

Employment Levels and Trends

Blacks and Hispanics are significantly underrepresented in science and engineering employment, while Asians generally are not. Among scientists and engineers, Native Americans equal their representation in the total U.S. labor force. In 1984, blacks and Hispanics accounted for only 2.3 percent and 2.2 percent of the employed scientists and engineers, respectively. During the same year, Asians accounted for about 5 percent (or 186,500) of all employed scientists and engineers, while Native Americans represented 0.5 percent (or 20,400) of the science and engineering work force (NSF, 1986).

In the 2-year period 1982-1984, employment of blacks rose by 27 percent, as compared to the 22 percent increase for whites. During the same time, employment of Hispanics climbed from 70,000 to 86,600, but their labor force proportional representation remained constant at about 2.2 percent. While employment of Native Americans increased more rapidly than that of whites (31 percent versus 22 percent), they still accounted for roughly the same share of the science and engineering work force over the 2-year period. The most phenomenal growth during the period was experienced by Asians, whose employment increased almost twice as fast as that of whites--39 percent versus 22 percent (NSF, 1986).

Even more significant differences arose among the groups with regard to employment of doctoral scientists and engineers. For example, in 1973, only 0.9 percent (or 2,000) of the doctoral work force was black. By 1983, that number had more than doubled (4,900). Despite an overall growth rate of 142 percent over the decade, black Ph.D.s continued to be extremely underrepresented (1.3 percent) in 1983. During the same decade, Hispanic representation increased dramatically from 0.7 percent (or 1,600) to 1.5 percent (or 5,400). Still, Hispanics also continued to be severely underrepresented in the science and engineering doctoral work force. Native Americans account for a minute fraction of all employed doctoral scientists and engineers. Between 1973 and 1983, for example, Native Americans' share of employed doctoral scientists and engineers remained unchanged (0.1 percent). In sharp contrast, the current representation of Asians among doctoral scientists and engineers is considerably higher than their representation among all scientists and engineers (8 percent versus 4.6 percent). Between 1973 and 1983, Asian employment increased nearly 190 percent, as compared to 62 percent and 142 percent for whites and blacks, respectively (NSF, 1986).

Field Distribution

Racial/ethnic groups differ significantly with respect to their distributions across fields. In 1984, blacks accounted for 5 percent of all mathematical and social scientists but less than 1 percent of the environmental scientists. Among doctoral scientists and engineers in 1983, black field representation was highest in social science (2.5 percent) and lowest in environmental science (0.2 percent). The field distribution of Hispanics in science and engineering is similar to that of all scientists and engineers. For example, approximately 55 percent of both Hispanics and the total were engineers. Among scientists, Hispanics are somewhat more likely to be social scientists. The field distribution of Hispanic doctorate holders is similar to that for all doctoral scientists and engineers.

Since 1982, the most rapid growth has been in the mathematical and physical sciences. In 1983, 70 percent of the Native Americans were concentrated in either psychology or the life and social sciences. In comparison to the other groups, Asians were more likely to be employed in engineering than science: in 1984, nearly two-thirds of Asians, as compared to slightly more than one-half of whites, were in engineering. Across scientific fields, Asians were most likely to be in computer specialties and least likely to be in psychology. The field distribution of Asian and white doctoral scientists and engineers differed substantially: in 1983, about two-thirds of Asians and slightly more than 80 percent of whites were employed in science fields (NSF, 1986).

With regard to professional experience, black and Hispanic scientists and engineers report fewer years of professional experience than do whites. In 1984, for example, about 40 percent of both blacks and Hispanics had fewer than 10 years of work experience, compared to nearly one-third of the whites and Asians. Among Native Americans, roughly one-fourth had less than 10 years of experience (NSF, 1986).

Racial/ethnic variations emerged with respect to scientists and engineers reporting 10 or more years of experience. For example, a higher proportion of Asians (23 percent) and blacks (20 percent) than whites (15 percent), Hispanics (15 percent), and Native Americans (12 percent) reported having 10-14 years of experience in 1984 (NSF, 1986).

Career Patterns

In comparison with other racial/ethnic groups, black scientists and engineers are less often employed in industry. In 1984, for example, slightly more than one-half of the blacks--compared to nearly two-thirds of the whites, Hispanics, and Native Americans and three-fifths of the Asians--were working in this sector (NSF, 1986; Pearson, 1985).

