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ABSTRACT

The scientific literacy of the average citizen is primarily the result of formal education in science. Such education is very important in an increasingly technological society such as the United States. To get a feel for students' understanding and appreciation of science, it is important to examine their mastery of basic skill levels as well as their exposure to more advanced concepts. The goal of this report is to provide some of the data necessary to evaluate how well the secondary school system is meeting these goals. The focus of this initial report is on coursework in science and mathematics as one measure of the successes and shortcomings of the education system. The bulk of the analyses described in this document was carried out on the base year data from the High School and Beyond Study. Related data from other sources are discussed to fill out the picture provided by these analyses. Highlighted in this report are: (1) "National Trends"; (2) "Regional Diversity"; (3) "Physics and Chemistry"; (4) "Race and Ethnic Background"; (5) "The Gender Gap in Mathematics and Science"; and (6) "Post-Secondary School Plans." (CW)

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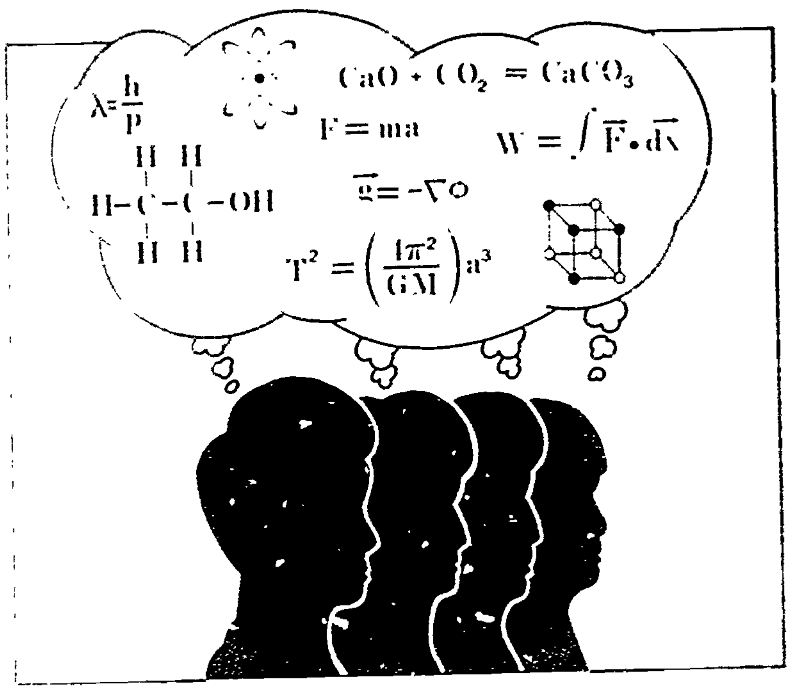
WHO TAKES SCIENCE?



A Report on Student Coursework in High School Science and Mathematics

Roman Czujko and David Bernstein

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WHO TAKES SCIENCE?

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INTRODUCTION

Education, in a conceptual sense, can be described as the interplay between the quality of instruction and the students' aptitudes, ambitions, and aspirations. Its purposes include informing students about the past, teaching them to open their minds to new possibilities, providing them with the tools to reach their full potential, and generally preparing them to lead productive lives. The information discussed in this report does not deal directly with the quality of teaching; rather, it focuses on the student and the structural components of the educational environment.

Our interest is in the specific role of science and mathematics in education. The scientific literacy of the average citizen is, in large part, the result of formal education in science. Such education has never been more important than in today's increasingly technological society. To get a feel for students' understanding and appreciation of science, it is critical to examine their mastery of basic skill levels as well as their exposure to more advanced concepts.

The goal of this report is to provide some of the data necessary to evaluate how well the secondary school system is working. Any examination of the education system begins with fundamental issues such as literacy rates, equal access to quality education, and high school completion rates. It also encompasses whether students have received instruction and counseling consistent with both their individual aspirations and the long term needs of the society.

The national interest in the efficacy of the education system today encompasses more than our basic humanitarian and egalitarian concerns. It is also in our own self interest to ensure the intellectual development of today's youth. As Harold Hodgkinson (1985) has pointed out, today's work force will find its retirement income generated by those individuals currently in the education pipeline. Furthermore, tomorrow's work force will be shrinking compared to the groups it will need to support. "In 1950, seventeen workers paid the benefits for each retiree. By 1992, only three workers will provide the funds for each retiree and one of the three workers will be a minority."

The focus of this initial report is on coursework in science and mathematics as one measure of the successes and shortcomings of the education system. The bulk of the analyses described in this report was carried out on the base year data from the High School & Beyond Study which is described later in this chapter. Related data from other sources are discussed, where appropriate, to fill out the picture provided by these analyses.

The analyses point to the following general trends. Most students who enter high school with solid basic skills in mathematics, reading and vocabulary get into a college preparatory program. The students on this academic track are the most likely to take physics, chemistry, intermediate and upper level mathematics. However, very few of those students who are not in college preparatory programs, including those with strong cognitive skills, take any of those science and mathematics courses. The likelihood of mastering the basics and of getting into a college preparatory curriculum is strongly related to:

1) where the student attends school;
2) the student's racial/ethnic background; and
3) the sex of the student.

It is recognized that there are other factors affecting the process of education and many of them are discussed in depth in the following pages. However, they appear to be of secondary importance to the main factors listed above. This report stresses that learning fundamental skills early does have a long term impact. It also identifies some of the segments of the high school population who are capable students but are not exposed to junior and senior level science and mathematics.

HIGHLIGHTS

National Trends

- Over three-quarters of the high school seniors in 1980 took algebra I, about half took geometry and algebra II, while less than one in twelve had taken calculus. Seniors were twice as likely to have taken chemistry than to have taken physics (37 and 18%, respectively).
- In 1980, the vast majority of states (39) had few, if any, statewide requirements in mathematics or science for a high school diploma. By 1985, 42 states required two years or more of each subject.
- The likelihood of a secondary school offering such courses as physics and calculus is related to the type of school (public, catholic, or other private), the state in which the school is located, and the size of the enrollment.
- About 28% of all high school seniors are both enrolled in a college preparatory curriculum and score above average on tests of mathematics achievement. The vast majority of all students who took calculus, trigonometry or physics come from this small group (79, 69 and 66%, respectively). Only a handful of students who were not in college preparatory programs, regardless of their cognitive skills, took any of those courses.

Regional Diversity

- The overall number of high school graduates is projected to decline by 10% between 1980 and 1998. However, the number of students graduating from the Mountain, West South Central and Pacific states will actually increase during that time period (23, 22 and 9%, respectively). Thus, a greater proportion of tomorrow's high school seniors will be attending school in many of those states that currently come out near the bottom on measures of education in mathematics and science.
- The students attending schools in New England and the Middle Atlantic States graduate with the most rigorous mathematics and science backgrounds: over one-third take trigonometry, nearly one-quarter take both physics and chemistry, and one in eight take calculus.
- Over half of the high school seniors in New England and the Middle Atlantic are enrolled in a college preparatory curriculum, most aspire to a bachelors degree or more, and they score above the national average on achievement tests in reading, vocabulary and mathematics.

- The students attending schools in the East South Central and West South Central graduate with the least rigorous mathematics and science backgrounds: only one-sixth take trigonometry, less than 10% take both physics and chemistry, and only one in twenty take calculus.
- Compared to high school seniors in any other part of the country, students in the East South Central have the lowest educational aspirations, score lower on achievement tests in reading and vocabulary, and proportionately fewer of them are enrolled in a college preparatory program (barely one-quarter).

Physics and Chemistry

- Most high school seniors (60%) have taken neither physics nor chemistry. Dramatic attrition occurs very early in the mathematics course sequence for students who do not take physics or chemistry.
- Among high school seniors, those who take physics have the highest achievement test scores in mathematics, reading and vocabulary. Physics students are also the most involved in extra-curricular activities.
- An educational process starting with mastering basic skills and enrolling in an academic curriculum will most likely result in students taking physics and chemistry as well as aspiring to graduate from a four year college.
- Less than one third of the women in a high school chemistry class will take physics, while over half of the men will do so.
- Nearly 60% of the students who take high school chemistry but not physics are female.
- Students who anticipate majoring in education during college are the least likely of any other surveyed major to have taken a high school course in physics or chemistry. Students who intend to major in the health sciences and social sciences are predominantly female and are most likely to have taken chemistry but not physics in high school.
- Students who anticipate majoring in engineering or the physical sciences during college are overwhelmingly male and are the most likely to have completed physics in high school.

Race and Ethnic Background

- There is a strong relationship between achievement levels in reading and mathematics. Students with below average reading skills are likely to exhibit similar problems in mathematics. Conversely, those with strong reading skills are likely to do well in mathematics.
- Among students with poor reading skills, Blacks and Hispanics are more likely than Asians or Whites to have problems with mathematics as well.
- Among students with strong reading skills, Asians and Whites are more likely than Blacks or Hispanics to have strong mathematics skills.
- 84% of the Black students and 78% of the Hispanic students score lower in the mathematics achievement test than the average White student.

- Among students with exceptional mathematics achievement test scores, Black students are more likely than students from any other racial group to take both physics and chemistry.
- Black students have high post-secondary school expectations but proportionally few are enrolled in college preparatory programs.
- Among seniors with above average achievement scores in mathematics, Hispanics are the least likely to be enrolled in a college preparatory program.

The Gender Gap in Mathematics and Science

- Females score lower than males on tests of mathematics achievement.
- Females and males are equally likely to take algebra I, but males are somewhat more likely to take geometry, algebra II and chemistry. In trigonometry and calculus, however, males outnumber females by 3 to 2.
- Male and females students who score equally well on the mathematics achievement test are equally likely to take chemistry and trigonometry. But females of high mathematics aptitude are somewhat less likely than males of similar aptitude to take calculus.
- Significantly fewer female students with exceptional achievement test scores in mathematics take physics compared to their male classmates with identical test scores. There appear to be unique barriers keeping females out of physics classes.
- Even though women are participating in the labor force and in higher education in record numbers, they are still heavily drawn into female dominated careers and infrequently move into traditionally male careers.
- Neither differences in mathematics achievement nor differences in mathematics and science coursework can account for the overwhelming gender-related differences in educational and occupational goals.
- In many ways, the aspirations of high achieving females resemble low achievers more than they do the aspirations of high achieving males.

Post-Secondary School Plans

- Students with strong cognitive skills have high educational aspirations and aspire to prestigious occupations.
- Educational plans are related to the type of curriculum in which students are enrolled. However, the relationship between occupational objectives and curriculum type seems even stronger.
- There is a strong relationship between long term goals and courses taken. Of the students who expect at least four year degrees, 60% took high school chemistry and 32% took physics. Of those who expect less than four year degrees only 10% took physics.
- Among the college bound, seniors intending to major in education are the least likely to have taken high school physics and intermediate level mathematics courses.
- Students who expect to graduate from two year institutions represent the most

heterogeneous group displaying a variety of abilities and occupational objectives.

- Of the students who expect to continue their education after high school, 72% expect to earn at least a bachelors degree. However, enrollment data indicate that many of those students will end up going to a two year college.

A NOTE ABOUT THE DATA

The bulk of the data upon which this report is based was collected in 1980. Thus, it is important to consider whether these data are relevant to today's school system. There are three basic reasons why these data should be examined even though nine years have passed since the respondents to the High School and Beyond Study (HS&B) were high school seniors.

First, the HS&B Study is comprised of a series of longitudinal surveys. The data collected in 1980 are the base year information describing individuals who were then queried about their work and educational histories in 1982, 1984 and 1986. Thus, the 1980 survey is an integral part of an unique information resource. Our next report will examine occupational and educational paths through 1986 of the senior class of 1980.

Second, the levels of exposure of high school students in 1980 to mathematics and science serve as an important benchmark against which recent changes can be judged. While a number of important changes have occurred in the education system since 1980, not all of the changes have been positive and most of them have not had a profound effect. The following are several examples of such trends.

- Most school districts around the country have increased high school graduation requirements and have apparently increased the proportion of their graduates who have a minimal competence in reading and mathematics. However, there has been little change in the proportion of high schools that offer junior and senior level mathematics and science today compared to 10 years ago (Weiss, 1987). Many of today's students are fulfilling the stricter requirements by playing catch-up and taking below-grade courses. In fact in 1986, "only about half of all 17 year olds ... reached a proficiency associated with material taught in junior high school mathematics" (Dossey et al, 1988).
- Only 20% of the senior class of 1986-87 had taken high school physics (Neuschatz and Covalt, 1988). This is barely higher than the 18% reported by the seniors of 1979-80 in the High School & Beyond Study.
- The high school graduation rates for Blacks has increased but the rate at which these Black graduates are attending college has gone down. Consequently, there are actually fewer Blacks enrolled in institutions of higher education in 1985 than there were in 1975 (Snyder, 1987).
- There is little evidence that women, even those with exceptional mathematics ability, are taking much more junior and senior level coursework in mathematics and science than those women who graduated in 1980. Furthermore, they are certainly not taking these courses with the same frequency as their male classmates. Consequently, the

question raised by Alice Rossi in Science back in 1965 "Women in science, why so few?" was still being asked in 1980 and is still a major concern in 1989.

Third, the 1980 data are more detailed and cover a wider range of personal, institutional, educational and attitudinal information than any other survey conducted since. Thus, these data can be used to better understand the factors that are related to science and mathematics education. This report is intended to do more than describe the mathematics and science background of high school seniors. Its primary goal is the examination of the features of the environment and the characteristics of the students that appear to facilitate or hamper education in mathematics and science.

Thus, while it is true that a higher proportion of today's high school students graduate and they take more science and mathematics coursework than those in 1980, the factors affecting the quality of their education are essentially unchanged. In short, it is the position of the authors that the relationship between data described and the issues raised in this report continue to be relevant to today's education system.

High School & Beyond Study Methodology

The principal data source for the high school science and mathematics report is the High School & Beyond Study conducted by the National Center for Education Statistics of the Department of Education[1]. In the spring of 1980, NCES surveyed a sample of over 28,000 (out of the population of 3 million) high school seniors. The overall student response rate was around 96%.

Each student responded to a 30-page questionnaire on course taking, demographic information, extracurricular activities, family circumstances, and both educational and occupational aspirations. These data were linked with information about the school each student attended and scores on a battery of tests in reading, mathematics and vocabulary.

These data benefit from being descriptive of past behavior but have three limitations that should be noted. First, many are self-report data and there are no transcripts available against which to validate these responses. Second, individual course grades are not available with which to measure how well a student has learned the material. Third, the data do not include the course taking of students who dropped out of school before the spring of their senior year in high school.

There are some errors of a self report nature in the HS&B data base (Fetters, Stowe & Owings, 1984). Those that most affect the analyses in this report have to do with the courses taken in mathematics and science. However, in a few of the cases dealing with courses taken in physics, corrective measures were employed to properly identify the students who actually did take that course. (See Appendix B for the rationale and extent of these data corrections.) Thus, some of the HS&B data presented in this report may not agree with other published reports.

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[1] The National Center for Education Statistics is now called the Statistics Center for the Office of Education Research and Improvement.

Corrections to the data make the relationships between taking physics and other education variables stronger. For example, it was observed that physics students had higher achievement test courses than students who did not take physics. After the data were adjusted for some students who incorrectly claimed to have taken physics, the group mean of the remaining physics students was even higher than before. As a result, the contrasts between the two groups - those who took physics and those who did not - became even greater.

Some errors may exist for the data on other science and mathematics courses as well. It is assumed that if it were possible to identify and correct mistakes in those data, the relationships between those courses and other educational variables might be strengthened as were those for physics students. In short, many of the conclusions drawn in this report are probably conservative and the effects noted may actually be more powerful than the self-report data indicate.

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CHAPTER 1
NATIONAL TRENDS

I. State Requirements

The level of exposure of high school seniors to mathematics and science is related to structural variables and the students' aptitudes and demographic characteristics. Before discussing the kinds of coursework taken by secondary school students nationally, it is appropriate to describe the local milieu in which these subjects are offered. We begin with a discussion of state requirements for a high school diploma.

In 1980, the majority of states had few, if any, specified requirements in mathematics and science. According to the National Association of Secondary School Principals (Parrish, 1982), nearly one-third of the states (15) did not specify a statewide minimum requirement in either area and deferred to local school boards to decide whether, and at what levels, standards should be set. Another 22 states only required one year each of mathematics and science.

During the early 1980's a great deal of concern was expressed regarding the adequacy of secondary school education (*A Nation at Risk*, 1983). This concern centered on two areas: first, the teaching of basic skills such as reading and mathematics, and second, the apparent failure of secondary shools to appropriately prepare students to be productive in an increasingly technological labor market (*Tomorrow*, 1984). According to the Education Commission of the States (1987), most states have now either set standards in mathematics and science or increased their minimum requirements. Thus, half of the states with no statewide minimums specified in mathematics and science in 1980 now require two, and in a few cases three, years of each (see Table 1). Similarly, almost all of those states which required only one year each of mathematics and science in 1980 have increased the minimums in those subjects to at least two years of each.

Setting higher minimum requirements in a subject area forces students to take courses in subjects that they might not ordinarily take.

TABLE 1. Number of states by level of graduation requirements in mathematics and science, 1980 and 1985.

Years of Mathematics	Years of Science	1980	1985
none	none	15	6
one	one	22	2
two	one	4	6
one	two	3	0
two	two	5	25
three	two	1	5
three	three	0	4
five		0	2

Sources: National Association of Secondary School Principals; and the Education Commission of the States.

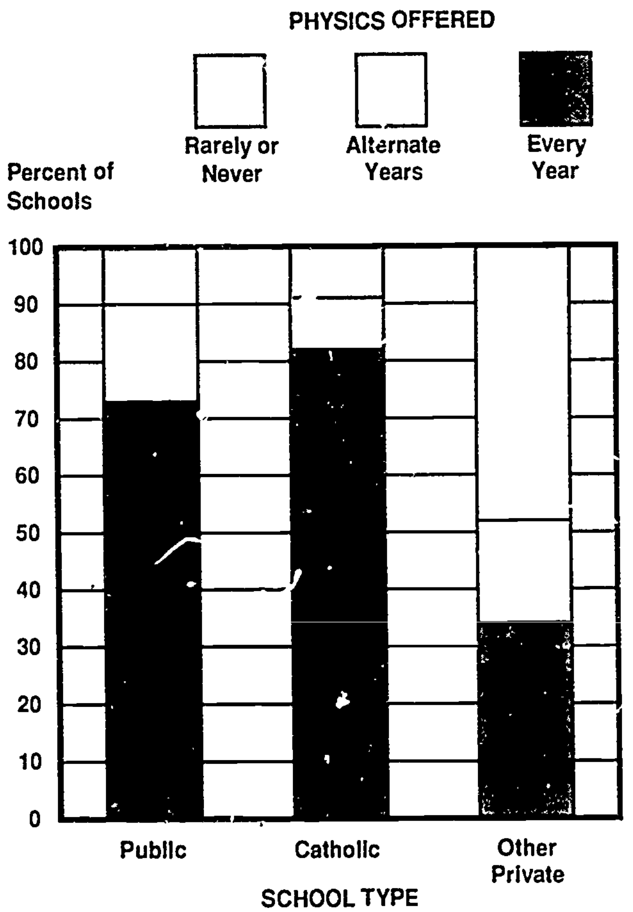

FIGURE 1. Percent of high schools offering physics by school type, 1987. (Source: American Institute of Physics)

However, the increase in minimum requirements may have only a minor impact on the frequency with which students take upper level courses such as calculus and physics. For example, many students complete requirements in mathematics by taking elementary courses such as remedial, general and business mathematics. As Figure 1 indicates, despite the increase in science requirements put into effect by the 1986-87 school year, fewer than three-quarters of all public secondary schools offered physics every year and approximately 10% infrequently, or never, offer it (Neuschatz & Covalt, 1988). Furthermore, there is considerable regional variation in junior and senior level course offerings. Public high schools in the south and west offer physics courses much less often than those in the east and north. (See Appendix A for a listing of the states in each geographic division.)

The pattern of physics offering in the private sector is quite different. Regardless of their geographic location, over 80% of catholic schools offer physics every year. In marked contrast, around half of all other private schools across the country, with the exception of those in New England, rarely or never offer a course in physics. In brief, then, the probability of attending a school that even offers certain classes such as physics is highly dependent on the type of school in which the student is enrolled and the state in which the school is located.

The likelihood of a school offering junior and senior level courses such as physics is also related to the size of the school. Secondary schools with small enrollments (i.e., senior classes of less than 50) are the least likely to offer physics (see Table 2). By contrast, schools with larger enrollments, which are almost always public schools, offer so many physics classes that it is not uncommon for them to have more than one teacher of physics. Thus as noted in Figure 2, comparatively few of the high school seniors (3%) in school year 1986-87 attended those public schools that rarely or never offer physics. The figure for catholic school seniors was similary low at 5%. However, nearly a quarter of all other private school seniors were enrolled in schools that never offer physics. Similarly, the trends in the offerings of other upper level courses such as trigonometry, calculus and chemistry appear to be related to geographic location, school type and size of institution (Weiss, 1987).

TABLE 2. Frequency that physics is offered by size of senior class, 1986-87.

Physics Offered	Average Senior Class Size 1-10 %	10-49 %	50-199 %	200+ %
Every Year	4	37	82	98
Alternate Yrs.	20	38	11	1
Never	76	25	7	1
Senior Enroll. (in thousands)	10	166	811	2028

Source: "Physics in the High Schools" AIP Pub. No. R-340, 1988.