These findings are supported by recent studies of the employment patterns of various racial/ethnic groups who hold membership in the American Chemical Society (ACS). For example, Gaston and Pearson (1986) reported that black chemists were considerably less likely than whites to work in private industry (and government). This led the authors to speculate that private industry may provide different opportunities for blacks. In his study of Chinese ACS members, Tun (1986) found that slightly more than four-fifths were employed in industry. Much of the variation among racial/ethnic groups, with respect to industrial employment, may be accounted for by field choice and degree attainment. Thus, having a Ph.D., particularly in the natural sciences or engineering, increases employability in private industry. In 1984, an equal proportion (30 percent) of blacks and whites reported management or administration as their primary work activity across all sectors. Field differences also arose. For example, among engineers, one in three whites--compared to one in four blacks and Hispanics, one in five Asians, and two in five Native Americans--reported this sector as their primary work activity (NSF, 1986).

Among doctoral scientists and engineers employed by 4-year colleges and universities in 1983, roughly two-thirds of whites and Native Americans--compared to one-half of Asians, blacks, and Hispanics--held tenured positions. Among groups for which data were available, 6.5 percent of blacks held nontenure track positions compared to 9.8 percent, 12.9 percent, and 12 percent of whites, Asians, and Hispanics, respectively. Field differences also emerged. In general, scientists were about twice as likely as engineers to hold nontenure track positions (10.5 and 4.9 percent, respectively). Specifically, 4.6 percent and 10.5 percent of white engineers and scientists, respectively, were in these positions. Among Asians, 8.3 percent of engineers, compared to 14 percent of scientists, held nontenure track appointments (NSF, 1986).

However, scientists were only slightly less likely than engineers (62 percent versus 64 percent, respectively) to hold tenured positions (NSF, 1986). Among whites 67 percent of engineers and 62 percent of scientists were tenured. Comparable figures for Asians were 50 percent and 56 percent. For Hispanics, engineers (67 percent) were more likely than scientists (57 percent) to hold tenure. Unfortunately, comparable data were unavailable for blacks and Native Americans.

Labor Market Indicators

In 1984, labor market experiences differed considerably by racial/ethnic group. Overall, whites were more likely than minorities to be employed in science and engineering occupations and less likely to be unemployed. Specifically, 86.8 percent of whites were in science and engineering jobs compared to 81.3 percent of blacks, 90.8 percent of Asians, 78.3 percent of Native Americans, and 80.3 percent of Hispanics. Unemployment figures revealed that only 1.5 percent of whites but 2.7 percent of blacks, 2.4 percent of Asians, 3.4 percent of Native Americans, and 2.1 percent of Hispanics were not in the labor force. A more striking pattern emerged with regard to underemployment. For example, the underemployment rate for blacks (6.6 percent) was considerably higher than that of whites (2.5 percent), Asians (1.8 percent), Native Americans (2.9 percent), and Hispanics (4.2 percent) (NSF, 1986). Thus, these figures reveal major differences in the extent to which these various racial/ethnic groups participated in science and engineering.

In 1984, annual salaries varied across racial/ethnic lines. For example, black scientists and engineers earned salaries that were, on average, 87 percent of those of whites ($32,500 versus $37,500). Further, annual salaries for blacks were lower than those for whites across all science and engineering fields. In the field of environmental science, where the largest differentials occurred, salaries for blacks were roughly 81 percent of those for whites. In contrast, black computer specialists earned salaries that were about 91 percent of those of whites. Among doctorate holders, the black/white differential in annual salary was smaller: in 1983, black doctoral scientists and engineers earned median annual salaries of $37,000, or $3,100 less than their white peers (NSF, 1986).

Among recent scientists and engineers, salary differentials are more pronounced than those reported for the total science and engineering work force. Among those receiving bachelor's degrees in science in 1982 and 1983, blacks reported salaries that were approximately 70 percent of those earned by their white peers in 1984. Among engineering graduates, black/white salary differentials were negligible (NSF, 1986).

Across most fields, the average annual salaries for Asian scientists and engineers were above those of whites. For example, in 1984, salaries for Asians were $38,200 compared to $37,500 for whites. Except for the physical sciences and engineering, the salary differential favored Asians by 1-8 percentage points in all fields. While Asian physical scientists earned average salaries that were $1,000 lower than their white peers, salary differentials for Asians and whites in other disciplines were negligible. At the doctoral level, Asian and white scientists and engineers received essentially equal salaries--$39,500 and $39,800, respectively (NSF, 1986).