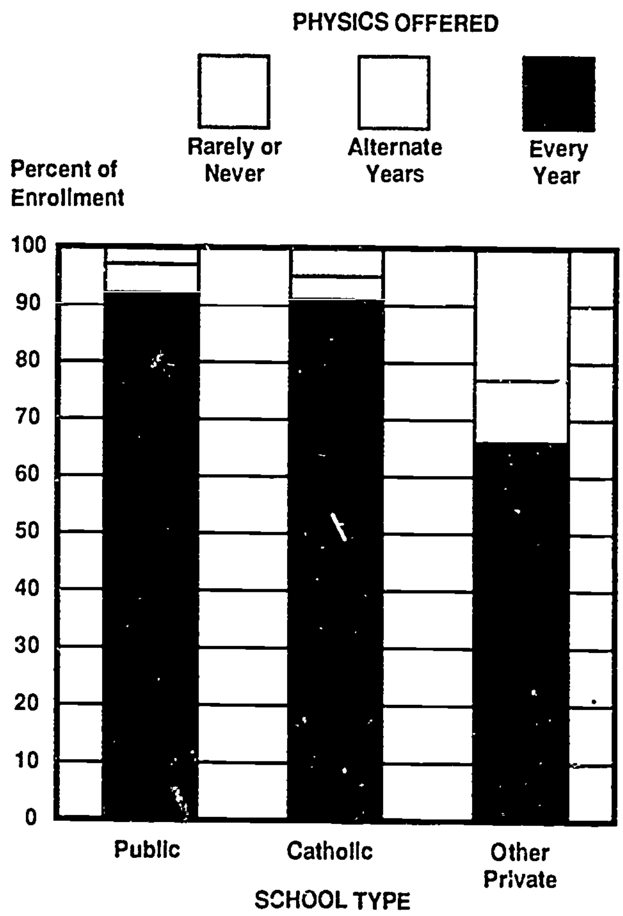

FIGURE 2. Percent of seniors enrolled in schools offering physics by school type, 1987. (Source: American Institute of Physics)

II. Mathematics

Students who were high school seniors in 1980 report that, on average, they took two years of mathematics during grades 10 through 12. In describing the exposure to mathematics, it should be recognized that courses do vary in difficulty and that courses in this subject do fall into a "typical" sequence. Algebra, geometry, and calculus form a sequence in that each is more difficult than the earlier. Consequently, over 95% of the students who took calculus had already taken geometry and over 95% of those who took geometry had already taken algebra.[1]

Figure 3 notes the percent of seniors who reported taking different mathematics courses in high school. Nearly four out of five students (78%) had reported taking a course in algebra, only half had taken geometry, and less than 10% had completed calculus. By comparison, a large segment had taken either remedial or general mathematics (30%). Since 1980, two years of mathematics has become the normative requirement for a high school diploma. Consequently, it is likely that, compared to students in 1980, a higher proportion of today's students have completed below grade courses such as general mathematics or have taken the first two courses in the traditional mathematics track, algebra and geometry. However, it is questionable whether requirements based only on years of study in a subject will have much impact on enrollment in junior and senior level courses in mathematics.

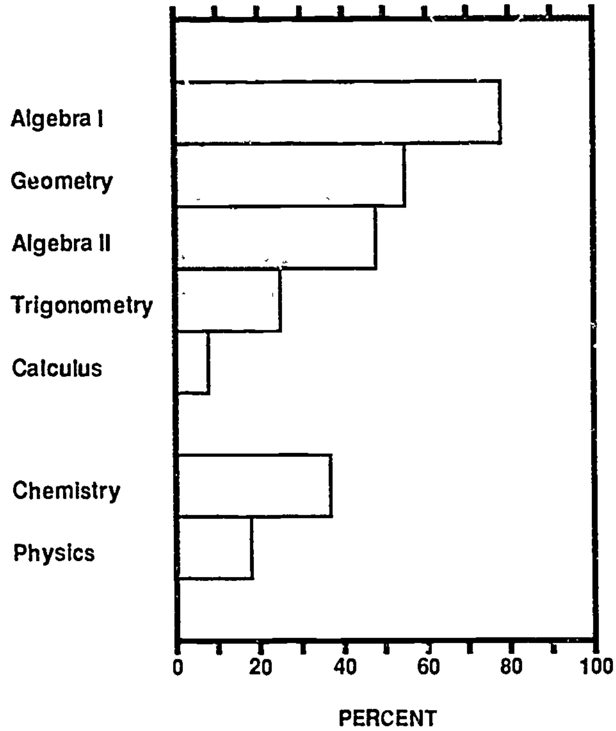

FIGURE 3. Percent of high school seniors who have taken selected mathematics and science courses, 1980.

III. Chemistry and Physics

High school seniors in 1980 reported that they completed about one and a half years of science during grades 10-12. As Figure 3 indicates, over a third had taken chemistry, but less than a fifth had completed high school physics. Science courses also form a sequence. The progression tends to begin with a course in general science or biology and then moves on to chemistry and ends with physics. However, the sequence found in science is not as rigid as the one in mathematics. In some schools, students are urged to take physics before chemistry, in some cases students take only physics for scheduling reasons and, in a few cases, students take several years of physics and no chemistry. Thus, fewer than half of all chemistry students had completed physics, and not all of the physics students (80%) had taken chemistry.

The sequences that mathematics and science courses form are based on more than difficulty. They are built upon a logical progression with a set of rules and principles that cut across the courses in a given area. However, upper level courses do more than enable a student to work through a problem faster or to solve a more complex version of a problem encountered in an elementary course. In comparing algebra with geometry, or chemistry with physics, it is essential to recognize that these

[1] Algebra II and trigonometry belong between geometry and calculus in the mathematics "sequence". However, not all students who took calculus report that they have taken algebra II or trigonometry. In part, this is because of a lack of uniformity in what the latter courses are called and in what they cover.

courses expose students to kinds of knowledge that are qualitatively very different. The content of courses in algebra and geometry, for example, are so dissimilar that a student who completes the former but not the latter is unlikely to learn, on his own, the information contained in geometry.

Graduation requirements that are based simply on years of study in a subject area do not adequately address the issue of what a student should learn. There is a need for a more detailed evaluation of curriculum content. Educators and local groups are being asked to confront such questions as: is there a minimum set of ideas that a student should be exposed to during high school? What kinds of knowledge should the average citizen possess to help the nation solve the tough technological problems of tomorrow? While this report does not answer these questions, it does describe the courses that high school students are taking.

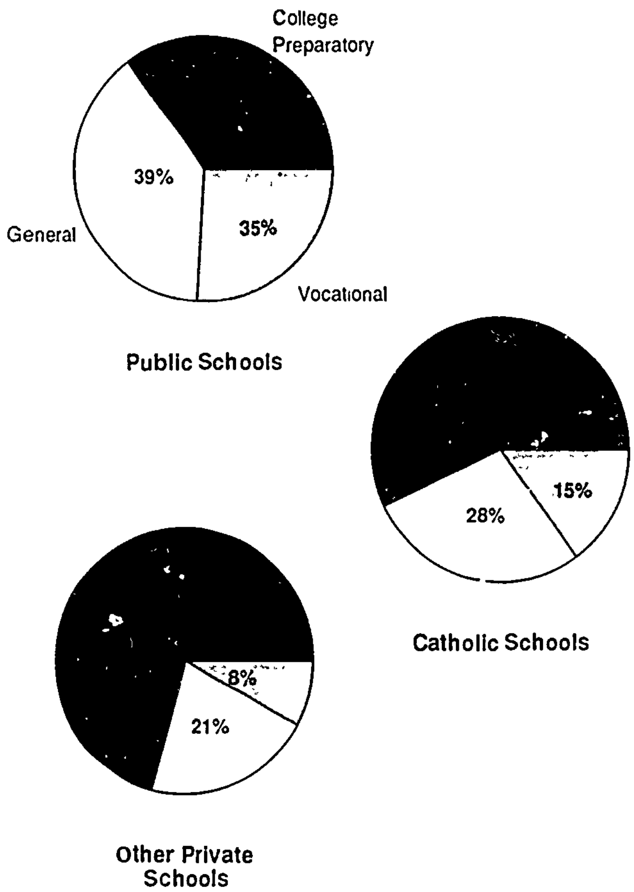

FIGURE 4. High school curriculum by school type, 1980.

TABLE 3. Mean standardized scores on achievement tests in mathematics, vocabulary, and reading by curriculum type, 1980.

	Mathematics	Vocabulary	Reading
College Preparatory	56	55	55
General	47	48	48
Vocational	46	46	46
National Average	50	50	50

Source: High School & Beyond Study

IV. Curriculum type

Overall, about the same proportions of high school seniors are enrolled in college preparatory and general programs (38% and 37%, respectively). The remaining quarter are taking a vaocational sequence.[2] However, these base rates differ by the type of school the student is attending. As noted in Figure 4, only about a third (35%) of public school students are in college preparatory programs, over half of catholic school students (57%) and nearly three-quarters of other private school attendees (71%) are in such programs. Conversely, the bulk of enrollment in vocational programs is in the public school system. In fact, it is almost as high as the enrollment in general programs within the public schools.

The type of curriculum in which students enroll is related to a variety of indicators of educational background including: basic skills learned, number of mathematics and science courses completed, and hours spent on homework. On many measures of achievement and rigorousness of background, however, there is little or no difference between students in general and vocational tracks. By contrast, those in college preparatory programs excel along every dimension. Thus, as Table 3 indicates, students

[2] The distinction between college preparatory, general and vocational curricula may be a fuzzy one in some schools. However, the differences based on the students' self report are quite pronounced clear. If it were possible to eliminate the ambiguities in how the curriculum labels were applied, the actual differences might be even more striking.

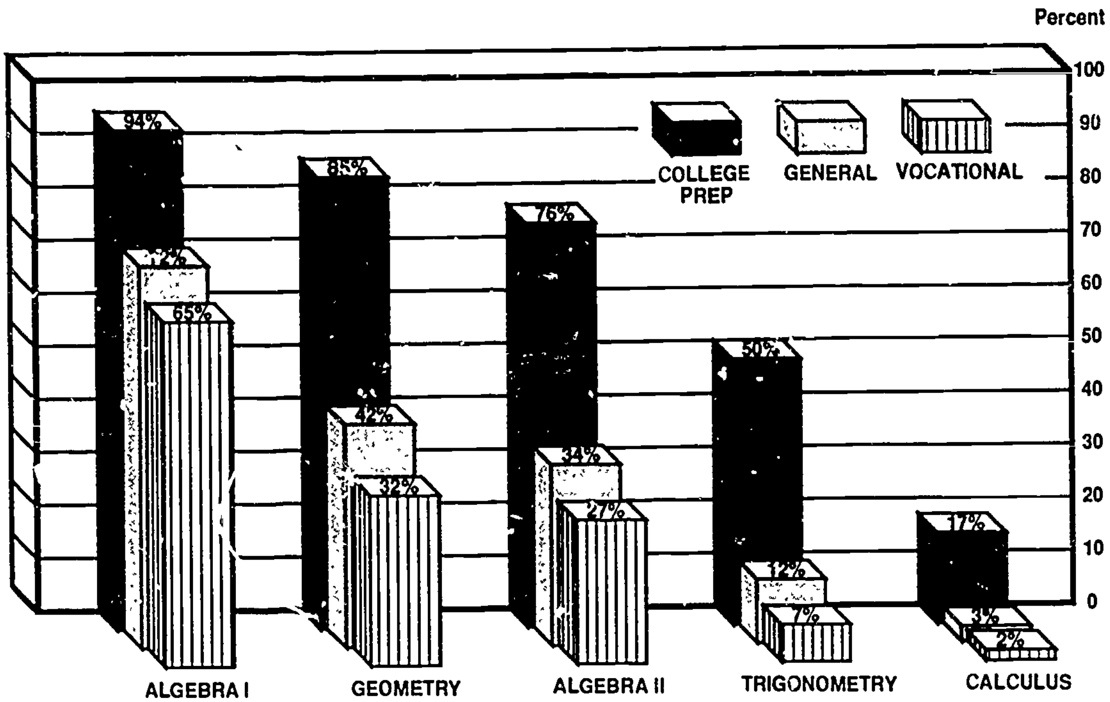

FIGURE 5a. Percent of high school seniors who have taken selected mathematics courses by curriculum type, 1980.

in general programs score, on average, only a point and a half higher than those in vocational programs on the battery of tests in mathematics, reading and vocabulary. However, they average seven points less than those in college preparatory sequences[3].

Clearly, one expects students in college preparatory programs to take a more rigorous course of study than the average student. In designing their high school programs, they must keep in mind both the entrance requirements of the college that they aspire to attend and the specific backgrounds that might be expected of them in their prospective fields of study. Students enrolled in college preparatory programs take considerably more mathematics and science than those in general or vocational sequences (see Figure 5). Nearly all of the students in a college preparatory curriculum had taken geometry, one in six had completed a course in calculus, and two-thirds had taken either chemistry or physics. Only one third of those enrolled in college preparatory programs, however, had completed both chemistry and physics.

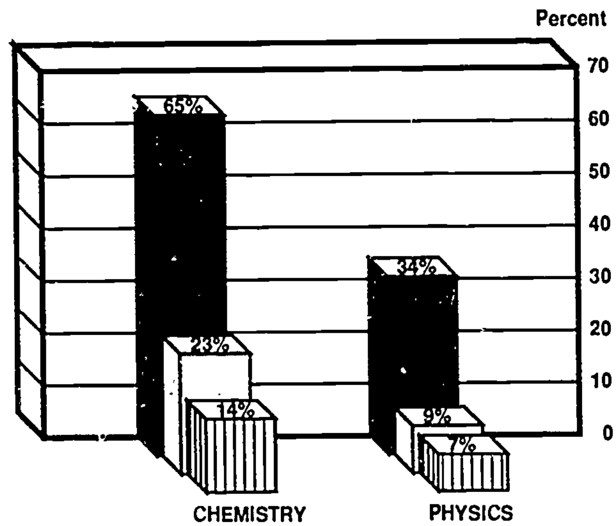

FIGURE 5b. Percent of high school seniors who have taken selected science courses by curriculum type, 1980.

It is also true that many high school students who intend to go to college are advised

[3] Test scores were standardized to a mean of 50 with a standard deviation of 10. There were two parts (of 25 and 8 items) to the mathematics test and two parts (of 15 and 12 items) to the vocabulary test. To strengthen the reliability of these data, only the averages of the two mathematics scores and the two vocabulary scores are reported. Combining pairs of test scores reduced the standard deviation to 9.

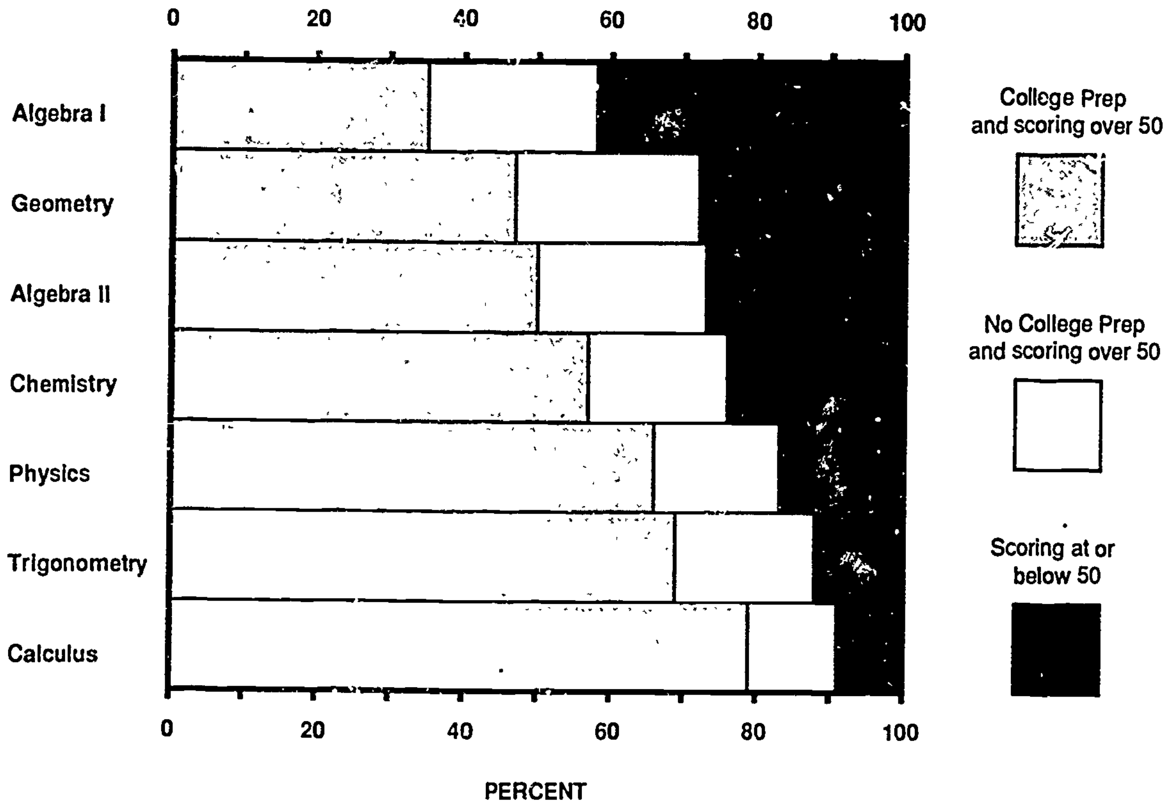

FIGURE 6. Percent of high school seniors who have taken selected mathematics and science courses by mathematics achievement scores and enrollment in a college preparatory program, 1980. Test scores were standardized to a mean of 50 with a standard deviation of 10. There were two parts (of 25 items and 8 items) to the mathematics test. To strengthen the reliability of these data, only the averages of these two scores were used. Combining the scores reduced the standard deviation to 9.

against taking courses such as calculus and physics. Both of these senior level courses are considered difficult and few colleges require them. Thus, students who do take calculus or physics run the risk of lowering their GPA. Many colleges do look at GPA as part of their admissions decisions.

Virtually none of the students in general or vocational programs had taken calculus and about three-quarters had completed neither a chemistry nor a physics course. In addition, these students were only half as likely as college preparatory students to have completed a course in geometry. Thus, the overall level of mathematical and scientific literacy of high school graduates who were in general or vocational programs is minimal at best.

Most students who score above average in the mathematics portion of the battery of tests administered in HS&B are enrolled in a college preparatory program. Those students who have above average ability in mathematics and are in a college preparatory program comprised about 28% of the senior class. Junior and senior level mathematics and science courses draw almost exclusively from this small, academically-elite group (see Figure 6). The bulk of all seniors who took calculus, trigonometry and physics (79, 69 and 66%, respectively) come from this select group. The majority of the remaining students who took these courses also have above average mathematics aptitude scores but, for whatever reason, are not in a college preparatory program. Chemistry, algebra II and geometry, while not quite as concentrated, draw almost as heavily from these same student populations. In short, only a handful of those students (60% of all seniors), who neither are in a college preparatory curriculum nor possess above average mathematics ability, ever take junior or senior level mathematics and science.

In some secondary schools the distinction between a college preparatory curriculum and a general one may be fuzzy. In addition, only a minority of the students in general programs expect to earn a bachelors degree. However, the actual number is high enough that one must question the advice that these students receive from counselors and teachers in developing a course of study consistent with their academic aspirations. The next report will examine the degree to which completion of a general rather than a college preparatory curriculum in high school affects success in college. Regardless of the outcome of those analyses, however, the data will not be able to answer the question of cause and effect. Did these students do poorly on tests of achievement because they did not take a demanding course of study in high school or were they advised to take an easier curriculum because of pre-existing deficiencies in their basic skills?

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CHAPTER 2
REGIONAL DIVERSITY

Decisions regarding secondary school education are made at the state and local level. This chapter is intended to provide regional groups with information needed to evaluate the adequacy of the mathematics and science education that students in their areas are receiving in high school. Ideally, this chapter should be based on state by state analyses. However, the data from the High School & Beyond Study cannot be disaggregated to that level. Thus, the comparisons are made across nine geographic divisions.

As noted previously, students who were high school seniors in 1980 reported that, on average, they took two years of mathematics and about one and a half years of science during grades 10 through 12. However, these national trends vary greatly by geographic location. Even though most states, in 1980, stipulated few if any requirements in science or mathematics, students in various parts of the country exhibited very different tendencies in course taking in these subjects. Many regional factors play a part. Two such factors are certainly the require-

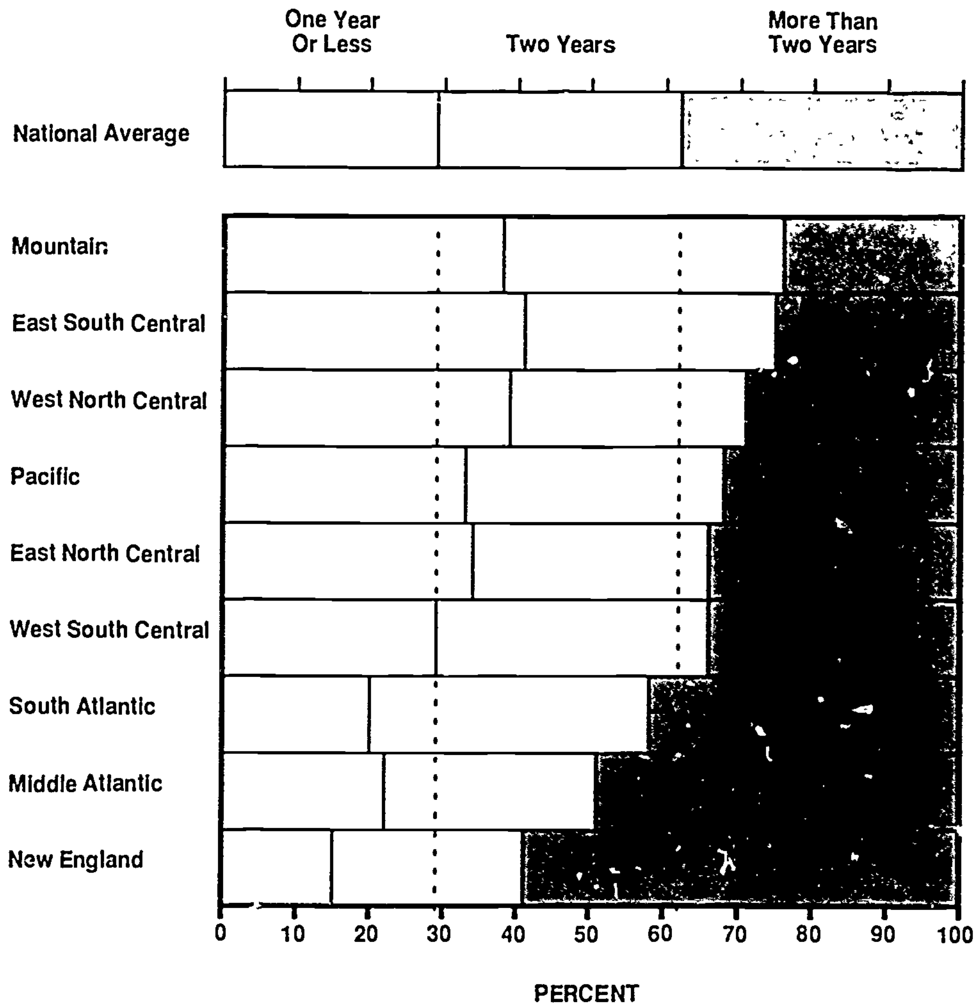

FIGURE 7. Years of mathematics completed during grades 10 12 within each geographic division, 1980.

ments set by many local school districts and the entrance requirements set by the colleges and universities which the student hopes to attend.

1. Mathematics

High school students in some parts of the country graduate with the minimum possible years of mathematics and science, while the norm in other areas is to take several years of each subject. As illustrated in Figure 7, half and more of the high school seniors in New England and the Middle Atlantic states take more than 2 years of mathematics during grades 10-12 [1]. In sharp contrast, the seniors in the Mountain and East South Central states are only half as likely to have completed that many mathematics courses.

The regions in Table 4 are ordered by the percent of their high school seniors who completed geometry. Within mathematics, this subject exhibited the greatest variability across the geographic divisions. The differences are so great that seniors in New England were as likely to complete a geometry course as those in the East South Central were to complete a first level algebra course.

The regions that rank high in Table 4 are generally the same as those whose students are the most likely to complete many years of mathematics (see Figure 7). The differences in relative position reflect the degree to which students are completing "traditional" mathematics sequences versus taking several elementary and below grade-level mathematics courses. Seniors in the East North Central states are an example of the traditional mathematics track. They are slightly below the national average in number of years of mathematics taken. However, they are above the national average in both the percent of their students who completed algebra and the percent completing geometry.

Conversely, there is reason to believe that students in some areas are satisfying their mathematics requirement by taking the most rudimentary courses. The students in the West South Central are apparently an example. Over 70% of the seniors in this area completed two or more years of mathematics during grades 10-12, but fewer than half of the seniors had taken geometry and, more strikingly, proportionally fewer took calculus than in any other geographic division. These data appear to support the concern that raising requirements for graduation may have little effect on advanced training, although stiffer requirements might have an impact on basic skill levels.

TABLE 4. Percent of high school seniors who have taken selected mathematics courses within each geographic division, 1980.

	Algebra I %	Geometry %	Algebra II %	Trigonometry %	Calculus %
New England	84	70	64	35	12
Middle Atlantic	79	63	57	40	12
East North Central	81	59	47	25	8
Pacific	79	56	47	22	6
West North Central	77	52	42	22	6
South Atlantic	75	51	46	21	7
Mountain	79	47	39	16	6
West South Central	77	47	48	17	4
East South Central	71	40	36	15	5
National Average	78	55	48	25	8

Source: High School & Beyond Study

[1] See Appendix A for a listing of the states in each geographic division.

II. Science

A strong mathematics background is generally seen as an important prerequisite for the successful completion of junior and senior level science courses. Thus, it is not surprising that the pattern for the number of years completed in science closely resembles that for the number of years completed in mathematics. The geographic divisions that occupy the high and low ends of the spectrum on science taking, as depicted in Figure 8, are the same as those at the extremes in mathematics taking. While 37% of the high school seniors in New England and the Middle Atlantic states took more than two years of science during grades 10-12, only 15% of the seniors in the East South Central completed that many science courses.

The level of the science courses completed by students varies by geographic location of the school. Once again the students in New England and the Middle Atlantic states excel as noted in Table 5. Nearly one-quarter of them take both chemistry and physics in secondary school. By comparison, only about 10% of the high school seniors in the west and the south have that rigorous a background in science. In fact, two out of three of their students do not complete a course in either chemistry or physics.

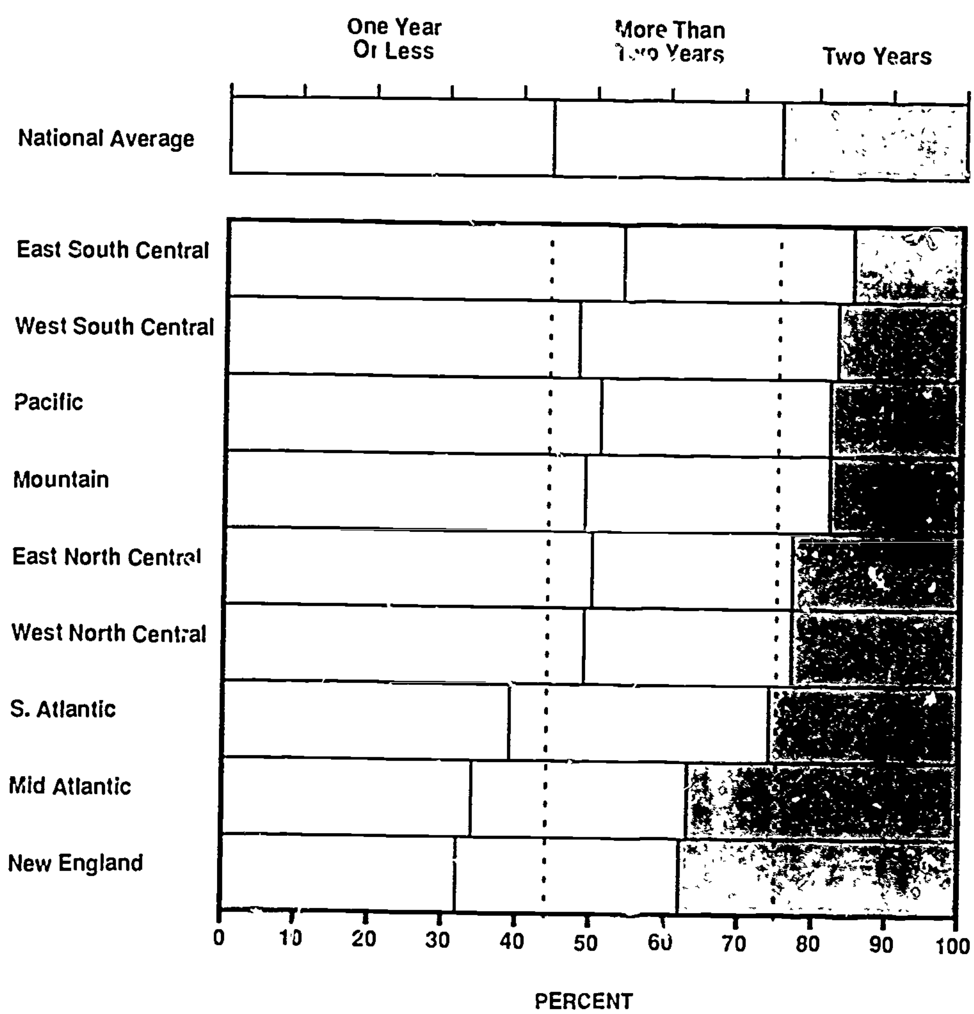

FIGURE 8 Years of science completed during grades 10-12 within each geographic division, 1980.

These regional differences in the completion of science courses may have serious implications in both the short and long term. Because of their weak preparation in mathematics and science, the high school graduates from the south and west may be precluded from sucessfully pursuing college level majors in these fields (Sells, 1978). In fact, they may have difficulty in pursuing any major that requires a strong background in mathematics or physical science.

Although the states in the west and south have set stronger graduation requirements in mathematics and science, the future does not look promising. These two areas of the country have higher proportions of their populations among primary school age than the north and east. As Figure 9 indicates, the overall number of high school graduates is projected to decline by 10% between 1980 and 1998 (McConnell & Kaufman, 1984). However, the number of students graduating in the Mountain, West South Central and Pacific states will actually increase during that time period (23, 22 and 9%, respectively). Thus, a greater proportion of tomorrow's high school seniors will be attending school in those states that currently come out near the

TABLE 5. Percent of high school seniors who have taken selected science courses within each geographic division, 1980.

	Both Physics and Chemistry %	One Course Only %	Neither %
MA	23	29	48
NE	22	33	45
ENC	15	25	60
SA	14	26	60
WNC	14	22	64
Pac	11	22	67
Mtn	10	23	67
WSC	9	22	69
ESC	9	21	70
Nat'l Avg	15	25	60

Source. High School & Beyond Study

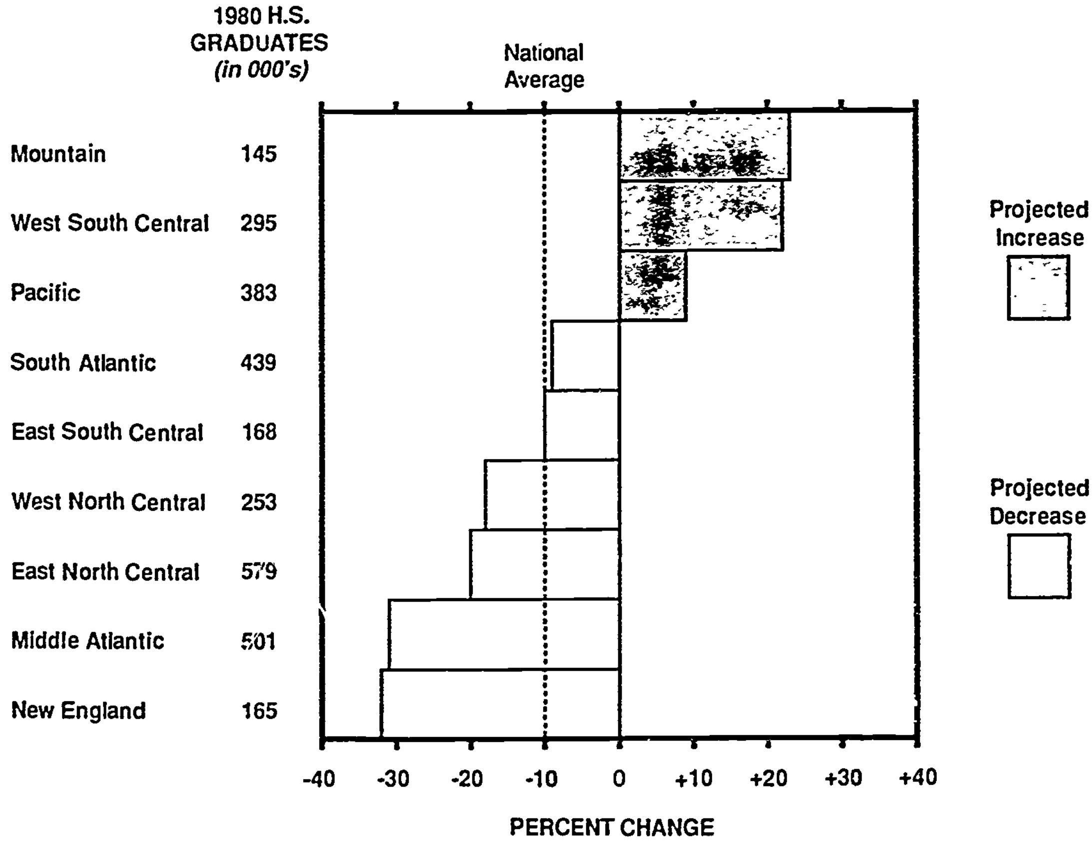

FIGURE 9. Projected change in the number of high school graduates between 1980 and 1998 within each geographic division. (Source. Western Interstate Commission for Higher Education)

bottom on most measures of education in mathematics and scie... The pressures of enrollment growth may make it difficult for these states to improve their offerings in these subjects.

The quality of education in the East South Central is particularly troublesome. The seniors in this area have consistently come out last on all measures of high school preparation in mathematics and science. The East South Central is the only region where fewer than three-quarters of the potential graduates completed a first level algebra course in high school and more of them take no chemistry or physics than in any other area. Thus, these students are likely to find it difficult to participate fully in today's increasingly technological labor market. In summary then, it appears that inadequate mathematics and science preparation of high school students is a deeply rooted problem in specific regions and states.

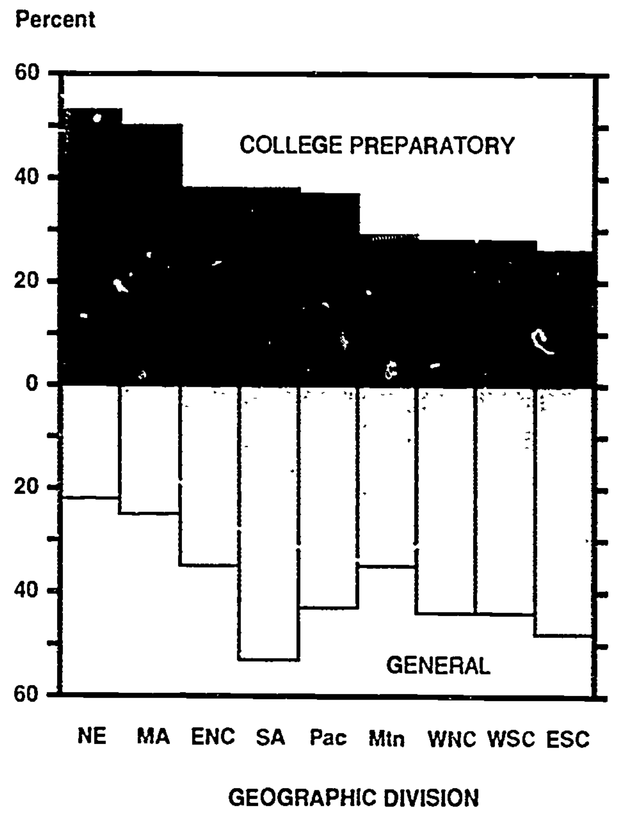

FIGURE 10. Percent of seniors enrolled in a college preparatory or general curriculum by geographic location, 1980.

III. Curriculum and Educational Expectations

One of the major determinants of the rigorousness of the mathematics and science background that students receive is the curriculum type in which they are enrolled. The likelihood of enrolling in a college preparatory program varies substantially by geographic location. As noted in Figure 10, over half of all high school seniors in the New England and Middle Atlantic states are enrolled in college preparatory programs. By marked contrast, barely one-quarter of the students in the East South Central, West South Central, West North Central and Mountain states are enrolled in such programs.

The low level of secondary school education in the East South Central extends beyond mathematics and science. Proportionally fewer of the students in this area are enrolled in college preparatory programs, they have the lowest educational aspirations and they score lower on reading and vocabulary tests than seniors in any other geographic divison (see Tables 6 and 7). It should be noted that these data are based on students who are on the verge of graduation. As indicated in Figure 11, the East South Central also has the highest high school drop out rates in the country. Presumably the dropouts in this region are even less prepared than their classmates who made it to the spring of their senior year. These trends may be related to the high level of poverty in the East South Central. However, the economic data available in the HS&B study are neither sufficiently detailed nor reliable enough to allow an in depth analysis of these issues.

Those few students enrolled in academic programs in southern and western states are receiving a background in mathematics and science below the national norms (see Table 8). College preparatory students in the Mountain and southern states are significantly less likely than their classmates across the nation to have completed courses of intermediate difficulty in mathematics: geometry, algebra II and trigonometry. Similar trends are to be found in science education. College preparatory students

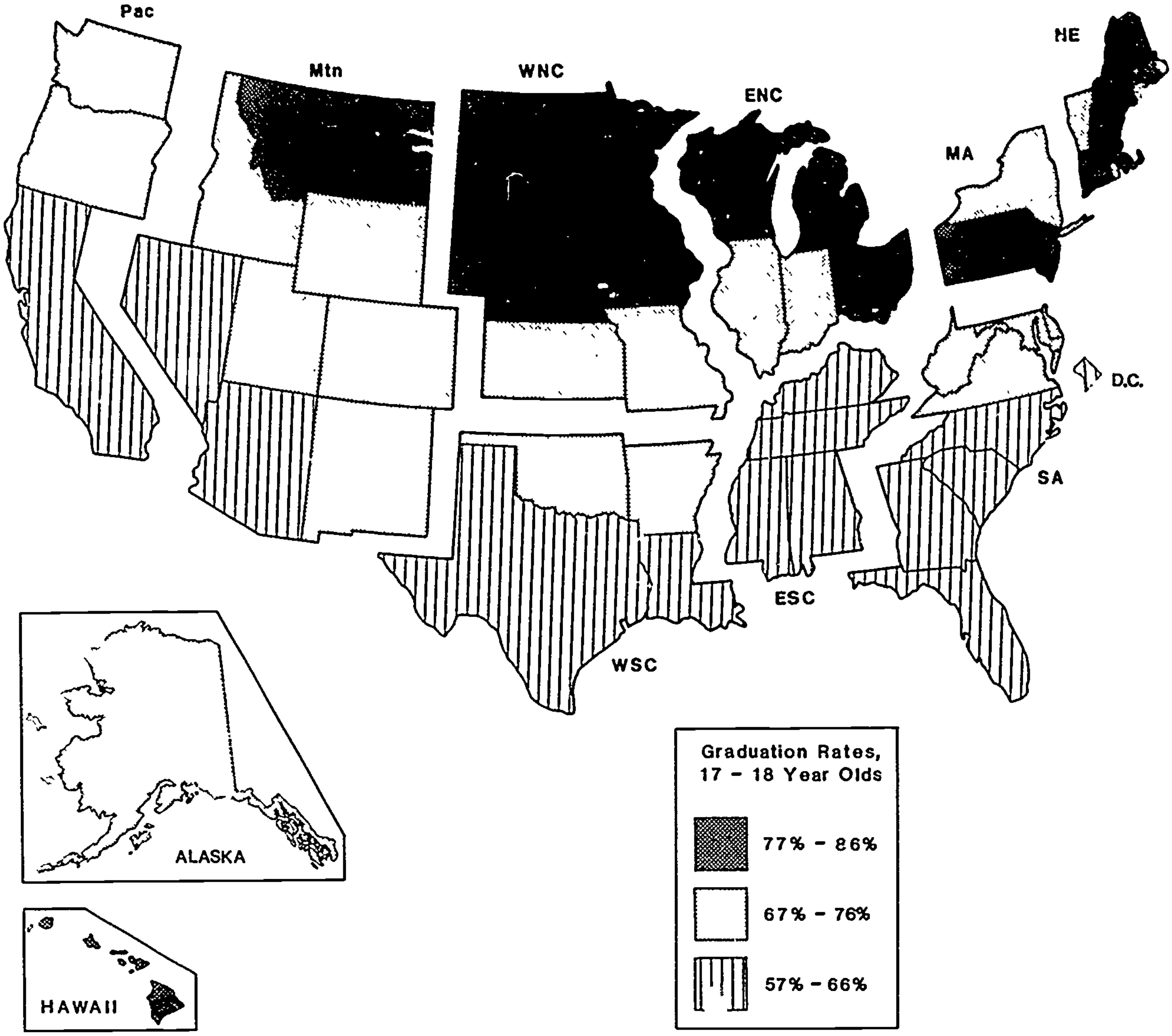

FIGURE 11. High school graduates as a percent of all 17 and 18 year-olds within each geographic division, 1980. (Source: U.S. Department of Education)

TABLE 6. Level of educational aspiration within each geographic division, 1980.

	High School %	Vocational Training %	Two Year College %	Bachelors or higher %
NE	18	18	14	50
MA	21	16	12	51
SA	21	23	12	44
ESC	24	24	12	40
WSC	23	21	11	45
ENC	21	24	11	44
WNC	19	30	9	42
Mtn	.6	28	14	42
Pac	14	21	17	48
Nat'l Avg.	20	22	12	46

Source: High School & Beyond Study

TABLE 7. Mean standardized scores on achievement tests in mathematics, vocabulary and reading within each geographic division, 1980.

	Mathematics	Vocabulary	Reading
NE	52	53	52
MA	52	52	51
WNC	51	50	51
ENC	51	50	51
Pac	51	50	50
Mtn	49	49	50
SA	48	48	48
WSC	48	48	48
ESC	47	47	48
Nat'l Avg.	50	50	50

Source: High School & Beyond Study

TABLE 8. Percent of college preparatory seniors who have taken selected mathematics and science courses within each geographic division, 1980.

	Trigonometry %	Calculus %	Both Physics and Chemistry %
NE	58	22	37
MA	65	21	39
ENC	48	16	32
SA	43	14	30
WNC	45	14	32
Pac	44	13	24
WSC	45	10	23
Mtn	35	15	23
ESC	36	14	23
Nat'l Avg.	50	17	31

Source: High School & Beyond Study

in southern and western states graduate with a weaker science background than the national average. Over 40% of the college preparatory students in the Pacific, Mountain, West South Central and East South Central completed neither a physics nor a chemistry course in high school. Thus, these states lag behind the rest of the nation even in educating their most academically motivated students.

It is recognized that not all students aspire to a college degree and, of those who do, not all must have an exceptionally strong mathematics and science background. However, it must be noted that the proportion of high school seniors who expect to earn a college degree varies less across geographic location than enrollment in college preparatory programs. New England and the Middle Atlantic states are the only areas that have a close correspondence between enrollment in college preparatory programs and aspiration to a bachelors degree. By comparison, the Pacific region boasts the third highest level of educational aspiration but their level of enrollment in college preparatory programs is below the national average.

Students in southern states have the largest disparity between their enrollment in academic curricula and their educational aspirations. More of these students, by 50%, expect to earn a college degree than are enrolled in college preparatory programs. Conversely, of the southern students in a general curriculum, a higher proportion anticipate earning a four year college degree than in any other geographic location. The reasons for and implications of this difference between preparation and expectation are discussed in depth in Chapter six.

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CHAPTER 3
PHYSICS AND CHEMISTRY

The extent to which students take science courses is one indication of their level of general interest and overall involvement throughout high school. But a simple tabulation of the number of years of science taken is, at best, only a partial reflection of students' science backgrounds. Such a tabulation could not differentiate between students who take two years of elementary science and those who take more involved courses during the junior or senior years. Information regarding specific science courses in the High School and Beyond Study focuses on physics and chemistry. While the data do not distinguish between first level coursework and advanced placement courses in either science subject, several clear patterns emerge regarding student achievement and involvement in the high school experience.

Students who take a course in physics or chemistry display a broad range of scholastic characteristics which set them apart from the rest of the senior class. Physics and chemistry are typically taken in the junior or senior year, so by the time students have enrolled in these courses, they have completed more science and mathematics than most of the graduating seniors. As will be described in this chapter, there is a strong relationship between overall high school achievement and exposure to mathematics and science.

The majority of students (60%) have not taken either chemistry or physics, while about one quarter of all seniors took only one of these science courses. The smallest group consists of those who have studied both subjects. These select students account for only about one sixth of the high school seniors.