In 1984, Native American scientists and engineers generally averaged salaries ($40,500) that were above those of whites ($37,500). Hispanics report median salaries ($33,100) that generally are below those earned by all scientists and engineers ($37,400). Given their fewer years of professional experience, this finding is not unanticipated. While salaries for Hispanics averaged about 89 percent of those for all scientists and engineers, substantial field variation arose. For instance, Hispanic engineers earned about 92 percent of the salaries earned by all engineers. In contrast, Hispanic scientists earned roughly 82 percent of the salaries earned by all scientists. Among scientists, the differential ranged from 94 percent among environmental and life scientists to 73 percent among social scientists. Salaries for Hispanics lagged behind those for all scientists and engineers regardless of experience levels. Among doctoral scientists and engineers, Hispanics earned approximately 96 percent of the average salary ($38,200 versus $39,700) in 1983 (NSF, 1986).

Summary

In general, blacks and Hispanics are underrepresented in the science and engineering work force while Asian Americans, Native Americans, and whites are not. The most phenomenal growth in the science and engineering work force was made by Asian Americans. Asian Americans not only increased their numbers, but also their proportional representation. While other minorities experienced increased growth, relative to that of whites, their proportional representation in the science and engineering work force remained virtually unchanged. Blacks, relative to other racial/ethnic groups, were less often employed in industry. Overall, blacks and whites were equally as likely to hold managerial or administrative positions. Among scientists and engineers employed in 4-year colleges and universities, whites and Native Americans were more likely to be tenured. Asian Americans and Hispanics were more likely to be in nontenured positions. Overall, minorities were considerably more likely than their white peers to be both unemployed and underemployed. On average, minorities earned annual salaries below those of their white counterparts. Small differentials emerged among science and engineering doctorate holders. Some of the disparities among the groups seem to be related to their distribution across fields.

Summary and Conclusions

The underrepresentation of racial/ethnic minorities such as blacks, Hispanics, and Native Americans in science and engineering graduate education may serve to limit further participation in American society. Because of this situation, Smith (1983) argued that a major national effort is needed to attract minorities--particularly blacks, Hispanics, and Native Americans--away from their current restricted, traditional career choices to career choices in science and engineering. To accomplish this goal, she believes that prevailing counseling practices must be altered. Additionally, Smith argued that some of the assumptions and constructs underlying many career choice theories may have limited relevance when applied to racial/ethnic minorities, particularly blacks and Hispanics. Given that racial/ethnic minorities do not constitute a homogeneous group, Smith suggested that more studies in vocational psychology and related areas should focus on racial differences in career aspirations among several racial minority groups rather than comparing one racial minority group with whites. It is through these kinds of studies, Smith believes, that a greater understanding of the factors that lead to career choices of racial minorities will be accomplished.

This review has shown that graduate educational and career progress have not been uniform across racial/ethnic groups. Such progress seems to be related to a variety of factors such as history, patterns of assimilation, educational achievement, and career behavior (Smith, 1983). In general, the findings suggest the need for different educational policy strategies to address the unevenness of the progress made by various racial/ethnic minorities (the same condition applies equally to gender within groups).

In one of the few studies that has focused on the educational experiences of minority graduate students, Duncan (1976) provided some important research findings. This study included blacks, whites, Mexican Americans, and Asian Americans. In capsule form, Duncan found that:

- Minority students, especially blacks and Asians, were considerably more likely than whites to report that they rarely or never socialized with other students in their graduate department. Such a pattern of isolation would make developing and maintaining a realistic perception of one's competencies and liabilities, as well as strengths and weaknesses, rather difficult.
- Minorities were also more likely to feel depressed or lonely.
- Minorities were about three times (38 percent) as likely as whites (13 percent) to consider dropping out of the program either daily or a couple of times per week. The major reasons cited by minorities were lack of faculty encouragement and financial pressures, while whites usually reported uncertainty about the future.
- Most students, irrespective of race/ethnicity, had not been taught by a minority professor.
- Minority students were more likely to be shut off from most informal learning opportunities, such as small study groups, which are invaluable for in-class discussions and preparation for examinations. Because most graduate instruction takes the form of seminars, this lack of informal interaction with other graduate students further isolates the minority students.
- Minority students were usually uncomplimentary of their relationships with professors. In particular, Mexican Americans, blacks, and Native Americans believed that their professors viewed them, relative to white students, as less adequate and in need of remediation. Similarly, Asians stated that they were treated as individuals who had to be tolerated.
- Minorities (one-fifth) were somewhat less likely than whites (one-fourth) to report that a professor had helped them become a professional in their field of study. Relatedly, three-fifths of the minority students reported that they were on the fringes of their departments.