Physics follows chemistry in the typical high school sequence. Thus, over 80% of the students in a given physics class took or will take chemistry. In contrast, only 40% or the students in a given chemistry class will take a high school physics course. It follows that of the students who take only one of the two science courses, most take only chemistry. This chapter examines the relationship between such science coursework and other features of the educational experience. The focus will be on students of different backgrounds: those who take physics, those who take chemistry but not physics and, finally, those who take neither of these courses in high school.

I. Students who have taken physics

Less than one-fifth of high school seniors have taken physics. As expected, a high percentage score well on the achievement test in mathematics, with over three quarters of them scoring above the mean. They also excel in reading and vocabulary. Over two thirds are above average in these cognitive skills. Figure 12 illustrates the comparative scores on mathematics, reading and vocabulary achievement tests among students with different science backgrounds. As will be seen in Chapter 4, there is a strong relationship between reading and mathematical skills. Basic reading ability is an important pre-requisite for capable performance in mathematics. In turn, mastery of both of these skills enables students to explore a wide variety of subjects in depth.

Grades are another measure of educational achievement. Even though the data are all self-reported, they are accurate within a fluctuation of approximately four percentage points (Fetters, 1984). Figure 13 draws a comparison of high school grades among students with different science backgrounds. Students in physics report having the highest overall grades.

The students who take physics maintain high grades while tackling difficult courses. Most are enrolled in a college preparatory curriculum, as illustrated in Figure 14. Since physics is usually taken during the junior or senior years, these students have taken a number of other science courses. Additionally, over two thirds of these students stay on the mathematics track through trigonometry. They are also nearly

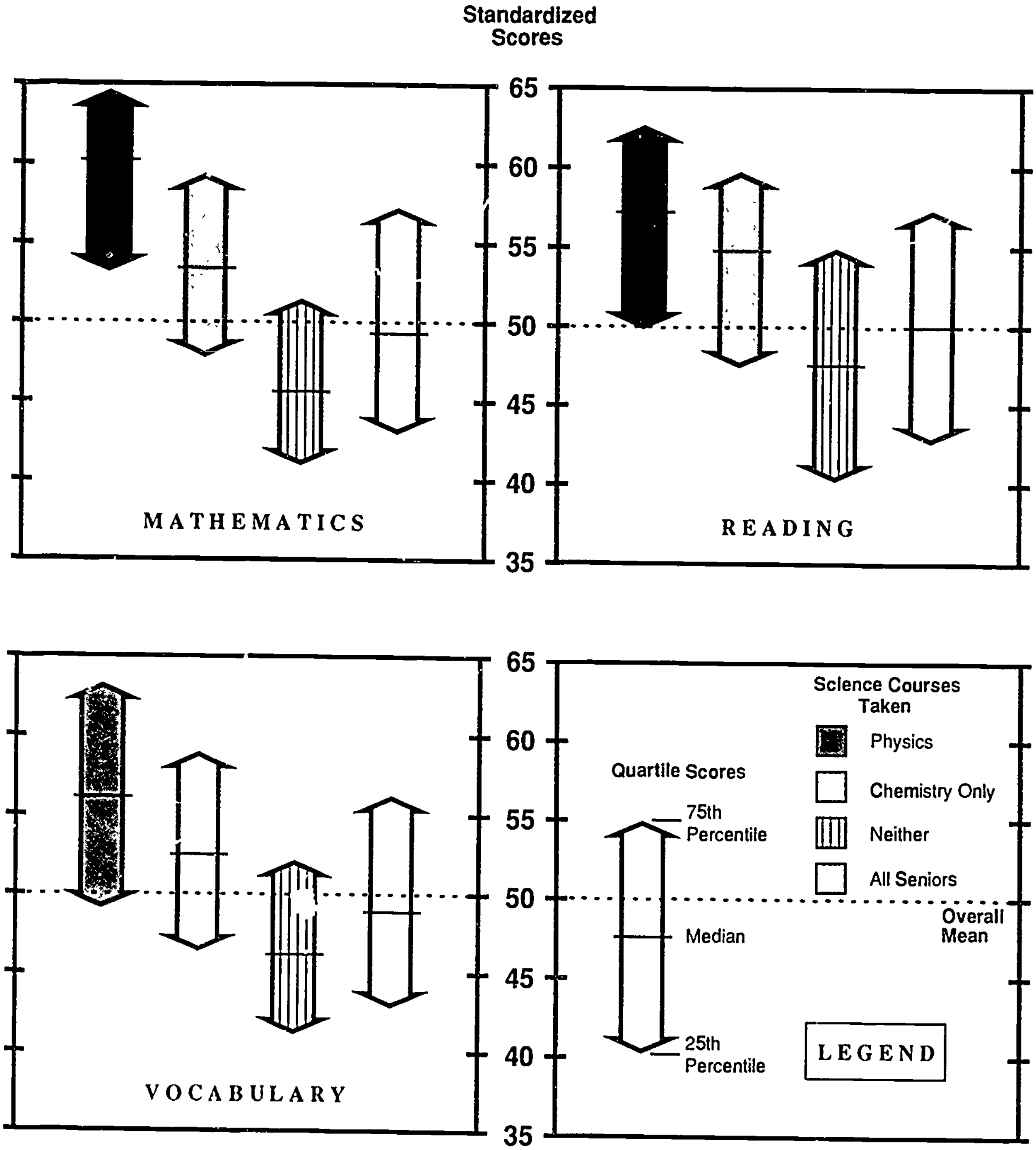

FIGURE 12. Median and quartile standardized scores on achievement tests in mathematics, vocabulary and reading by students' science background, 1980. Scores were standardized to a mean of 50 with a standard deviation of 10. There were two parts (of 25 items and 8 items) to the mathematics test and two parts (of 15 items and 12 items) to the vocabulary test. To strengthen the reliability of these data, only the averages of the two mathematics scores and the two vocabulary scores were used. Combining pairs of test scores reduced the standard deviation to 9.

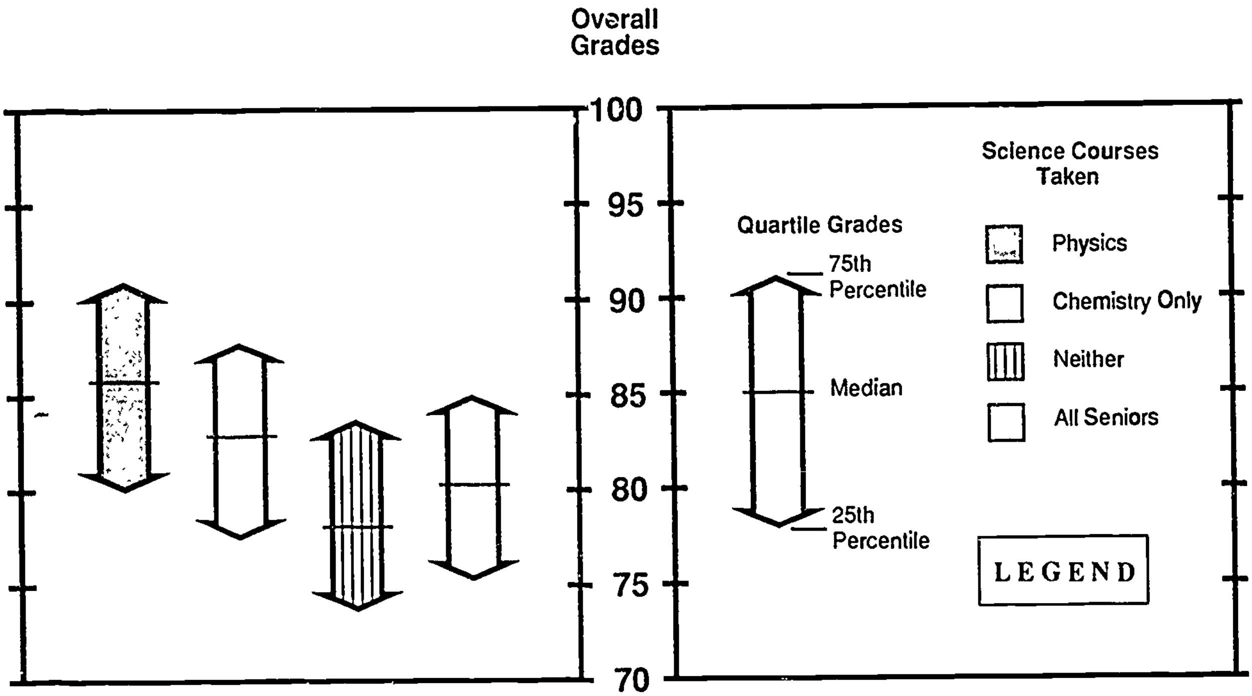

FIGURE 13. Median and quartiles for overall grades as reported by seniors with different science backgrounds, 1980.

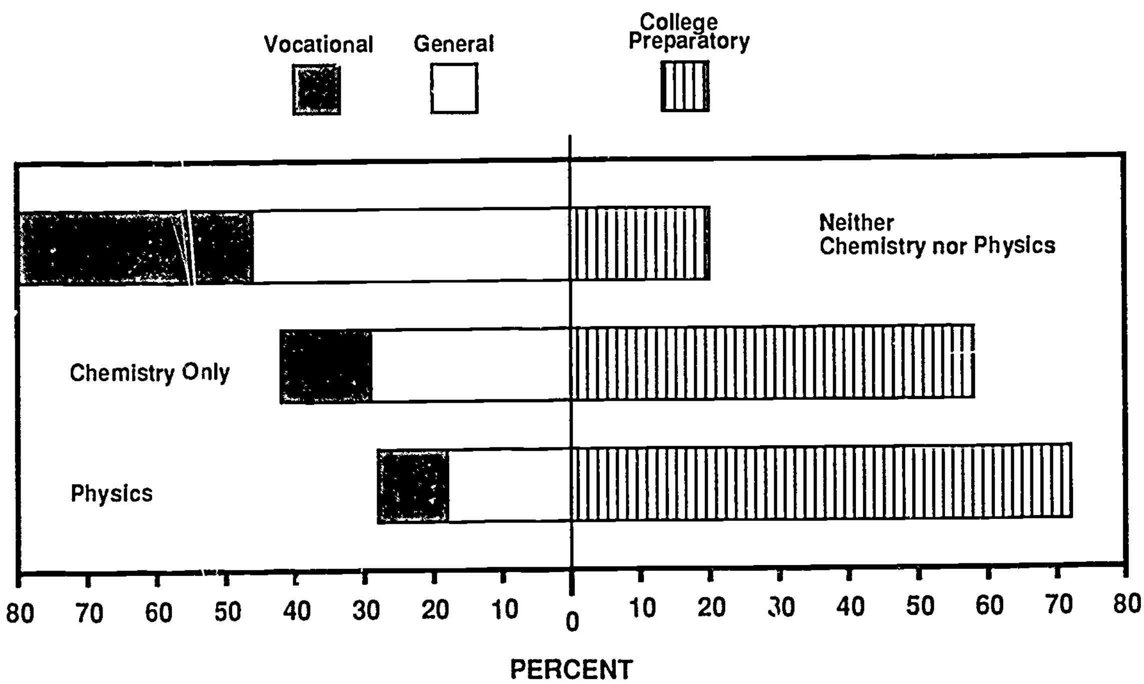

FIGURE 14. Percent of seniors enrolled in high school curriculum types by science background, 1980.

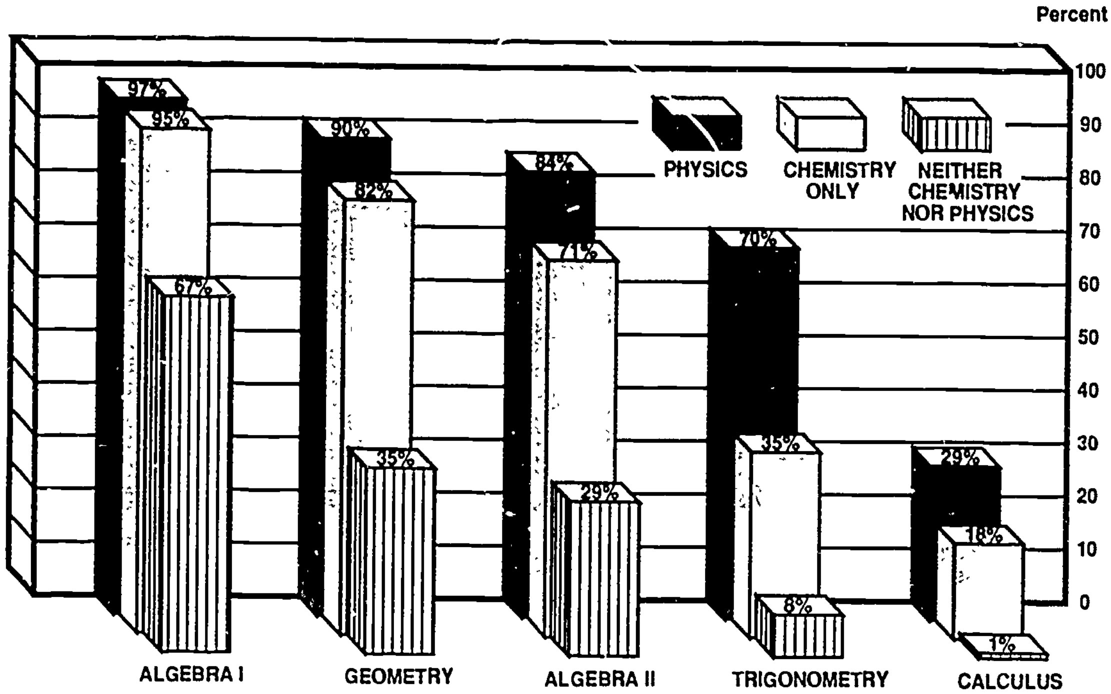

FIGURE 15. Percent of seniors with different science backgrounds who have taken specific mathematics courses, 1980.

four times more likely than non-physics students to take calculus. In contrast, half of all seniors never take geometry. Figure 15 illustrates the dramatic differences in course taking patterns among students of different science backgrounds.

Involvement in high school for most physics students does not end with academics. They report a high level of participation in extra-curricular activities, as noted in Figure 16. Sports related teams and general interest, as well as academic clubs, attract a higher percentage of physics students than other members of the senior class. It is apparent that students who take physics have a high degree of interest in a full range of high school experiences.

Enrollment in physics is only one step in an educational process involving the command of basic skills and participation in a wide array of high school experiences. These students are among the most capable in the secondary school system. But they were above average prior to the time that they entered a physics classroom. They had mastered the basic, cognitive skills and followed an academic curriculum suitable for college. Students who remain on the college preparatory track throughout high school are the most likely to take physics. Conversely those who veer from the track are unlikely to ever take physics, intermediate or advanced level mathematics. This is even true for capable students who, for whatever reason, veer from or don't get on the academic track. A limited exposure to mathematics and science can restrict future academic and subsequent career options.

II. Students who have taken chemistry only

As noted earlier, there is a large overlap between students who take physics and those who take chemistry. To get a clearer picture of these two groups, this section focuses on those chemistry students (60%) who do not take physics.

Students who take chemistry but not physics consistently score slightly lower than physics students on tests of cognitive ability. However, they remain above average on most indicators of academic achievement. Figure 12 shows that nearly all of the students who take only chemistry score above the mean in

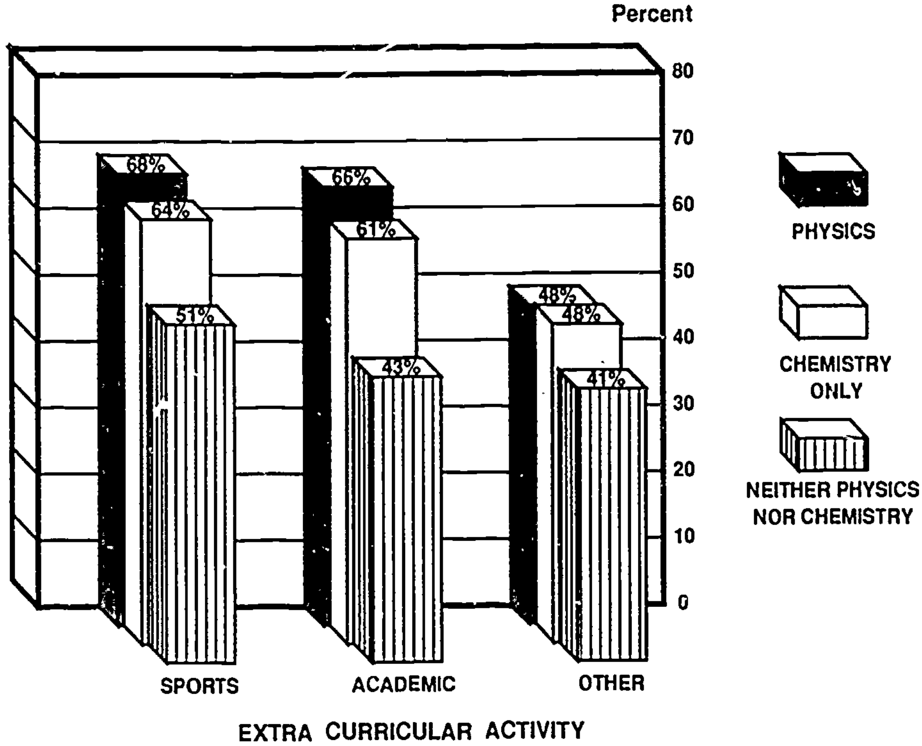

FIGURE 16. Percent of seniors with different science backgrounds who reported participating in specific extra-curricular activities, 1980. Academic activities included the school newspaper, student government, debating, and subject matter clubs. Other non-sports activities included band, chorus, dance and hobby clubs.

mathematics, reading and vocabulary. About half of them take more than two years of mathematics during grades 10 through 12 and they are more likely than most students to have completed intermediate and high level mathematics courses. The majority of these students are enrolled in college preparatory programs and two thirds aspire to at least a bachelors degree.

Although chemistry students, as well as physics students, aspire towards high levels of educational achievement, the two groups do differ with regard to one major characteristic. Females comprise nearly 60% of the students taking only chemistry whereas males outnumber females in physics by a margin of almost two to one. The average chemistry class is made up of half males and half females. But it is not the structure of the class that is at issue, it is the underlying dynamics. Over half of the men in that class will take (or have taken) physics whereas less than a third of the women do so.

The disproportionate male-female ratios exhibited in physics classes reflect the sex differential in upper level mathematics classes. The low proportion of females in high school physics is partly attributed to the fact that such a small percentage take higher level mathematics courses. While the more basic mathematics courses produce balanced sex ratios, junior and senior year mathematics classes such as trigonometry and calculus produce nearly the same lopsided male to female ratio as seen in physics classes. By the last two years of high school, the sex differential in the sciences and mathematics are well defined.

There are signs that this strong sex stratification will persist after graduation. The students' projected college majors indicate proportional differences between the sexes. Majors such as physical science and engineering attract the largest proportions of males and physics students. The 2:1 male to female ratio seen in high school physics can be projected to about a

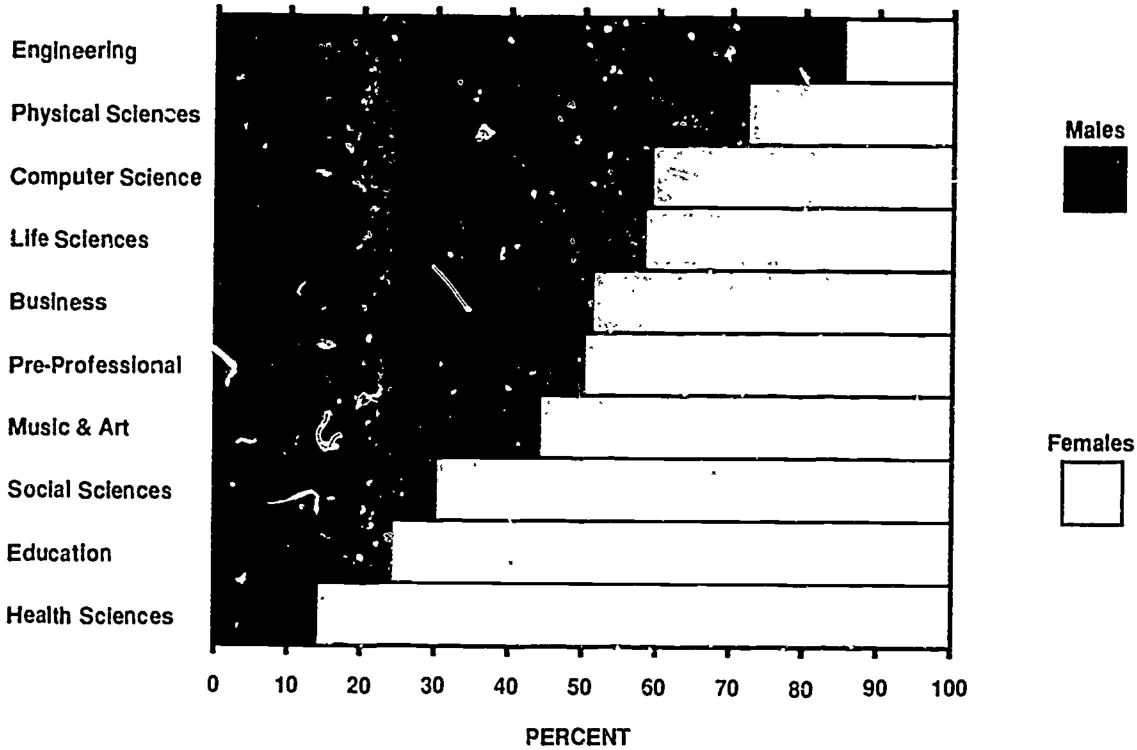

FIGURE 17. Anticipated college majors by sex for students expecting to earn at least a bachelors degree, 1980.

6:1 ratio in college physics. In contrast, non-mathematics based fields such as health, education and the social sciences are preferred majors of females and chemistry students. Figure 17 contrasts the anticipated majors which draw the highest proportions of males to those which draw the highest proportion of females. Figure 18 illustrates similar contrasts between physics and chemistry students. Most of the women and students who take chemistry only are restricted to fewer choices in college majors than men and physics students because their participation in high school science and mathematics is more limited.

The divergence between the sexes in terms of their exposure to science and upper level mathematics courses is not a reflection of a lack of ability. More women than men (46% to 41%) report that they receive mostly A's and B's in mathematics courses. But women receive slightly lower scores on mathematics tests than men. Females and males had median scores of 48 and 51, respectively. The degree to which men outnumber women in physics and upper level mathematics courses is much greater than the differences in mathematics achievement test scores between the sexes. The causes and implications of the disparities between ability and exposure to the sciences and mathematics among the sexes are examined in greater detail in Chapter five.

III. Students who have taken neither physics nor chemistry

Over half of the high school seniors who are on the verge of graduating never took a course in either physics or chemistry. They exemplify what happens when basic skills have not been mastered upon entering high school. Because of poor cognitive skills, these students begin high school taking lower level and remedial courses without much promise of advancing to intermediate, let alone, upper level work.

Students who have taken neither chemistry nor physics have inadequate reading and vocabulary skills. Their mathematics skills is even

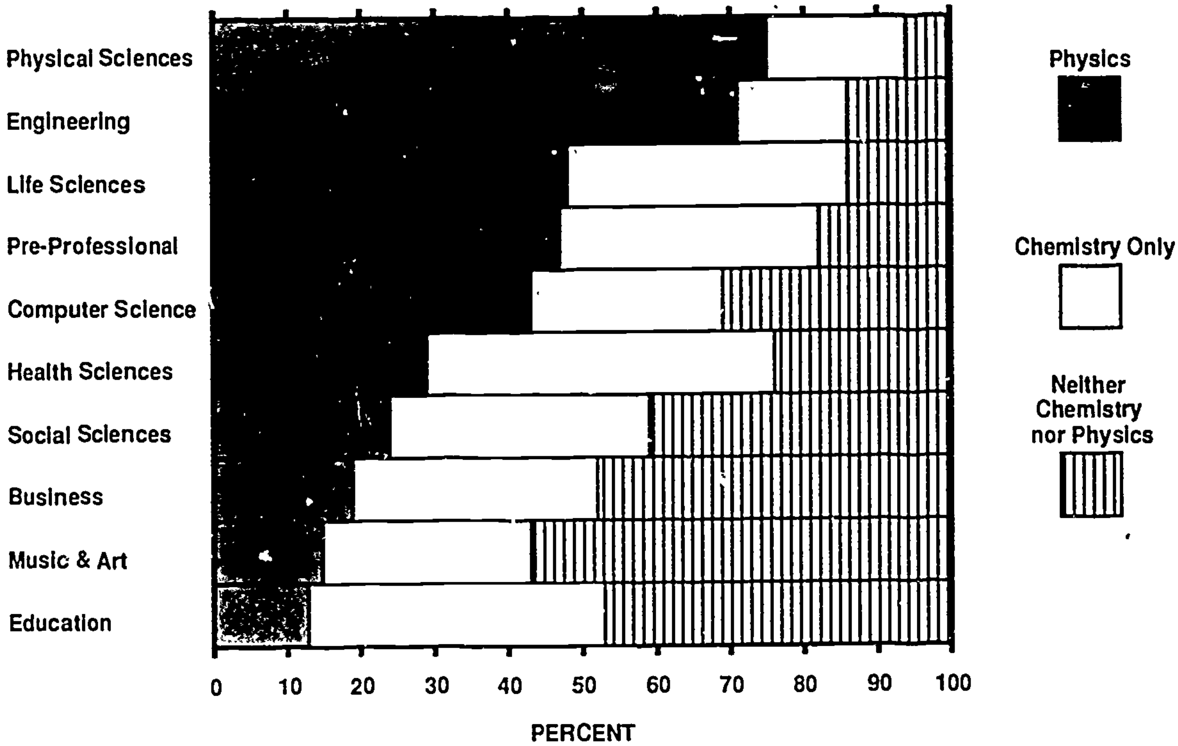

FIGURE 18. Anticipated college major by students' science background for seniors expecting to earn at least a bachelors degree, 1980.

weaker. Nearly three quarters of the seniors in this group score below the mean on mathematics achievement tests, as illustrated by Figure 12. Unless reading skills are mastered, there is little chance for achievement in mathematics. The following chapter will highlight the relationship between reading and mathematics skills.

The lack of mathematical skills displayed by students who have not taken physics or chemistry is manifested in the low proportions taking specific mathematics courses during grades 10 through 12, as illustrated by Figure 15. Only two thirds of these students take algebra I, the first course in the traditional mathematics sequence. Considerably fewer take intermediate level courses. Among the students who did not take chemistry or physics, only one-third had taken geometry.

The sharp attrition rate in mathematics exhibited by students who have not taken physics or chemistry occurs later in the mathematics sequence for chemistry students and later still for physics students. The bulk of the seniors who have taken chemistry (but not physics) continue in mathematics through geometry and algebra II. Most of the physics students remain in mathematics courses through trigonometry. Thus, those students not taking physics or chemistry have the weakest mathematics backgrounds. The imposition of graduation requirements may be the only factor compelling them to take any classes in mathematics.

The students with no physics or chemistry background exhibit lower levels of academic achievement and are also less involved in high school. Of the seniors with different science backgrounds, they are least likely to be enrolled in a college preparatory curriculum and are least involved in extra curricular activities.

Certainly, some of the students who have not had physics or chemistry are performing at or above average in high school. Over 10% score above the mean in mathematics, reading and vocabulary standardized tests. Table 9 provides information on some characteristics of students who do not take physics or chemistry but score well on all three tests. Although these students have strong skills, their characteristics

TABLE 9. Selected characteristics of seniors with high aptitude who did not take physics or chemistry, 1980. Students of high aptitude are defined as scoring over the mean on standardized tests in mathematics, vocabulary and reading.

YEARS OF MATHEMATICS	High Aptitude (no p-c)[a] %	All with High Aptitude %	National Average %
More than Two	34	58	38
Two	38	29	33
One or less	28	13	29

YEARS OF SCIENCE	High Aptitude (no p-c) %	All with High Aptitude %	National Average %
More than Two	8	44	25
Two	25	30	31
One or less	67	26	44

MATHEMATICS IS INTERESTING	High Aptitude (no p-c) %	All with High Aptitude %	National Average %
Yes	42	51	42
No	58	49	58

MATHEMATICS IS USEFUL	High Aptitude (no p-c) %	All with High Aptitude %	National Average %
Yes	60	71	62
No	40	29	38

CURRICULUM	High Aptitude (no p-c) %	All with High Aptitude %	National Average %
College prep	42	68	38
General	36	22	37
Vocational	22	10	25

HOURS PER WEEK SPENT ON HOMEWORK	High Aptitude (no p-c) %	All with High Aptitude %	National Average %
More than 5	24	39	24
1 to 5	54	47	52
Less than 1	22	14	24

EDUCATIONAL EXPECTATIONS	High Aptitude (no p-c) %	All with High Aptitude %	National Average %
Bachelors or more	52	75	46
Some college or less	48	25	54

(a) no p-c refers to seniors who have not taken either physics or chemistry

Source: High School & Beyond Study

are more like those of average students than of students with strong skills. Apparently there is some reason other than the level of achievement which causes these students to avoid science.

The majority of capable students with no physics or chemistry background stay on the mathematics track through intermediate level courses. Although the proportions do not rival those of students with the stronger science backgrounds, this group is taking a mathematics courseload which reflects enrollment in an academic curriculum. The smaller proportions in intermediate and advanced mathematics courses do not seem to be due to a lack of ability. Their average score on the mathematics standardized test is equal to the physics students' averages and higher than those of chemistry students. These are able students who apparently chose not to have taken a full secondary school courseload in mathematics or science.

In light of the low level of student exposure to basic science concepts in the secondary school system, it is crucial to draw more students into the sciences and mathematics. Greater effort could be made to reach out to those students who have basic skills but, for whatever reason, do not take intermediate level

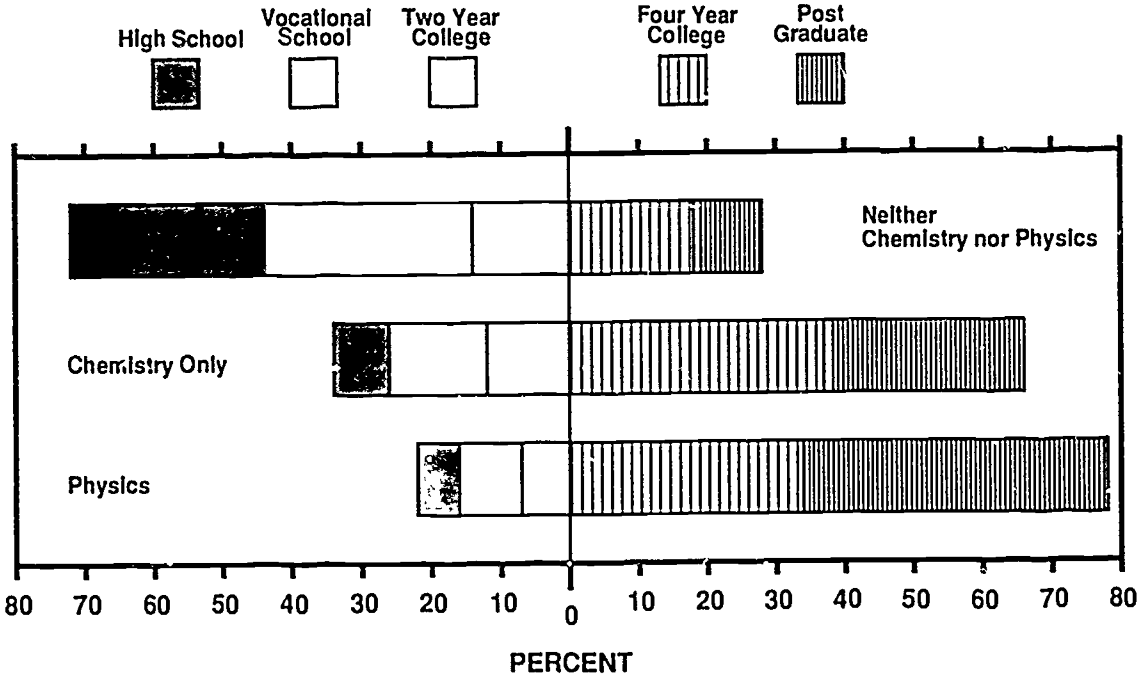

FIGURE 19. Level of educational aspiration by high school science background, 1980.

mathematics and science courses. Stressing high school coursework in these areas will enable those students to keep the doors open to a wider array of college majors and subsequent careers. Even for those not headed for college, some science knowledge is essential in understanding how the decisions made in a technological society affect their lives. An interest in and appreciation for the sciences and mathematics could certainly be instilled in a much broader segment of the high school population than is currently the case.

IV. Aspirations

High school physics and chemistry are not usually ends unto themselves. They represent educational experiences that keep open a broad array of career possibilities. Conversely, taking neither physics nor chemistry in high school can severely limit long term educational and career options.

As illustrated in Figure 19, over three quarters of all physics students expect to earn at least a bachelors degree. Two out of three students who take chemistry but not physics have similar educational expectations. On the other end of the spectrum, most of those students who have taken neither chemistry nor physics aspire to only a high school diploma or some vocational training thereafter.

The particular science courses taken by the college bound students vary significantly by their anticipated college major (see Figure 18). Students may be advised to take specific science courses depending on their majors and career choices. Thus, of all seniors who expect to major in either physical science or engineering, nearly three quarters have taken physics and most of the rest have at least taken chemistry. By contrast, over half of all music and art majors and nearly half of all prospective business and education majors take neither science courses.

Among the college bound, the potential education majors are the least likely to have taken a high school course in physics. The science and mathematics background of this group is, in part, a reflection of the high proportion of females among education majors. Over three quarters of prospective education majors are female. Few females take high school physics and there are disproportionate ratios favoring males in intermediate and upper level mathematics. Whatever the reason, the next generation of educators may bring with them a negative attitude toward mathematics and science.

The two other groups of prospective majors dominated by females, Health Sciences and Social Science, are also among the most likely to have taken only chemistry and not physics in high school. Chapter six provides a detailed analysis of the anticipated college majors in terms of students' high school science backgrounds.

Students who take high school physics or chemistry are among the better educated in our secondary school system. Most of these students are not aspiring physicists and chemists. But their enrollment in these subjects is one indication of their interest in learning and their high educational goals. They are proof of what the education system can achieve when students have strong basic skills and high expectations of themselves.

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CHAPTER 4
RACE & ETHNIC BACKGROUND

The physical sciences traditionally have had difficulty in attracting Black and Hispanic students. As Figure 20 illustrates, over the last decade only about 2% of all PhDs awarded in the physical sciences were earned by Blacks, Hispanics and American Indians (National Academy of Sciences). Even at the bachelors degree level the percentage is not much higher (less than 6%). Yet, minorities represent about one fifth of the college age population (18 - 24 year olds). Such disparity between the proportion of minorities earning degrees and the percentage that they constitute of the population raises questions about the efficacy of the educational system.

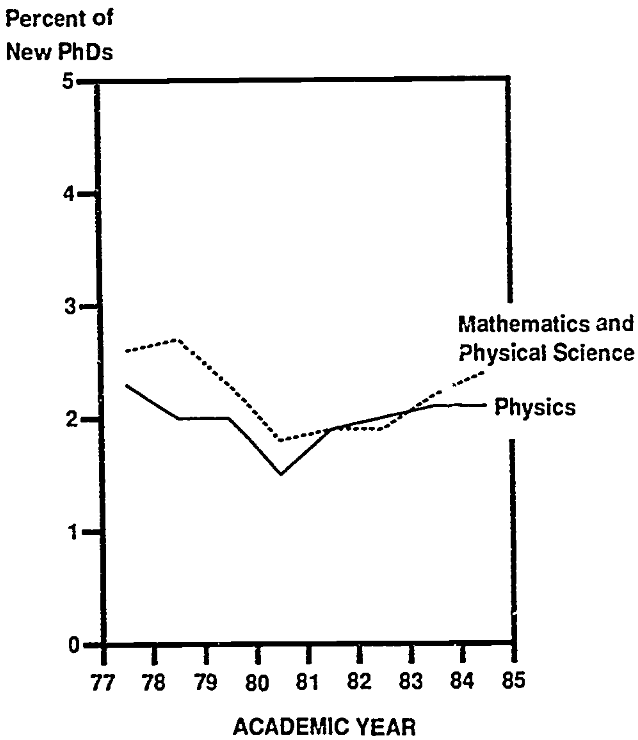

FIGURE 20. Percent of new physical science PhDs earned by U.S. Hispanics, Blacks and American Indians, 1977-1985. The curves were smoothed using two year averages. (Source: National Academy of Sciences)

Changing demographics accentuates the importance of improving mathematics and science education for minorities. The proportion of the grade school population that Blacks and Hispanics comprise is increasing dramatically. Thus, the kinds of problems that minority students presently have in the secondary school system will be exacerbated during the next decade. Furthermore, demographers project that by the end of this century, about one third of the college age population (18-24 year olds) will be Black or Hispanic (Mingle, 1987). If these individuals do not possess even the basic educational skills, science educators in universities and colleges will be hard pressed to find enough students to keep their programs alive.

A strong background in both mathematics and science is important to success in today's increasingly technological labor market. This chapter describes the exposure to mathematics and science, specifically physics and chemistry, of several racial and ethnic groups. It also attempts to identify some of the barriers that have precluded minorities from succeeding in science.

I. Achievement Tests

As part of the High School and Beyond Study, students were tested in mathematics, reading and vocabulary - the basic skills which are vital in a student's educational development. The scores reveal fundamental differences in achievement levels among four race and ethnic groups: Hispanics, Blacks, Asians and Whites who are not Hispanic. These dramatic differences are illustrated in Figure 21.

The groups divide into two pairs along their respective scores in mathematics, reading and vocabulary. Black and Hispanic students are concentrated towards the lower end of each test score range (below the overall medians), about a full standard deviation below their

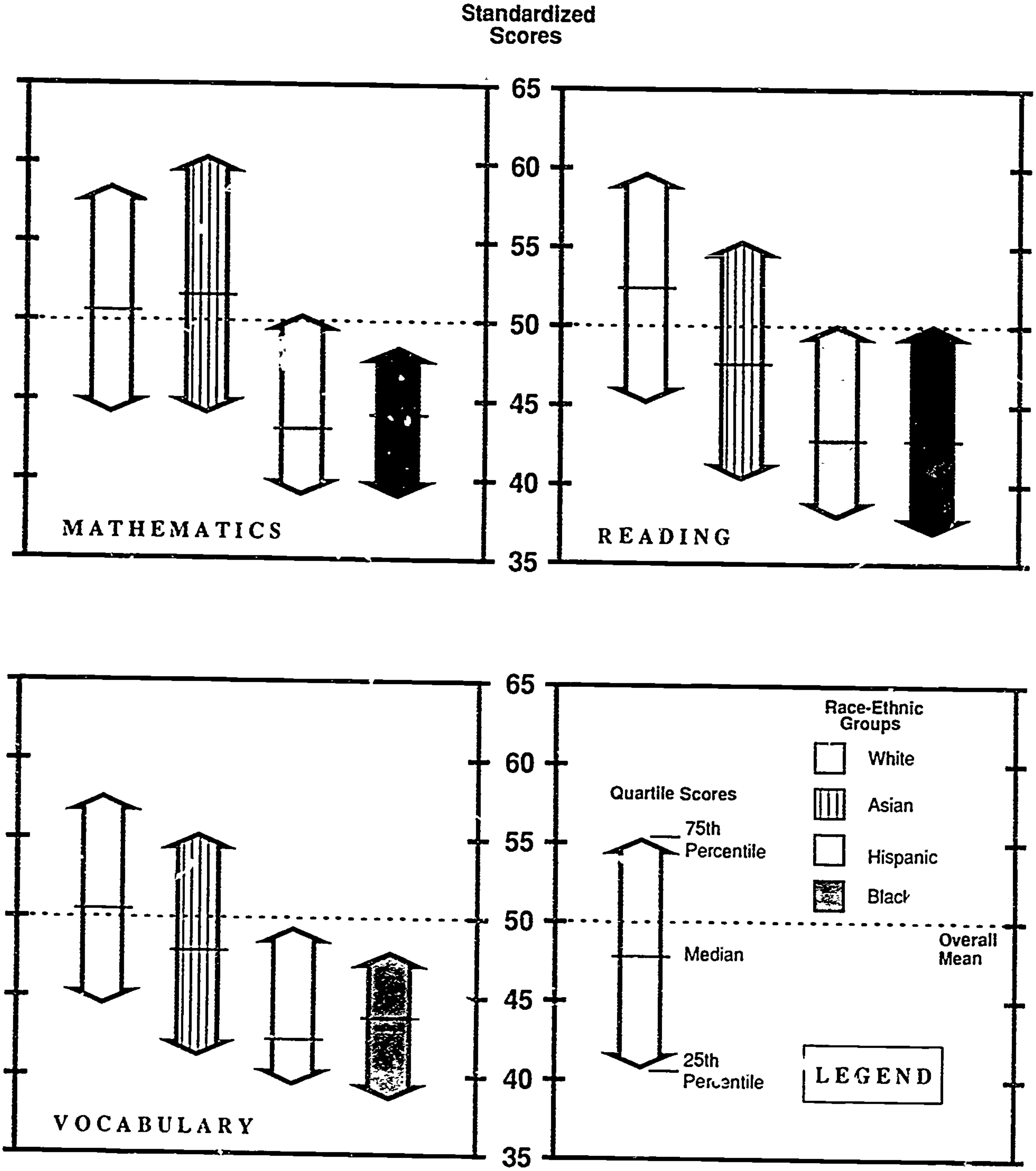

FIGURE 21. Median and quartile standardized scores on achievement tests in mathematics, vocabulary and reading by race and ethnic background, 1980. There were two parts (of 25 items and 8 items) to the mathematics test and two parts (of 15 items and 12 items) to the vocabulary test. To strengthen the reliability of these data, only the averages of the two mathematics scores and the two vocabulary scores were used. Combining pairs of test scores reduced the standard deviation to 9.

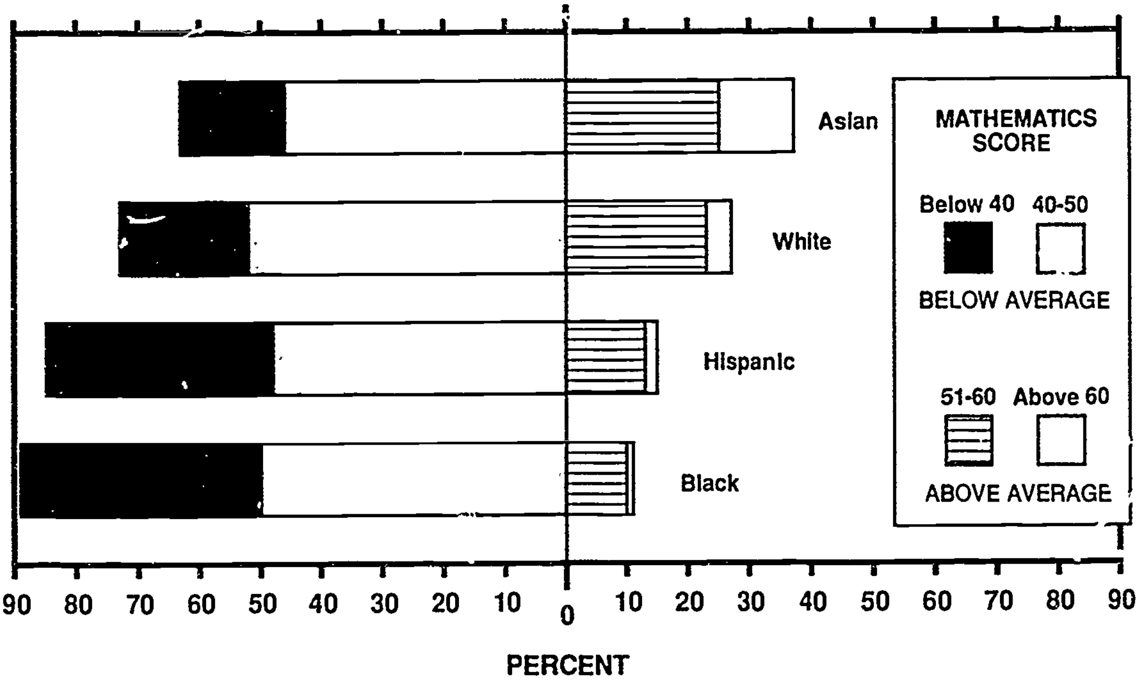

FIGURE 22. Mathematics standardized scores of students with poor reading skills by race and ethnic background, 1980. Seniors with poor reading skills are defined as students who scored below average on the reading achievement test.