If these experiences are typical of minority graduate students in general, it is not surprising that so few minorities are in science and engineering. There is some evidence that institutions and departments with reputations of indifference or racism do not attract minority students. By the same token, the absence of a critical mass may be explained by that indifference or racism. Unlike professional schools, graduate schools have not usually mounted well-organized and systematic recruitment programs specifically designed to attract underrepresented students such as blacks and Hispanics (Blackwell, 1981). This is reflected in the fact that of the nearly 400 schools awarding doctorates in 1980-81, 211 did not award a single doctorate degree to blacks (Wilson and Melendez, 1984).

While the causes of the low representation of blacks, Hispanics, and Native American relative to that of whites in science and engineering graduate education is not fully understood, we do know that policymakers can improve the status of these groups by instituting efforts to increase the group's share of the initial mathematical/scientific talent pool or by reducing the group's attrition at each juncture in the education pipeline (Berryman, 1983). At the present rate, it will take many years before parity is reached, especially for blacks and Hispanics. Higher rates of enrollment with broader distributions will be necessary in order to offset usual attrition rates and normal patterns of field migration (Jackson, 1984). In the end, any progress in science and engineering will lie squarely on the shoulders of minority-group members themselves. Yet, the responsibility of the gatekeepers of the scientific community regarding equal opportunity cannot be ignored.

With an increase in the production of minority scientists and engineers, significant changes are likely to occur in the scientific and engineering work force. Current findings suggest that minority/majority profiles tend to converge somewhat among those holding the doctorate degree (Gaston and Pearson, 1986; NSF, 1986; Pearson and Gaston, 1985; Tun, 1986). This is particularly evident in the case of Asian Americans. Thus, the Ph.D. appears be a major barrier for race equity in science and engineering. This is not to argue, however, that with attainment of the doctorate, all differences will vanish because they will not. However, the differences will narrow considerably (Pearson, 1985).

It is important to point out that the employment patterns of Ph.D.s in the science and engineering work force, like in other work forces, is influenced by a number of factors, such as quality of training, disciplinary concentration and market conditions. For example, as a group there is no specific market for scientists and engineers. There are markets for individuals trained in particular disciplines, and these markets and disciplines do not always experience the same or similar conditions simultaneously (Office of Technology Assessment, 1985). A major problem confronting many minorities, especially blacks, is that they pursue graduate training in disciplines that are related to low-growth rather than high-growth industries.

A similar problem exists among individuals planning careers in academia. In a recent study of the career patterns of black and white Ph.D. scientists, Pearson (1985) reports that black and white graduates (between 1964 and 1974) of prestigious Ph.D. science departments began their careers in similarly ranked departments. Unfortunately, the proportion of blacks earning their doctorates in top-ranked science departments appears to be declining.

Finally, the results of this review reveal that much research is needed to better understand the causes of the continued underrepresentation of blacks and Hispanics in science and engineering. It is important, too, that we gain some understanding of those conditions that foster the overrepresentation of Asian Americans in science and especially in engineering. At the moment our knowledge of the graduate education experiences of various minority students in science and engineering remains limited. What little is known is largely dated, based on summary statistics, or highly descriptive. Nothing short of a comprehensive and systematic study is needed on the status of minorities in science and engineering education.

Our knowledge of role performances, communication patterns, job satisfaction, career decisions and patterns, perceptions of universalism, and motives for field migration also remains limited. While funding is needed to conduct studies at every juncture of the mathematics/science education pipeline, considerable knowledge is yet to be learned from those minorities who have successfully manuevered that pipeline. The benefits from a study would be enormous. The experiences of minority scientists and engineers would assist in developing educational policy strategies as well as in gaining insight into the coping mechanisms used by such individuals over their careers. Ultimately, funding agencies must determine the extent to which they are committed to sponsoring research on this topic. While some excellent biographies of black scientists are available, they provide little understanding of the experiences of the group as a whole. Nothing short of a well-financed, comprehensive, and systematic study will provide us with a broader understanding of the status of underrepresented minorities in science and engineering. Without such a commitment, our library shelves will continue to hold only a handful of books and articles on minorities in science and engineering.

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MINORITY UNDERREPRESENTATION IN SCIENCE AND ENGINEERING GRADUATE EDUCATION AND CAREERS

Cheryl B. Leggon

Much research documents the underrepresentation of minorities in science and engineering and identifies factors correlated with this underrepresentation. Much more research needs to be done in order to explain the causes of underrepresentation and overrepresentation and provide guidance for designing targeted intervention strategies. This discussion of Willie Pearson's paper focuses on the significance of intra-ethnic gender comparisons and the importance of targeting intervention strategies at different points along the scientific and engineering career path; finally, a promising paradigm for systematizing extant research findings is suggested as a necessary prerequisite to guide further research.