Asian and White classmates. In fact, 84% of the Black students and 78% of the Hispanics are scoring lower in mathematics than the average White student. By contrast, most Asian seniors score very well on the mathematics achievement tests.

Poor reading is highly correlated with poor mathematical achievement. About two thirds of Asian and White students who score below the mean on the reading test perform poorly on the mathematics test. The problem is even worse for Black and Hispanic students. Figure 22 shows that nearly 90% of Black and Hispanic seniors who are below average in reading are similarly deficient in mathematics. Conversely, there is a strong correlation between high achievement in reading and in mathematics. Almost 80% of Asian and White seniors who score above the mean in reading score that well in mathematics. While this relationship between high reading achievement and high mathematics achievement also holds for Hispanics and Blacks, it is not as strong. Only two thirds of the Hispanic students and proportionally fewer Black students who scored well in reading, scored above the mean in mathematics.

In order to overcome the mathematics difficulties of the students who also have reading problems, their reading skills must first be improved. Poor reading is almost a guarantee that Black and Hispanic students will be deficient in mathematics. Unfortunately, there is no assurance for them that corrective measures in reading will alleviate their problems in mathematics. Students who do read well may still have problems in mathematics. However, since their reading is already adequate, those students' mathematics problems can be addressed directly.

As Figure 21 illustrates, Asians are scoring lower in reading than White students, but both groups display remarkably better skills than their Hispanic and Black classmates. Although they are lagging slightly in reading and vocabulary, Asians are not displaying any significant problems in this area. Their mean score is just one point below the overall mean. Although this racial group is composed primarily of English speaking students, about 39% were not born in the United States. The reading and vocabulary scores for the Asians who are U.S. citizens are at the national average. Non-native

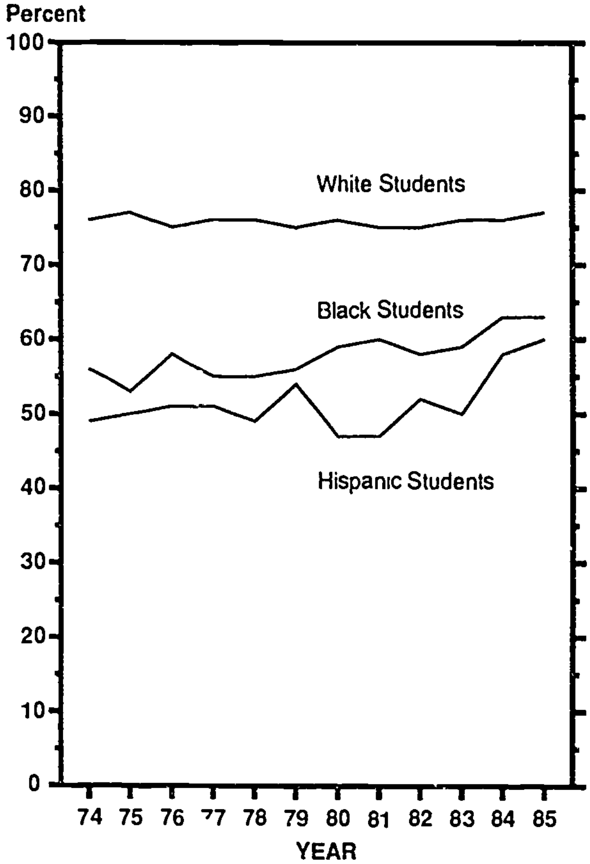

FIGURE 23. High school completion rates for 18 and 19 year-olds by race and ethnic background, 1974-1985. (Source: U.S. Department of Education)

Asians score only a few points lower. However, those Asian students who have difficulties in reading are somewhat more likely than the other groups with reading problems to score above average in mathematics (see Figure 22).

As poorly as the Black and Hispanic high school seniors are doing in reading and mathematics, they represent the members of their groups who are on the verge of graduating from high school. A large portion of students from these backgrounds have dropped out and were presumably doing much worse. As noted in Figure 23, the national high school graduation rate for persons 18-19 years old is 75%, while only 60% of all Black students and barely half of all Hispanic students graduate by that age (Stern, 1986). Thus, difficulty in reading and mathematics is of major proportions among the overall group of 18 and 19 year old Black and Hispanics.

Among students who score in the highest test score range, racial patterns differ from those previously discussed. By definition, students who score at the extremes constitute a small fraction of the overall population. As might be expected, students displaying the strongest basic skills take more science and mathematics than

TABLE 10. Mathematics and science background of high school seniors who score over 60 on the mathematics achievement test by race and ethnic background, 1980.

	MATHEMATICALLY EXCEPTIONAL STUDENTS[a]				
	Asian %	White %	Black %	Hispanic %	SENIOR CLASS AVERAGE %
YEARS OF MATHEMATICS					
More than two	83	73	77	73	29
2 years	15	21	17	25	33
Less than one	2	6	6	2	38
YEARS OF SCIENCE					
More than two	48	56	57	45	44
2 years	32	26	29	34	31
Less than one	20	18	14	21	25
CHEMISTRY AND PHYSICS					
Both	51	50	64	45	15
One only	38	32	27	28	25
Neither	11	18	9	27	60

(a) Students are defined as exceptional in mathematics if they score 60 or more (one standard deviation above the mean) on the mathematics test.

Source: High School & Beyond Study

the high school population, as a whole (Table 10). Over 80% are also taking physics and/or chemistry whereas less than half of the total population of students completed either of those courses. The greatest difference from previously noted racial patterns occurs among the exceptional Black students (those scoring over 60 on the mathematics standardized test). They are more likely than high achieving students from other racial and ethnic backgrounds to complete both physics and chemistry. On the other hand, over one quarter of the Hispanics who are high mathematics achievers take neither physics nor chemistry. While that proportion is much greater for Hispanics than for any other group of similar achievement, it is far less than the senior class as a whole (60%).

Students displaying strong fundamental skills are also spending more time on homework. Time devoted to homework may be an indication that positive external factors influence students to value education. Parents, teachers and peers, for example, may affect how students perceive the importance of education. Students' aptitude in basic skills, time spent on home study and regard for education are all intertwined. Over a third of the students performing well in the fundamentals claim to be studying over five hours per week (see Table 11). In contrast, only one quarter of the entire senior class claims to study that long. A particularly large percentage of high scoring Asians reported studying at least five hours a week. It is also important to note that nearly half of the Black students with high achievement test scores spend that much time on homework. In general, the better students' basic skills are, the more likely they are to spend quality time in school and complete greater amounts of upper level coursework in science and mathematics.

TABLE 11. Number of hours per week spent on homework as reported by seniors with above average aptitude by race and ethnic background. Students with above average aptitude are defined as those who have scored above the mean on all three achievement tests, 1980.

	Asian %	White %	Black %	Hispanic %
Less than one	6	15	10	16
One to three	18	26	17	29
Three to five	19	22	26	24
More than five	57	37	47	31

Source. High School & Beyond Study

II. Mathematics and Science Coursework

Exposure to physics and chemistry measures more than the nature of science education. In a broader sense, there exists a strong relationship between completing these science courses and success in other aspects of education. For instance, students completing these courses are most likely to score well on standardized tests in mathematics, reading and vocabulary. They are likely to take intermediate and upper level mathematics courses, enroll in a high school program suitable for college, and expect to earn at lease a bachelors degree. The degree to which students take upper level science varies greatly across racial and ethnic boundaries. Tracking these patterns will help identify the specific educational weaknesses of particular racial and ethnic groups.

Completion rates for specific mathematics courses indicate the degree to which students are exposed to advanced concepts. This is a qualitative aspect of education that is not necessarily related to the number of years completed in a subject. Figure 24a shows the proportions of students taking selected mathematics courses. Most of the Asian and White students go beyond geometry whereas barely over a third of the Black or Hispanic students go further than Algebra I. Even though many Black students take more than two years of mathematics during grades 10-12, many seem to be enrolled in such fundamental courses as remedial and business mathematics. Blacks and Hispanics also report poorer grades than other students in the mathematics courses which they do take (Table 12).

Calculus, the most advanced high school mathematics course surveyed, is taken by comparatively few students. This course, however, serves as a very strong indicator of the relative emphasis on mathematics by Asian students. Asians are two to four times more likely to complete a course in calculus than any of the other racial or ethnic groups. Proportionally, there are as many Asian students in calculus as

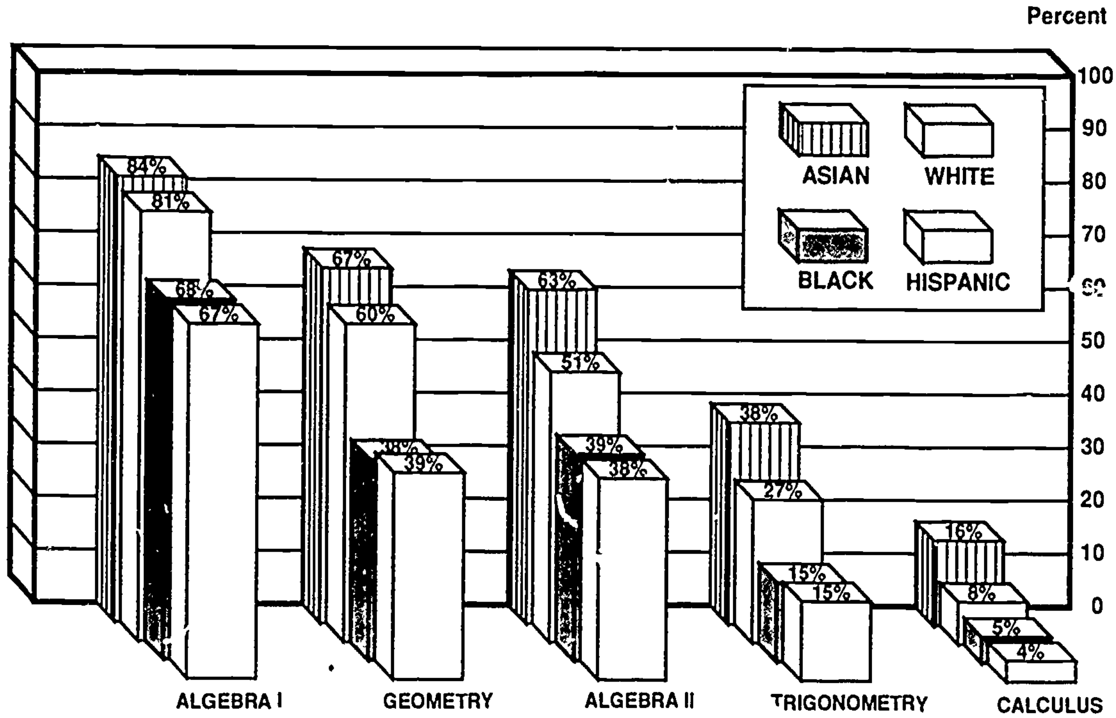

FIGURE 24a. Percent of seniors who have taken selected mathematics courses by race and ethnic background, 1980.

TABLE 12. Overall mathematics grades reported by seniors by race and ethnic background, 1980.

	Asian %	White %	Black %	Hispanic %
Mostly A's & B's	46	45	36	35
Other grades	54	55	64	65

Source: High School & Beyond Study

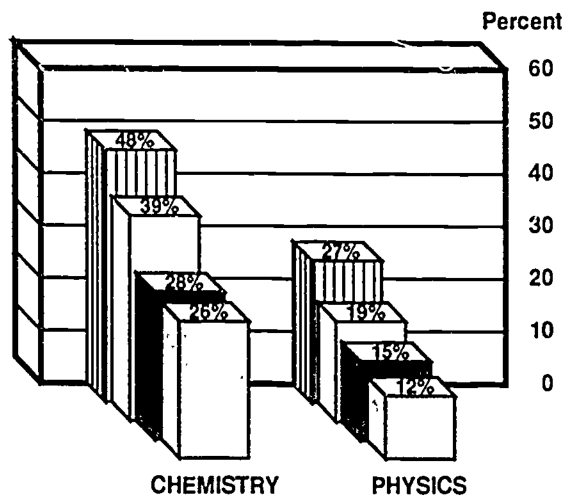

FIGURE 24b. Percent of seniors who have taken selected science courses by race and ethnic background, 1980.

there are Black or Hispanic students in trigonometry.

Asians are the most likely of any group to complete either chemistry or physics. The rate at which White students complete physics is at the national average. By comparison, both Black and Hispanic students are well below the national average for taking chemistry and physics. Refer to Figure 24b for comparisons in science background among the racial groups.

III. Program Types

As stated in the previous chapter, the mastery of cognitive skills is an essential prerequisite for academic pursuits, in general, and completion of coursework in science and mathematics, in particular. Most students with basic abilities in reading and mathematics get into college preparatory programs. Students in such a curriculum are the most likely to take chemistry and physics as well as intermediate and upper level mathematics. The concepts introduced in these subjects enable students to explore a wide array of areas and pursue many possible academic and career options.

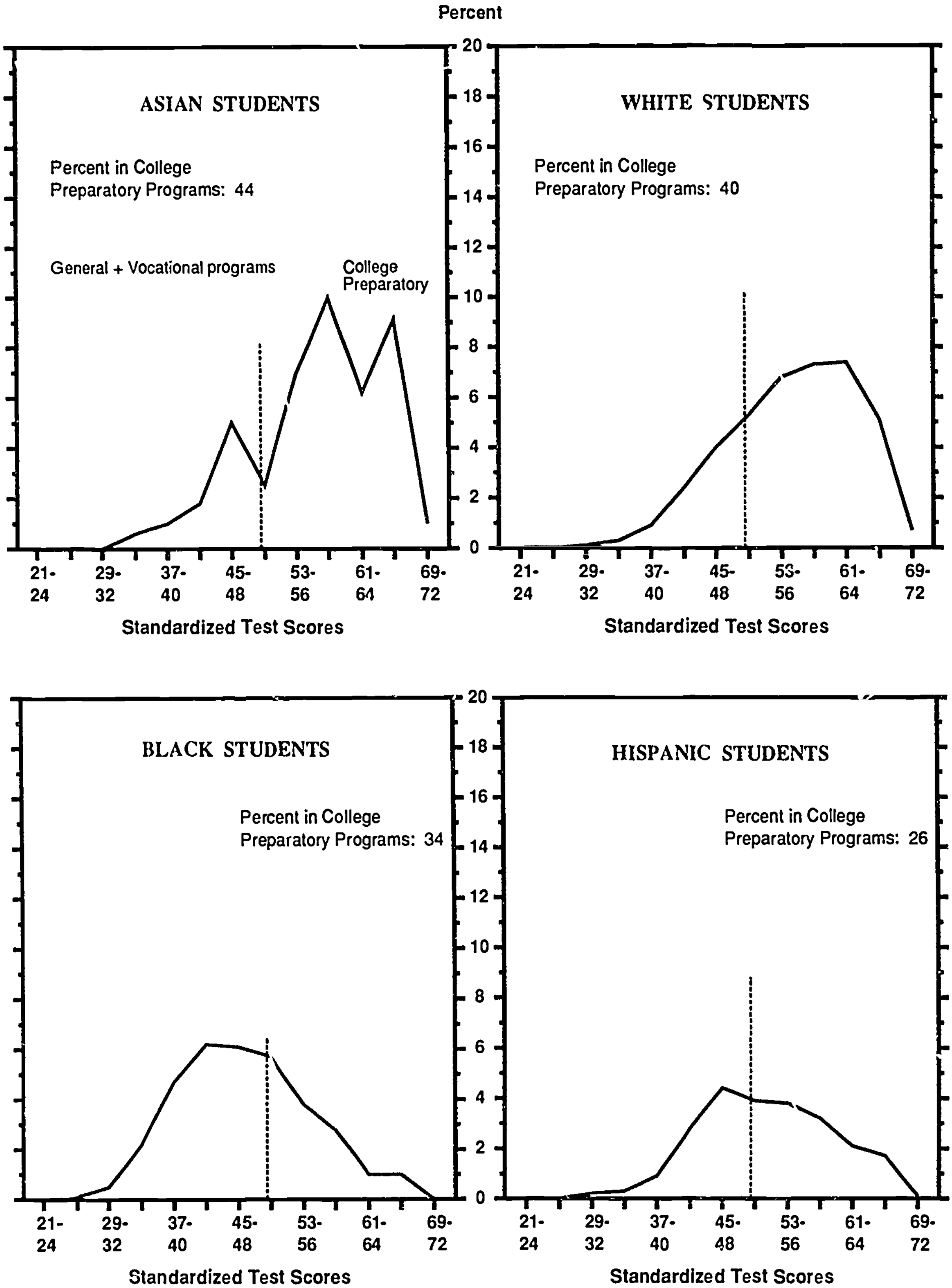

FIGURE 25. Distribution of standardized scores on mathematics achievement test by race and ethnic background and curriculum type, 1980. Dashed lines represent overall mean score (50) on mathematics achievement test.

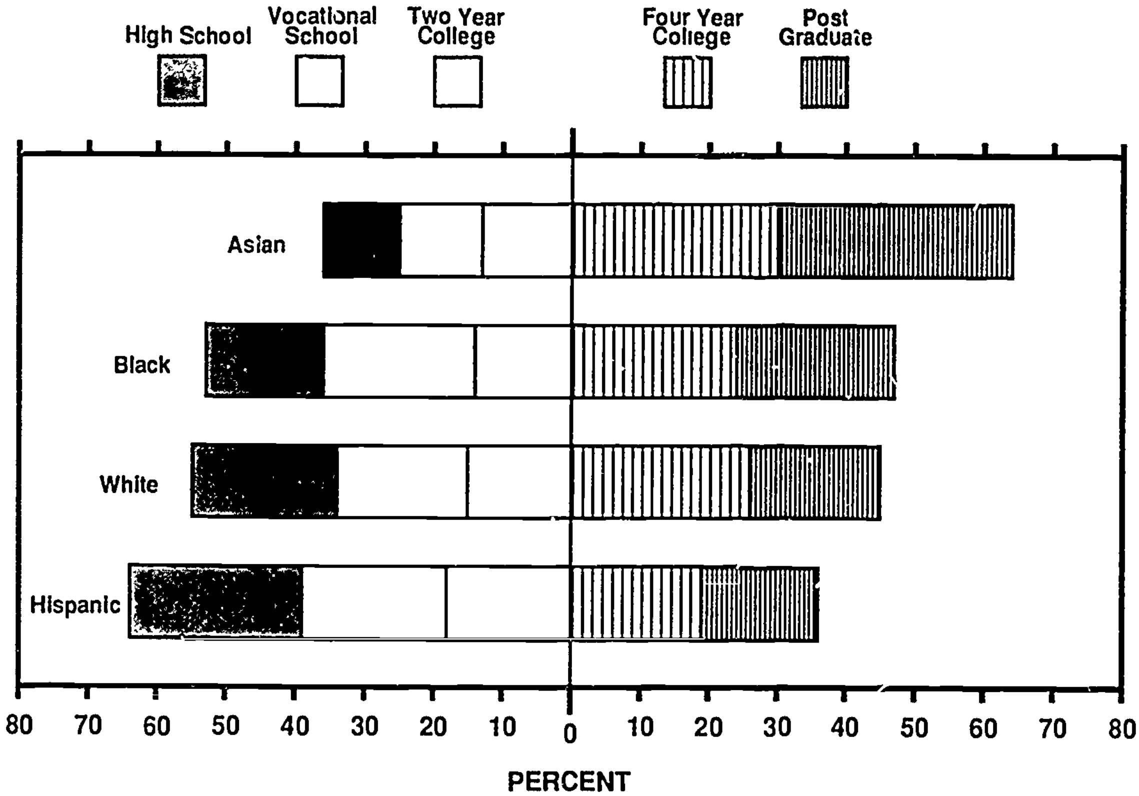

FIGURE 26. Level of educational aspiration by race and ethnic background, 1980.

Whether students have equal access to an academic curriculum is a particularly pertinent issue in the study of educational attainment among students of different racial and ethnic backgrounds. Nearly forty percent of all students get into a college preparatory program. But these proportions are not uniform across all racial and ethnic backgrounds. Only a third of all Blacks and barely one quarter of all Hispanics report being enrolled in an academic curriculum.

A college preparatory program offers above average students the challenges to fulfill their academic potential. The majority of students (60%) with above average scores in tests of mathematics achievement are in college prep.[1] As illustrated in Figure 25, high achieving Asian, White and Black students are all enrolled at about the same rate. However, only half of those Hispanics with above average skills get into the program. The fact that many capable students do not get on the academic track may account for some of the broad educational dissimilarities between Hispanics and the other racial and ethnic groups.

IV. Post-Secondary School Expectations

The post-secondary school expectations of different race and ethnic groups are very dissimilar. Nearly half of all Black high school students expect to earn at least a bachelors degree. Hispanics, on the other hand, are the least likely of the race and ethnic groups to get into college preparatory programs and also have the lowest post-secondary school aspirations. Figure 26 shows the educational aspirations of each racial and ethnic group.

[1] This discussion focuses only on mathematics scores. The trends between college prep enrollment and scores in reading or vocabulary are virtually identical to those for mathematics across the race and ethnic groups.

The hign school preparation for most Blacks and Hispanics is minimal in comparison to their educational aspirations (see Figure 25). They take few intermediate or advanced level mathematics courses and are unlikely to take chemistry or physics. In short, by the end of their high school tenure, many Black and Hispanic students are ill prepared to pursue a college education.

Black students display a large rift between their academic preparation and their educational aspirations. In spite of their difficulties in fundamental skills and their low enrollment in college preparatory curricula, a high proportion aspire to a bachelors degree or more. These students apparently maintain an interest in, or place a value on, education — an essential framework for educational The next report will examine the degree to which these students were able to attain their goals despite their poor preparation in high school.

The first year after high school graduation most students expect to either attend a four year college or work full time, as indicated by Table 13. A higher percentage of Asians than other groups expect to be enrolled in a 4 year college in their first year after high school. In contrast, a high proportion of Hispanics expect to be working at that time. If past trends prevail, many of the Blacks and Hispanics who anticipate going to a four year college will actually end up working or in 2 year schools. The next report will examine the educational paths which these racial and ethnic groups have actually taken and how deviations from that path affect the likelihood of achieving educational goals.

TABLE 13. Plans for first year after high school by race and ethnic background, 1980

	Asian %	White %	Black %	Hispanic %
College	48	38	39	28
Working/Mil.	26	37	39	45
Voc. School	12	12	13	14
Junior College	12	9	6	9
Homemaker	--	1	1	1
Other	2	3	2	3

Source. High School & Beyond Study

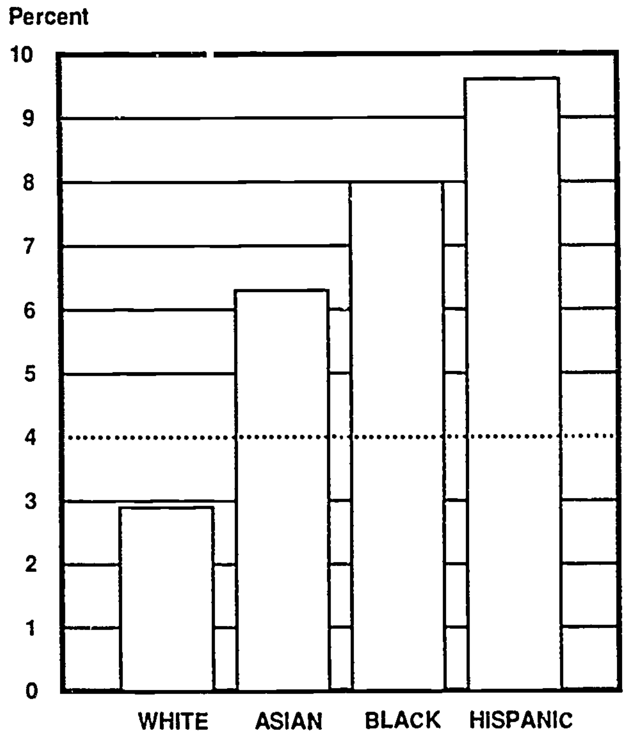

FIGURE 27. Percent of seniors 19 years of age and older by race and ethnic background, 1980. The dashed line represents the national average.

V. Summary

Too few students are taking challenging science courses in high school and too many are graduating with low English and mathematical ability. In order for the former to be resolved, the inadequacies in basic skills must be addressed. One of the failures of the educational system is its inability to educate the students, particularly Blacks and Hispanics, in fundamentals. Any significant gains in attracting minorities to the sciences will not occur until basic reading and arithmetic skills are properly mastered. It has already been documented that Black students who have very strong basic skills take as much physics and chemistry as any other group.

The degree to which Hispanic students attain relatively low levels of educational achievement extends beyond poor basic skills. The problem is compounded by the fact that so many capable Hispanic students do not get into academic programs. Some choose not to enter college preparatory programs, while others live in regions where college preparatory programs are not frequently taken. The educational problems displayed by this ethnic group as a whole are aggravated because so few of the capable students among them receive a strong education in high school.

An additional obstacle facing Hispanic students is a significant age difference between them and the other race-ethnic groups. Figure 27 illustrates that high school seniors of Hispanic origin are older than their classmates. Entering high school at a later age or taking longer to complete high school may account for this age disparity. The high drop out rate of Hispanic students has frequently been attributed to significant age differences (Olivas, 1986; Valdivieso, 1986).

The proportion of Blacks and Hispanics among the grade school population is increasing and such growth will be reflected in the high school population during the next decade. If a large percentage of minority students continues to perform below average then the secondary school system will become burdened with the learning disadvantaged. As a consequence, more time will be spent merely trying to bring such students up to minimum standards rather than spending the time encouraging students to reach their full potential. Unless there are active programs to better educate the minority students who are having difficulties, the educational system may face even tougher problems during the 1990's.

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CHAPTER 5
THE GENDER GAP IN MATHEMATICS AND SCIENCE

Women are severely underrepresented in scientific and technological fields. While half of all bachelors degrees were awarded to women in 1985, the gender ratio varied substantially by field of degree. Figure 28 depicts the percentage of bachelors degrees earned by women in several selected fields over the last 15 years (Snyder, 1987). Obviously, the health professions and education remain female dominated fields. By marked contrast, only one in seven of the bachelors degrees in engineering and physics were received by women in 1985. It should be noted that as low as this participation rate is, it represents a considerable improvement since the early 1970's. In the case of physics, the number of women receiving bachelors degrees has increased by 75% over the last 15 years and in engineering the number has jumped by 3000%!

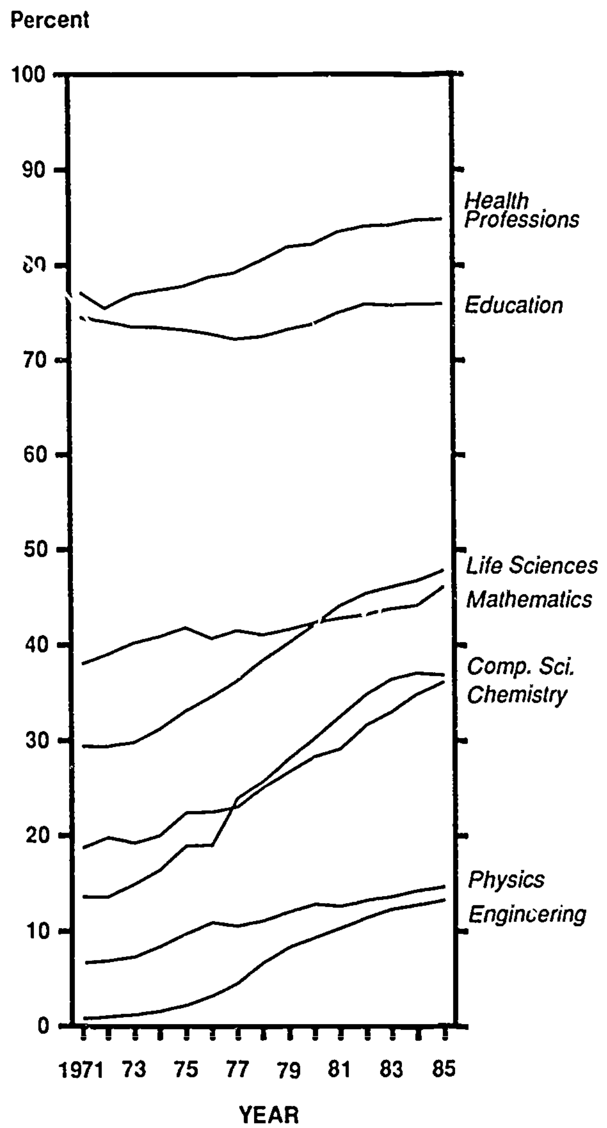

FIGURE 28. Percent of bachelors degrees in selected fields earned by women, 1971-1985. (source. U.S. Department of Education)

The disciplines at either end of the spectrum in Figure 28 vary according to their reliance on a strong mathematics background. Those fields in which women predominate require little mathematics preparation, while those fields in which few women major require considerable mathematics training. However, it would be inappropriate to infer that women stay away from all quantitatively based fields. The most notable exception is mathematics itself, where the gender ratio among bachelors degree recipients is close to parity. Thus, a key question is why many disciplines attract females and males disproportionally.

High school is one of the critical phases in the education pipeline. It is at this stage that women and men begin to exhibit markedly different preferences for science and mathematics courses. This chapter examines a variety of gender-related factors associated with individuals developing strong backgrounds in mathematics and science. It describes differences in exposure to mathematics and science at the high school level and reviews the data on mathematics test scores. It also considers some of the possible causes and consequences of the gender gap in mathematics and science, such as innate ability, socialization, and differential career goals.

I. Mathematics Achievement Tests

It is well documented that females score lower than males on standardized tests of mathematics achievement. As Figure 29 illustrate. females score 40 to 50 points lower than

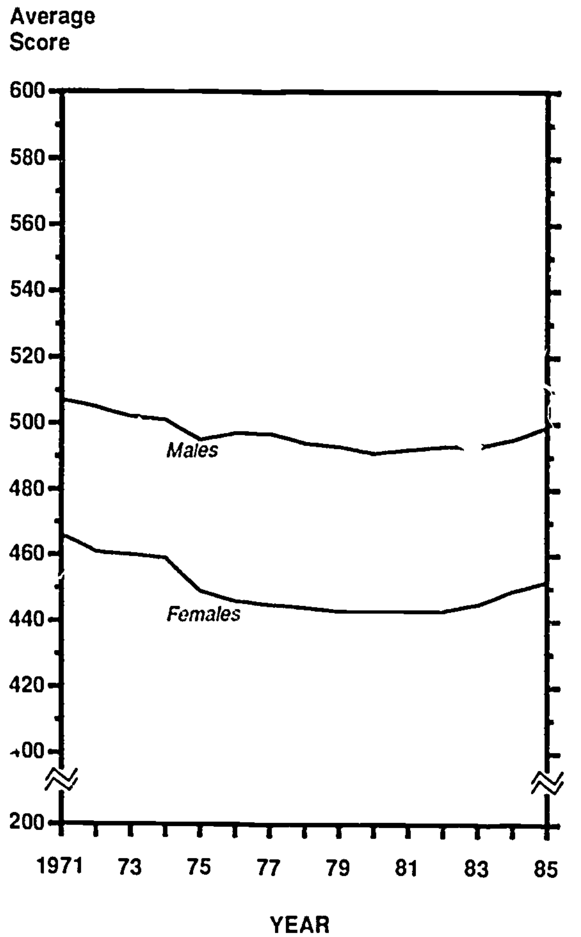

FIGURE 29. Average scores on SAT-M by sex, 1971-1985. (Source. College Entrance Examination Board)

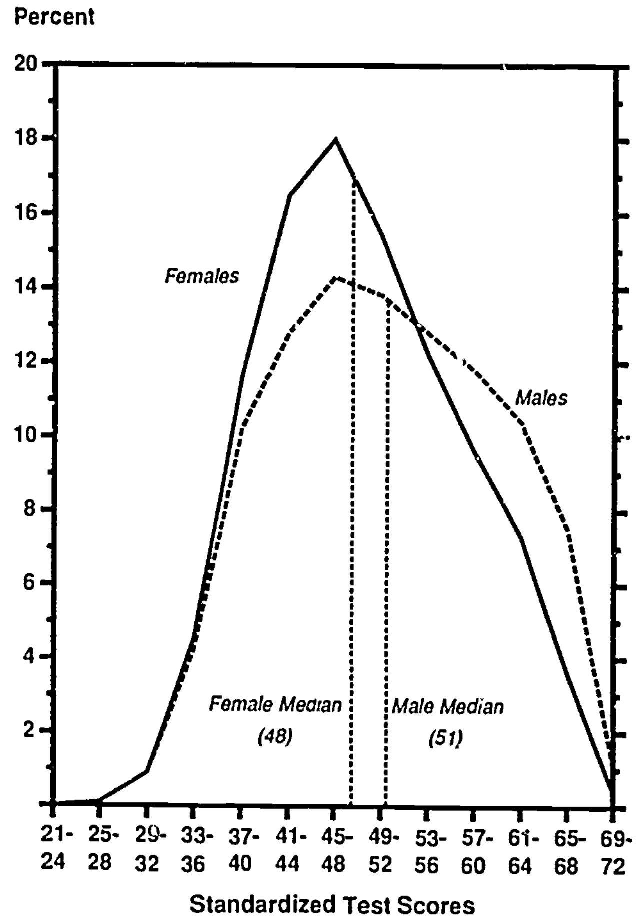

FIGURE 30. Distribution of standardized scores on mathematics achievement tests by sex, 1980. Scores were standardized to a mean of 50 with a standard deviation of 10. There were two parts (of 25 items and 8 items) to the mathematics test. To strengthen the reliability of these data, only the averages of the two mathematics scores were used. Combining the scores reduced the standard deviation to 9.

males on the mathematics section of the SAT exams (Snyder, 1987). The size of this difference is comparatively stable over time and across a variety of mathematics tests (Hyde, 1981).[1] The seniors in the HS&B study display gender-related differences of similar magnitude on the mathematics tests that were distributed as part of that study. As Figure 30 illustrates, females score about three points lower than males (medians of 48 and 51 respectively) on the mathematics test.[2] The achievement tests that were part of the HS&B study were administered in the spring of the students' senior year. The scores on these tests are a reflection of exposure to mathematics as well as innate ability.

While the differences in average scores between males and females on mathematics tests

[1] Hyde's review of the literature on cognitive gender differences found that the magnitude of the sex difference in quantitative ability averaged .43 of a standard deviation.

[2] The differences between male and female scores on the Mathematics SAT is about .45 of a standard deviation unit. Similarly, the differences between the sexes on the mathematics portion of the standardized tests administered as part of the High School & Beyond study is about .33 of a standard deviation.

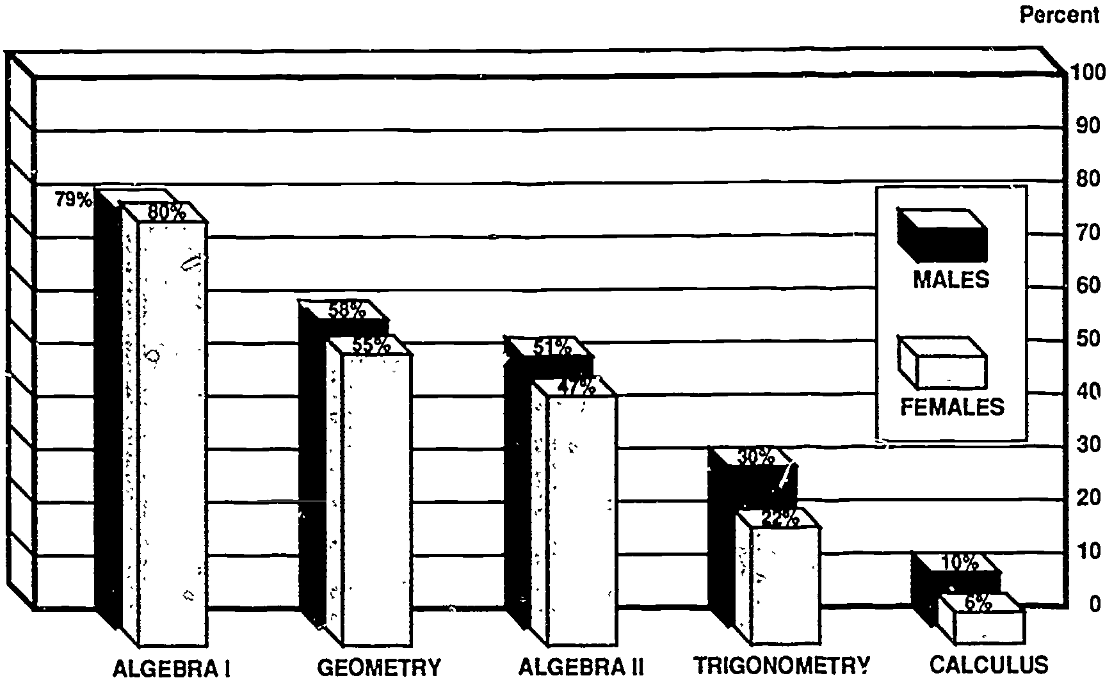

FIGURE 31a. Percent of seniors who have taken selected mathematics courses in high school by sex, 1980.

are highly consistent, the degree of overlap between their distributions is often overlooked. The curves in Figure 30, for example, indicate that 54% of males and 45% of females scored above average on the mathematics test. In other words, for every 5 males with above average mathematics scores, there are 4 females with comparable scores. At the extreme upper end of the curves, however, the difference between males and females grows. Nearly 19% of the males score above 60 (more than one standard deviation above the mean) but only 11% of the females achieve scores that high. Thus, the overlap at the upper end of the scale decreases to three females for every five males.

A few researchers argue that the differences in mathematics test scores are indicative of innate male superiority in mathematics (Benbow & Stanley, 1980). Some researchers argue that such differences reflect biases in the tests rather than real differences in ability (Donlon, 1973). Others argue that the differences are the result of female students having received less encouragement and less feedback (both positive and negative) from mathematics teachers compared to their male classmates (Eccles, 1984).

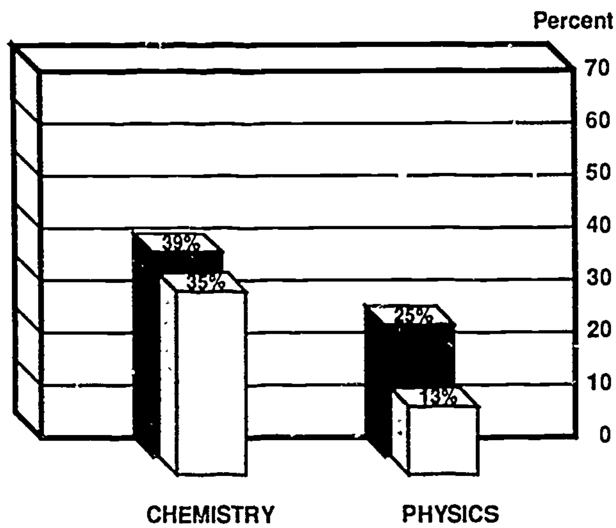

FIGURE 31b. Percent of seniors who have taken selected science courses in high school by sex, 1980.

The data in the HS&B study do not permit an evaluation of the validity of any of these positions. However, the data are clear in one respect. Females as a group score less well on standardized tests and, as is described in the next section, are likely to drop out of the mathematics sequence sooner than males. The remainder of this chapter shows that the differences in mathematics achievement, as measured by these tests, account for only some of the differences between males and females in terms of high school coursework, intended college major and anticipated career.

II. *High School Mathematics and Science Background*

As students progress along the traditional mathematics sequence, the disparity in the gender ratio in those courses grows. Figure 31 depicts the proportion of male and female seniors who took traditional mathematics and science courses. Students regardless of their sex are equally likely to take algebra I. However, at the intermediate level. geometry, algebra II and chemistry, a rift begins to show. In upper level mathematics courses. trigonometry and calculus, males outnumber females by 3 to 2.

High school physics courses typically require a background in intermediate, and often upper, level mathematics. Thus, given the differences in the traditional mathematics coursework completed by females and males, it is no surprise to see a very large gender disparity in physics. The male-female ratio is 2 to 1 in that course, significantly larger than the gender gap in even the highest level mathematics courses.

As noted in Chapter 3, there is a strong relationship between students' achievement test scores and the mathematics courses that they have taken in high school. Students with high mathematics achievement test scores are more likely to take junior and senior level mathematics than their less skilled classmates. As Figure 32 illustrates, almost all students who score 65 or higher on the mathematics achievement test (mean equals 50 and the standard deviation is 9) take trigonometry. A similarly large proportion of those students with high mathematics aptitude also take chemistry. By contrast, calculus is taken by fewer than half of them even though it draws almost exclusively from bright mathematics students. This is, in large part, a problem of access. Only about a third of all secondary schools offer calculus (Weiss, 1987).

Women score less well on mathematics achievement tests and they are also less likely to take upper level mathematics courses. However, male and female students, who score equally well on the mathematics achievement test, are not equally likely to have taken the same mathematics courses. As Figure 32 shows, these differences are comparatively small, but they are consistently in the same direction and are statistically significant for calculus.

When difference in mathematics achievement are taken into account, physics displays the strongest gender bias among the junior or senior level mathematics and science courses. Significantly fewer female students with exceptional mathematics aptitude take physics compared to their male classmates with identical scores on the standardized tests (see Figure 32). There appear to be unique barriers keeping females out of physics classes and these barriers are social rather than aptitude.

III. *Educational Attainment*

Over the last 15 years, women have dramatically increased their level of participation in the labor force. Most women over the age of 16 are working. In fact even among all married women with children under the age of 1, virtually half (49.4%) were in the work force in 1985. This figure can be contrasted to 31% in 1975 and only 24% in 1970 (Hayghe, 1986). As the participation rate of women continues to grow in a labor market that is becoming more and more technological, the quality of their employment will depend in part on their educational background.

Women are participating more fully in higher education. As illustrated in Figure 33, women earn half of all bachelors and masters degrees, a modest increase over the last 15 years In addition, women have made considerable gains in both PhD and professional degrees, such as medicine and law. They now earn a third of the degrees at those levels.

These gains are not uniform across disciplines. While the science and mathematics back grounds of females and males in high school are

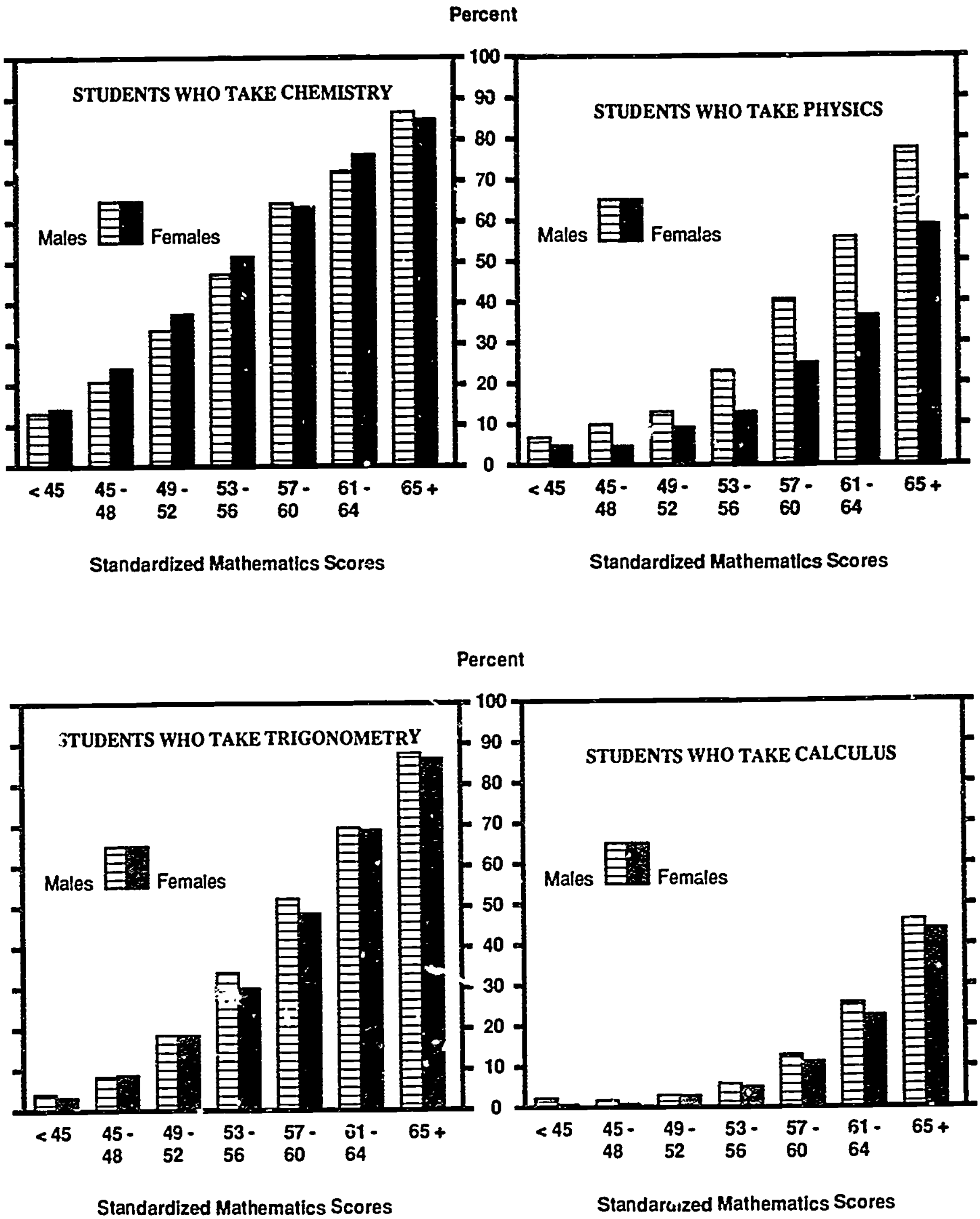

FIGURE 32. Likelihood of taking selected mathematics and science courses by mathematics achievement test score and sex, 1980.