Significance of Gender Comparisons

At the beginning of his paper, Pearson states that "the principal assignment is to review the literature on the participation of blacks, Hispanics, and Native Americans in science and engineering graduate education and careers, relative to that of whites (and Asians) . . . ." Then, however, he states that his discussion will exclude the status of minority women in science and engineering. I contend that a discussion of the status of minorities in science and engineering must include, by definition, a discussion of the status of minority women. Excluding minority women implies that there is no significant difference between them and their male counterparts--an implication that the data do not support.

Most of the published sources on the underrepresentation of minorities in science and engineering careers contrast all majority persons to all members of one or more minority groups. Racial/ethnic groups are distinguishable by certain educational profiles (e.g., field selection, support in graduate school, time-to-completion of

*The author greatly appreciates the assistance of Susan Coyle and Betty Maxfield of the National Research Council staff in providing some of the data for this paper.

TABLE 1: Rates of Participation in Scientific Fields, by Degree, Ethnicity, and Gender: 1980-81 (in percent)

	Bachelor's		Master's		Doctorate	
Ethnicity	Men	Women	Men	Women	Men	Women
Blacks	0.50	0.63	0.40	0.63	0.40	0.27
Hispanics	0.34	0.38	0.34	0.34	0.25	0.16
Asian Americans	1.57	1.13	1.86	1.13	3.29	0.88

NOTES: Rate of participation = percentage of degree holders that a group comprises divided by its percentage of the population. Scientific fields include the biological sciences, computer and information sciences, engineering, mathematics, physical sciences, psychology, and social sciences.
SOURCE: Susan Chipman and Veronica G. Thomas, "The Participation of Women and Minorities in Mathematical, Scientific, and Technical Fields," unpublished paper commissioned by the Committee on Research in Mathematics, Science, and Technology Education of the National Research Council's Commission on Behavioral and Social Sciences and Education, 1984.

doctorate, and postgraduation plans), but these profiles do not necessarily describe the women of these groups. Combining data for both genders obscures the fact that differences within ethnic groups (intra-ethnic differences) may be as great as or even greater than differences between ethnic groups (inter-ethnic differences). For example, 1980-81 data show that among all doctorate degree holders in science and engineering, U.S. citizens who are Asian American participate in scientific careers at a rate three times greater than their proportion of the U.S. population. Broken down by gender, the rate for men is 3.29, while for women it is 0.88; this difference is larger than the inter-ethnic difference between Hispanics and blacks.

Disaggregation by gender reveals that the situations of men and women within minority groups can differ as much as the situations of men and women in the white majority--although not always in the same way (Chipman and Thomas, 1984). Like black, Hispanic, and white women, Asian American women are less well represented than their male counterparts among doctorate degree holders; however, unlike black, Hispanic, and white women, the ratio for Asian American women is lower than that for Asian American men at all three levels, although the greatest inter-gender difference occurs among Asian Americans at the doctorate level (Table 1).

Disaggregating data by gender reveals that minority women share the fate of those in their gender group as well as those in their ethnic group. Regardless of ethnicity, women are less well represented than men among holders of the doctorate. Moreover, within each group--black, Hispanic, Asian, and white--there is an inverse correlation between level of degree and proportion of women holding that degree. To illustrate: in 1981, blacks were only about half as well represented among recipients of bachelor's degrees as they were in the population as a whole. When the data are broken down by gender, however, the ratio of all bachelor's degree recipients to proportion of United States population is 0.50 for black men while the ratio for black women is 0.63; at the master's level, the ratio is 0.40 for men and 0.63 for women; and at the doctoral level, the ratio is 0.40 for men contrasted to 0.27 for women. Similarly for Hispanics in 1981, at the bachelor's level the ratio was 0.34 for men, but 0.38 for women; at the Master's level the ratios for Hispanic men and women were the same (0.34); but at the doctoral level the ratio was 0.25 for men but only 0.16 for women (Table 1).

From 1975 to 1985, both women and minorities increased their proportion among doctorate recipients. When the data is disaggregated by gender, two significant trends emerge:

(1) Each minority female subgroup grew in its proportion of total doctorates earned (Table 2), and
(2) All women increased their percentages within their respective ethnic subgroups (Table 3).

In 1975, black women earned slightly over one-third of the doctorates awarded to all blacks (34.5 percent), while Asian, Hispanic, and white women earned slightly over one-fifth of the doctorates awarded to their respective ethnic groups. In 1985, black women earned

TABLE 2: Women as Percent of All Citizens Earning the Ph.D., by Race and Year of Doctorate, 1975 and 1985

Ethnicity	1975	1985	Percent Change
Asians	0.2	0.8	300
Hispanics	0.2	1.1	450
Blacks	1.3	2.3	76
Whites	23.5	38.2	62

SOURCE: Unpublished data, Survey of Doctorate Recipients, National Research Council, 1986.

TABLE 3: Growth in Proportion of Women Ph.D.s Within Each Ethnic Group: 1975-1985 (U.S. citizens only)

	1975		1985		Percent
	Number	Percent	Number	Percent	Change
Asians	64	22.3	187	36.3	+ 62
Hispanics	61	20.1	261	46.7	+132
Blacks	349	34.9	531	58.4	+ 67
Whites	5,716	22.0	7,891	34.7	+ 57

SOURCE: Susan Coyle and Peter D. Syverson, Summary Report 1985: Doctorate Recipients from United States Universities, Washington, D.C.: National Academy Press, 1986.

more than one-half (58.4 percent) of the doctorates awarded to black Americans while Hispanic women earned almost one-half of the doctorates to Hispanics, and white and Asian women earned slightly over one-third of all the doctorates awarded in 1985 to their respective ethnic groups. Although by 1985 black women earned the largest percentage of doctorates awarded within their racial group, the greatest percentage increase among women earning doctorates between 1975 and 1985 occurred among Hispanic women, as shown in Table 3.

Because minority women share the fate of both the men in their racial/ethnic group as well as that of women, it is critical to analyze their situation separately from those of minority men and majority women. Such analysis not only highlights the differences of the rates of underrepresentation in science and engineering among and within minority groups, but also facilitates the identification of the causes and correlates of these rates, which, in turn, will facilitate the development, implementation, and evaluation of intervention strategies tailored, when necessary, to different race-gender groups.

Targeting Intervention Programs

In addition to being tailored to different population groups, programs designed to increase the participation of minorities in science and engineering can be tailored to different points along the career path. Although Pearson states that, at least for blacks, attrition occurs throughout the education pipeline, he proceeds to hypothesize that minorities' underrepresentation in scientific and engineering careers "probably stems largely from precollege experience." If attrition occurs throughout the education pipeline for blacks (and, as pre-

TABLE 4: Median Time-to-Degree for University-Supported Students, by Field, Race, and Sex, 1985 (U.S. citizens)

	Total	Asian	Black	Hispanic	White	Men	Women
All fields	8.0	8.1	11.0	9.0	7.9	7.6	15.3
Physical sciences	6.5	7.1	6.5	7.3	6.5	6.5	6.3
Life sciences	7.7	7.8	8.8	7.3	7.7	7.6	8.2
Social sciences	8.3	9.0	8.6	8.9	8.2	8.2	8.3
Engineering	6.6	7.3	6.3	7.5	6.6	6.7	6.2

SOURCE: Susan Coyle and Peter D. Syverson, Summary Report 1985: Doctorate Recipients from United States Universities, Washington, D.C.: National Academy Press, 1986.

vious discussion indicates, for women, too), then it seems reasonable to assume that strategies to increase minority participation in science and engineering should be applied throughout, and not be limited to a particular segment.

Education is the primary criterion for entry into scientific and engineering careers. A recent trend for programs designed to increase the number of underrepresented minorities in science and engineering seems to be to focus on the high school, junior high school, and elementary school levels; proportionately few programs focus on the graduate school level. Nevertheless, the low rate of participation in higher education is one substantial factor accounting for the underrepresentation in scientific careers of both minorities and women (Chipman and Thomas, 1984). One factor affecting the rate of participation in higher education is support. Graduate students receiving university-related support tend to finish their doctorates in less time than those not receiving such support. Differences among groups in their primary sources of graduate support are illuminating. Across all fields, more men than women report their primary source of support as university-related, 45.7 percent to 33 percent, respectively; correlatively, women take longer than men to complete the doctorate. Similarly, a smaller percentage of blacks than Asians and Hispanics report their primary source of support as university-related; the median time to complete the doctorate., across all fields, was 14.4 years for blacks, 11.8 years for Hispanics, but only 9.7 years for Asians (Table 4).

Is the difference that university-related support makes in an individual's scientific or engineering career only financial? Data suggest that insofar as this support can be interpreted as a university's vote of confidence in the awardee's ability to successfully pursue a career in science and engineering, that university-related support also provides socio-emotional encouragement. Graduate students can be just as discouraged by the lack of encouragement as by the presence of discouragement.

Suggestions for Further Research

After briefly summarizing diverse findings from several research studies, Pearson concludes that "nothing short of a comprehensive and systematic study is needed on the status of minorities in science and engineering education." A necessary prerequisite to such a study, however, is a systematic analysis of the entire body of relevant data already produced. This "meta-analysis" not only synthesizes existing research findings and identifies key variables impacting on the graduate education and careers of minorities in science and engineering, but also facilitates the identification of linkages among diverse research findings that have practical significance as well as statistical significance.

The sociological constructs of "cumulative advantage and disadvantage" seem particularly promising for analyzing the overrepresentation of some groups as well as the underrepresentation of others in science and engineering. In brief, these constructs view advantage and, conversely, disadvantage as a series of discrete gains and losses respectively, resulting in an overall advantage (or loss) that is greater than the sum of the discrete gains (losses). Each advantage increases the probability of receiving subsequent advantages. For example, research indicates that university-related support during graduate school may be a factor in accounting for the differences among groups in the time from the bachelor's degree to the doctorate. University-related support tends to be partially a function of field choice: research and teaching assistantships tend to be more prevalent in such fields as the natural sciences and engineering than in education.

Since Asian Americans tend to be more prevalent in the natural sciences and engineering and less prevalent in education, they are more likely to receive university-related support; consequently, Asian Americans are more likely to complete the doctorate in less than the median time. On the other hand, blacks and Hispanics tend to be concentrated in education, where they are less likely to receive university-related support; consequently, they take longer than the median time to complete the doctorate.

Cumulative advantage and disadvantage not only indicate that the effects of both advantage and disadvantage are synergystic rather than additive but also help us to design, target, and evaluate intervention programs more effectively. University-related support is of two basic types--research and teaching assistantships. Of the two, research assistantships are viewed as preferable because they provide socialization into the profession, as well as enhancement of research skills.

Among those receiving assistantships, data across all fields indicate that minorities tend to receive fewer research than teaching assistantships; consequently, minorities tend to be at a disadvantage in terms of acquiring research experience and opportunities. These findings indicate that intervention programs on the doctoral level should promote socialization into the profession in particular and into academe in general, as well as provide financial assistance.

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SUMMARY OF OPEN DISCUSSIONS

Statistical and Historical Overview

Roosevelt Calbert, of the National Science Foundation, commented on that agency's increasing financial support to minority institutions. In 1980, minority institutions received less than $500,000 in research grants. By 1986, the total had risen to over $4,000,000 to the same institutions--an increase of 700 percent. Minority researchers, he said, submit only four-tenths of one percent of all proposals to NSF. There is an urgent need to increase this number.

Herman Branson, Lincoln University, said that one factor associated with minority underrepresentation in science is the large number of black students who are attending 2-year, rather than 4-year, institutions.

Bob Jones, American Chemical Society, said that blacks who have been raised in this country seem to feel strongly that their work should reflect their "blackness." There is a tradition of blacks in medicine and in law because these individuals serve their local communities. Such a connection is much harder to make in the physical sciences and in engineering. Howard Adams, executive director of the National Consortium for Graduate Degrees for Minorities in Engineering, Inc., said that information is the key factor. Minority students need to know about career opportunities, about the importance of graduate education, and how to pursue their goals. He noted that although there is no tradition of blacks excelling in scientific fields, the number of minorities in engineering has increased since 1973 because information about career opportunities became available to students.

George Castro, Society for Advancement of Chicanos and Native Americans in Science, felt that the underrepresentation of minorities has been sufficiently documented, resulting in a number of successful efforts to increase minority participation. Resources should be concentrated on expanding those programs and on developing innovative programs for areas that have not yet been addressed. However, Gloria Denecochea, Carnegie Corporation of New York, noted the lack of minorities at levels where science education decisions are made and suggested that greater participation there would increase the number of role models for minorities.

Precollege Education in Science and Mathematics

Josephine Davis, Albany (Georgia) State College Graduate School, said that the gap in achievement between minority and nonminority students cannot be discussed without taking into account students' opportunities to learn mathematics. Some problems for minority students are that the content of mathematics courses is not standard nationally and that minority students have a high rate of repeaters in mathematics courses. She added that students understand the terms but are unable to apply them, citing the fact that blacks enrolled in advanced mathematics courses perform less well on achievement tests than Algebra I enrollees as a whole. Enhancing the overall learning experience must be a goal. Lloyd Cooke, chair of an Opportunities in Science Program in New York State, said a forthcoming report on ACT data shows that if one plots full years of college preparatory mathematics courses versus ACT scores for the last five years, the result is linear. Earlier data show a non-linear relationship because courses in business math, remedial arithmetic, and general algebra automatically excluded students from the college preparatory track. Howard Adams said that in looking at achievement test scores, it was important to note that the scores of minorities are improving and that the number of minority students taking these tests is increasing. That is evidence that the potential pool of minorities for science and engineering careers is increasing.

Dr. Branson cited a New York Times article that listed dropout rates for minority students after the ninth grade. The most recent statistics for the state of New York were 62 percent for Hispanics, 53 percent for blacks, and 46 percent for Native Americans. With these alarming dropout rates, how will there be sufficient minority representation in any field? Cora Marrett, University of Wisconsin, said there is some evidence that the dropouts are not confined to the poorest students. The school curriculum is so unattractive to some bright students that they are among the dropouts.

Discussion turned to the strengths and weaknesses of intervention programs. Richard Neblett, National Advisory Council for Minorities in Engineering, said that while intervention programs have been successful in retaining minority students who are already interested and who are doing well, such programs have had little success in actually expanding the pool of students. Melvin Webb, Clark College, said that one thing intervention programs do well is to put students in a healthy competitive environment. Another strength of intervention programs is the dedicated efforts of one or two individuals. However, he noted that in order to expand the pool, students must be reached before they fall behind in the system--that is, as early as the third grade--and teacher preparation must be improved. Michael Nettles agreed that because entire school systems are sometimes unable to attract and keep good teachers, teachers often are teaching outside their disciplines and the quality of instruction deteriorates. Nina Kay said that Huston-Tillotson College is working with NASA to build a data base on intervention programs and their impact; data will be broken down by race, ethnicity, and sex.

College Education in Science and Mathematics

Howard Garrison reviewed the data discussed in his paper on financial aid and persistence rates based on Astin's work. Amaury Nora said that his own study, in contrast to Astin's work, found student aid to have a large impact on persistence--more than grade-point average or other factors. His study was of Hispanic students (predominantly Mexican American) at 2-year institutions. Dr. Denecochea agreed that financial aid for minority students is an especially critical issue because many need support for their families as well. Drs. Branson and Manning expressed concern about the data being discussed, particularly the heavy use of test score statistics: Dr. Manning said that the caveats of the data are not sufficiently clear, and the issues are very sensitive. He feared that poorly understood data and studies could become the basis of important policy decisions. Dr. Ciriaco Gonzalez, director of the National Institutes of Health's Minority Biomedical Research Programs, said that emphasis on what intervention programs can accomplish would be more beneficial than concentrating heavily on statistics.

Discussion turned to the prevalence of females among black college students. One participant said he had heard that the current population of black students, particularly in predominantly black colleges, was primarily female and that the number of black male college students is decreasing. If this was correct, what implications are there for the future? Dr. Nettles said that this indeed was a major problem: in 1984, black women college students accounted for about 63 percent of black students. The overrepresentation of black women as compared with black men in science, added Dr. Denecochea, shows up as early as the seventh grade; in precollege programs in California, black and Hispanic girls outnumber boys by two or three to one.

Betty Vetter said the attrition rate for black and Hispanic students in higher education was important. Despite a slight increase in enrollment in the junior year, the completion rate is only 30 percent for black engineering students and 40 percent for Hispanic students. This compares to a 70 percent completion rate for the total class.

APPENDIX A

WORKSHOP ON MINORITIES IN SCIENCE AND ENGINEERING
National Academy of Sciences
November 21, 1986

Chair: Thomas W. Cole, Jr., President
West Virginia State College

8:30	Coffee	
9:00	Welcome, Introductions	James Ebert, National Research Council John Moore, National Science Foundation
9:30	Statistical Overview	Michael F. Crowley, National Science Foundation
9:45	Historical Overview	Kenneth Manning, MIT
10:15	Discussion	
10:30	Break	
10:45	Blacks and Native Americans at the Precollege Level	Cora Marrett, University of Wisconsin
11:15	Discussion	Michael Nettles, Educational Testing Service
11:45	Lunch	
1:00	Undergraduate Education for Blacks and Native Americans	Howard Garrison, Applied Management Sciences
1:45	Discussion	Michael Nettles
2:15	Hispanics' Precollege and Undergraduate Education	Richard P. Duran, University of California-Santa Barbara
3:00	Discussion	Amaury Nora, University of Houston
3:30	Break	
3:45	Graduate Education and Careers	Willie Pearson, Jr., Wake Forest University
4:30	Discussion	Cheryl B. Leggon, National Research Council
5:00	Adjournment	Alan Fechter, National Research Council

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