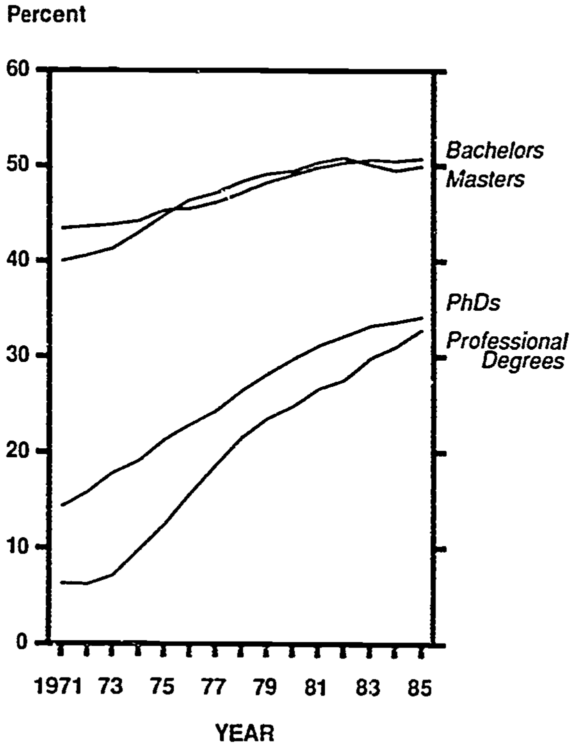

FIGURE 33. Percent of bachelors, masters, PhD and professional degrees earned by women, 1971-1985. (Source: U.S. Department of Education)

markedly different, the disparity is even more exaggerated further along the science education pipeline. For example, females make up nearly half of the chemistry class in high school, and receive over one third of the chemistry bachelors degrees, but they are awarded only about one-fifth of the chemistry PhDs. The gender disparity in physics is even more pronounced. The male to female ratio in physics classes is already 2 to 1 in secondary schools. Among physics bachelors degree recipients, the ratio grows to 6 to 1 and among physics PhDs it is 9 to 1.

Despite gains, the number of doctoral degrees in physics and engineering that are earned by women remains extremely low. In 1985, fewer than 200 women received PhDs in engineering (6% of engineering PhDs that year). Similarly, fewer than 100 women received PhDs in physics (9%) that year (National Academy of Sciences, 1986). The women who reach this level certainly have a strong aptitude in science and mathematics. However, such a background is essential for careers in fields other than engineering and physics. For instance, MD's pursue a demanding course of study that requires a rigorous background in both science and mathematics. Yet in 1985 nearly 5,000 women received MDs accounting for a 30.1% share of all MD's conferred that year (Bureau of the Census, 1988). Clearly, the differences in both mathematics aptitude and high school background in mathematics and science cannot account for the overwhelming gender-related differences between fields at the advanced degree level. Nor can it be argued that these educational path differences are the result of women being unwilling to make the time commitments required of careers at this level.

IV. Occupational Goals

As noted in Chapter 6, students generally take coursework in high school that reflects their educational and occupational aspirations. Thus, gender-related differences in anticipated careers may account for some of the differences in high school background. Figure 34 illustrates the broad range of both educational goals and intended careers for male and female high school seniors. At the lower end of the educational attainment spectrum, a high school diploma or vocational training, there is a complete divergence of employment paths. Half of the males aspire to craft, operative and laborer while virtually none of the females do. Conversely, half of the females aspire to clerical, homemaker and service (beautician, practical nurse, etc.), but an insignificant number of males do. There is virtually no overlap between the sexes in these goals.

High school seniors who hope to earn a two or four year college degree also aspire to careers that are split along gender lines. Men want to become proprietors, while women aspire to careers in teaching. In 1986, 85% of all elementary school teachers were women (Bureau of the Census, 1988). Similarly, there is roughly a 2 to 1 difference in male versus

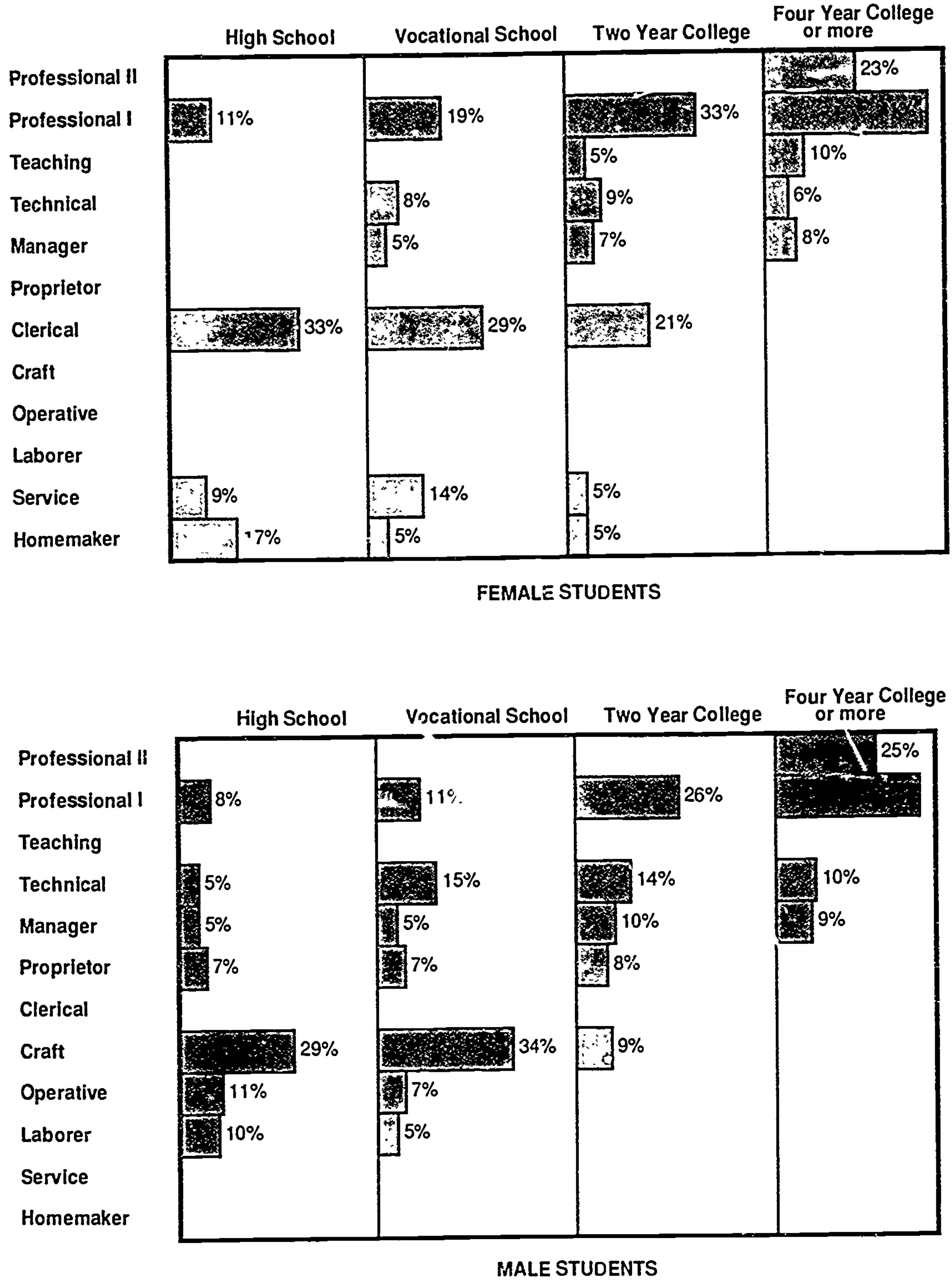

FIGURE 34. Predominant occupational goals by sex and level of educational aspiration, 1980. Occupations cited by less than 5% of the students are not displayed. See Table 15 for a listing of specific occupations within each category.

females aspiring to technical careers. In addition, within this category the kinds of technical careers they aspire to are different. Women plan to become health technicians while men are more likely to move into engineering and electrical technician areas. In 1986, 84% of all health technicians and technologists were women while fewer than one in six of the engineering and electronic technicians were women (Bureau of the Census, 1988).

Aspirations toward careers in categories Professional I and Professional II appear to be similar between the sexes but in fact mask the extent to which women and men are headed down very different career paths. Within the professional ranks, men aspire to occupations such as engineering and accounting. By contrast, women expect to become social workers, librarians, and registered nurses. In brief, even though women are participating in both the labor force and higher education in record numbers, they are still heavily drawn into female dominated careers and, with few exceptions, do not move into traditionally male careers.

V. Gender Related Differences among the High Achievers

For the purposes of this section, the high achievers are considered to be those students who are in a college preparatory program and score above the average on tests of mathematics achievement. Females and males of comparable aptitude in mathematics are equally likely to get into college preparatory programs. Within each sex, sixty percent of the students who score above average on mathematics are in college preparatory programs. Thus, of all high school seniors who are male, 31% are both in college preparatory programs and score above average in mathematics Of all female seniors, that figure is 27%. The discrepancy in these two figures is the result of the differences between the sexes in the mathematics achievement test scores.

As discussed in Chapter 1, junior and senior level mathematics and science courses draw, almost exclusively, from the high achievers. This pattern is true of both sexes. However,

TABLE 14. Anticipated college major by sex and achievement level, 1980. High achievers are defined as students who score above average on mathematics achievement tests and who are enrolled in a college preparatory curriculum.

	HIGH ACHIEVERS Female %	HIGH ACHIEVERS Male %	ALL OTHERS %
Engineering	5	27	7
Education	9	2	9
Health Sci.	11	2	9
Social Sci.	13	6	8
Pre Prof'l	12	12	6
Business	17	18	24

Source: High School & Beyond study

the differences between the sexes in mathematics and science courses that they have taken still persist for these students. The differences between the sexes in terms of enrollment in trigonometry, calculus and physics are virtually as severe among the high achievers as they are among high school seniors in general. Given these background differences among the capable and highly motivated, it is no surprise to see that the sex-specific differences in college and career goals also exist in these groups.

The aspirations of females who are high achievers resemble students of low mathematics aptitude as often as they do the aspirations of high achiever males (see Table 14). For instance, women regardless of ability do not envision pursuing certain "masculine occupations" such as engineering and physics (Kelly, 1985). Among the high achievers, males continue to outnumber females in likelihood of pursuing engineering as a major in college by more than 4 to 1. Thus, even women with strong mathematics skills and high motivation are, as a group, neither advised nor prepared in high school to pursue the physical sciences and technical careers.

VI. Conclusions

There is an enormous gender gap in mathematics and science. The mathematics and science education that women receive is, in many ways, inferior to that of their male classmates. The mathematics achievement levels are lower for females than males. Even when achievement test scores are held constant, females take less mathematics and science in high school than males. Of course, it is possible that females might score higher on mathematics achievement tests if more of them were encouraged to take upper level mathematics. Women take less mathematics and science than men in large part because their educational and occupational goals as teenagers are quite different.

The problems are ubiquitous. Depending on their sex, students receive differential advice and encouragement to pursue mathematics and science in high school. Teachers give their male students more detailed and substantive feedback than they provide to female students (Brophy & Good, 1970). Guidance counselors advise females not to take upper level mathematics (Casserly, 1975). Both fathers and mothers have higher achievement standards and expectations for their sons than their daughters (Maccoby & Jacklin, 1974). Parents' goals for their children's future indicates that they strongly subscribe to the view that careers in science and mathematics are a male domain (Gross, 1988). Compared to boys, girls are less self-confident in mathematics, believe it to be less useful and less enjoyable (Fox, 1987). Girls tend to attribute their failures to lack of ability and their successes to luck, while the opposite is true of boys (Dweck, 1983). And, there are, as can be deduced from the data, comparatively few female role models in science, engineering and mathematics.

All students have the right to a quality education. Yet women are clearly not receiving the encouragement, guidance or educational background needed to develop their abilities. Many capable females are being dissuaded from taking upper level mathematics and physics in high school. They are simultaneously being precluded from pursuing those fields as college majors and, thus, they are unlikely to be able to compete in those sectors of the economy. In short, women have not been provided with the tools necessary to participate fully in an increasingly technological labor market and contribute to the economic future of this country.

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CHAPTER 6
POST-SECONDARY SCHOOL PLANS

The plans that students formulate are subject to many changes. However, when viewed in the long term, these plans are closely related to the students' high school background. Actually, a reciprocal effect can be observed. Additionally, educational and occupational goals are interrelated and affect the courses which the students take in high school. In turn, ability, courses, and other high school experiences work in defining the students' long term goals. The students may acquire new interests from the courses which they take and thus decide to modify their previous plans. Through this reciprocity among coursework, educational and occupational goals, students continually reformulate their post-secondary school plans. This chapter discusses these reciprocal relationships in some detail, focusing particularly on the roles of coursework in mathematics and science.

An examination of students' success in achieving their goals may help identify the patterns and levels of coursework which best relate to goal fulfillment. The next report will focus on the educational and occupational status of the class of 1980 six years later. It will provide a solid basis for determining how effective their high school education was in helping them achieve their goals. Specifically, that report will focus on who pursued mathematics, science and related areas after high school. It will also examine whether a weak mathematics and science background contributed toward the failure to achieve certain kinds of occupational and educational goals (Sells, 1978).

I. Curriculum and Long Term Goals

High school seniors in each of the three different curriculum types — vocational, general and college preparatory — have distinctly different sets of educational aspirations and occupational goals (See Figures 35 and 36). As noted in earlier chapters, higher performing students tend to be enrolled in college preparatory programs. Thus, it is not surprising that students on the academic track have high educational aspirations. In fact, about two-thirds of all high school seniors who anticipate earning a bachelors degree went through high school in the college preparatory program. When the seniors were asked to indicate the occupation

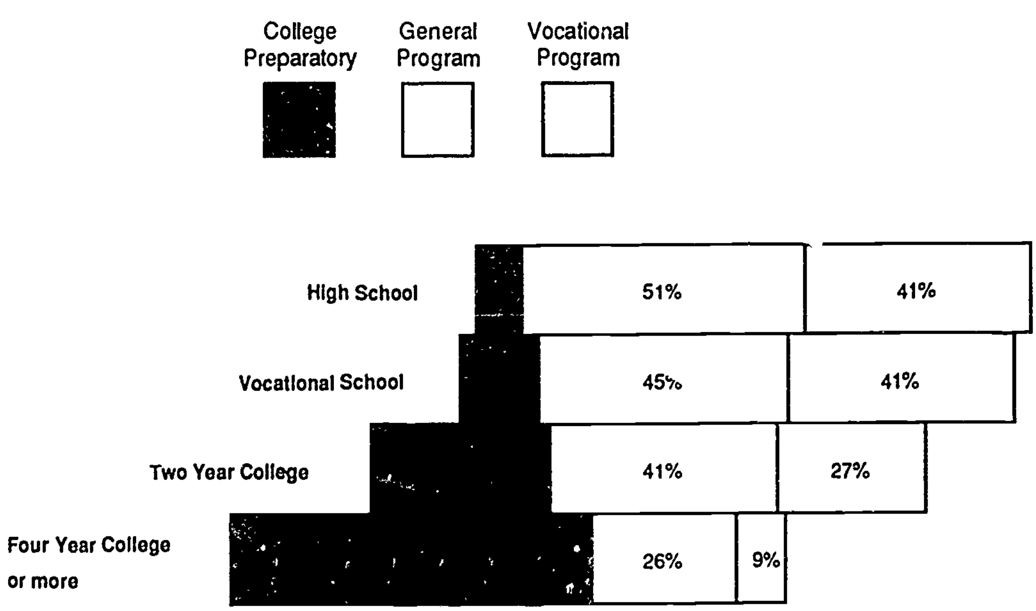

FIGURE 35. Level of educational aspiration by high school curriculum type, 1980.

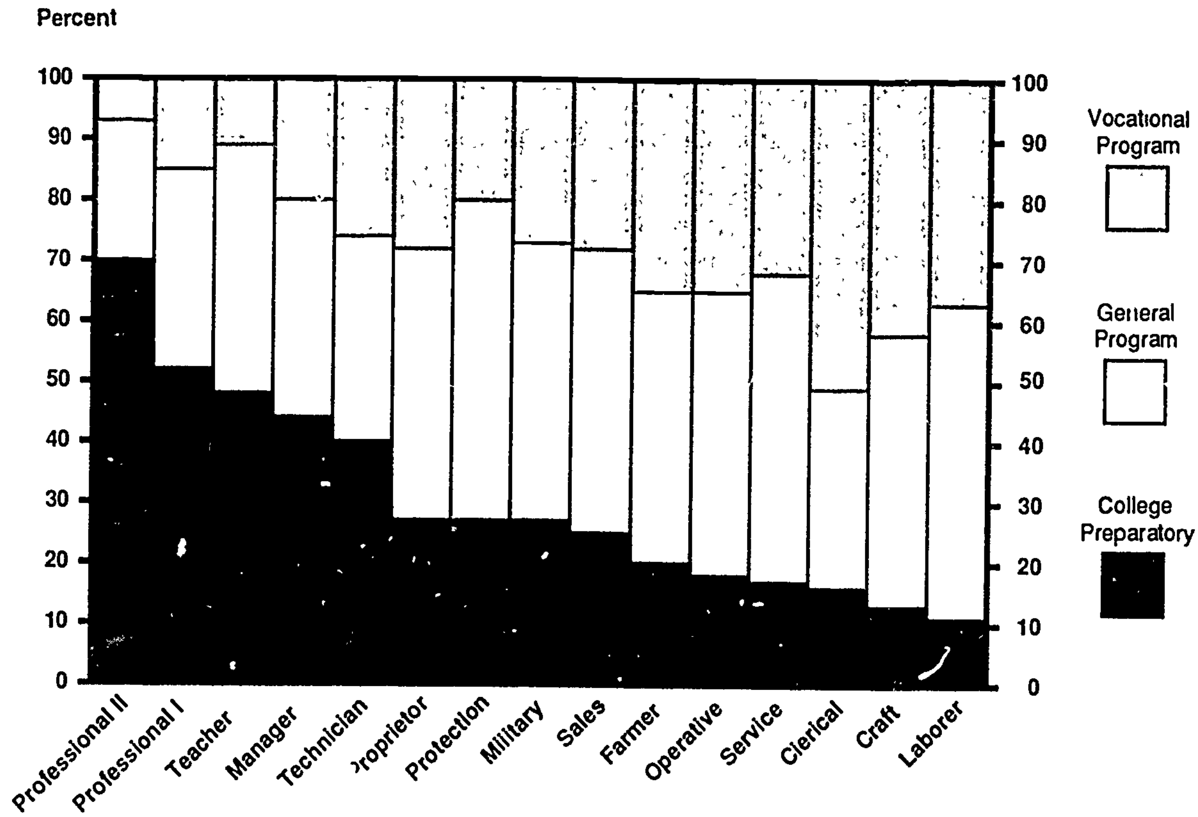

FIGURE 36. Occupational goals by high school curriculum type, 1980.

they expected to hold at age 30, the majority of those who aspired to the more prestigious jobs (Treiman, 1977), such as professional and managerial positions, were in college preparatory programs.

By contrast, students on vocational tracks in high school tend to have low educational aspirations. The majority expect to either attend a vocational school or receive no formal education after high school. While some do aspire to attend a two year academic institution, virtually none expect to earn a bachelors degree. The occupational goals of vocational track students are clustered among less prestigious jobs such as clerical and blue collar positions. Table 15 has a full listing of the occupations within each category.

The general track in high school presents what appears to be a paradoxical situation. On the one hand, a general curriculum is less defined than either the vocational or college preparatory programs. As noted in earlier chapters, students in a general curriculum take little mathematics and science in high school. In fact, they appear to take a little of many subjects but, as a group, do not focus on any particular academic or vocational area during high school. On the other hand, general track student exhibit a broad range of educational aspirations and, as a group, they have significant representation across the full spectrum of possible occupations. In short, the students in a general curriculum do not appear to be prepared for anything in particular. Even though public colleges in some states unconditionally admit their high school graduates (Boyer, 1985), students from the general track may find that this background raises serious barriers to their success as undergraduates.

II. High School Background and Long Term Goals

Long term goals are related to the courses taken during high school. As indicated by Figure 37a, a higher percentage of students aspiring

Table 15. Occupational categories and subcategories used in the High School and Beyond Study, 1980.

CLERICAL	bank teller, bookeeper, secretary typist, mail carrier, ticket agent
CRAFTSMAN	baker, automobile mechanic, machinist, painter, plumber, telephone installer, carpenter
FARMER, FARM MANAGER	
HOMEMAKER OR HOUSEWIFE	
LABORER	construction worker, car washer, sanitary worker, farm laborer
MANAGER, ADMINISTRATOR	sales manager, office manager, school administrator, buyer, restaurant manager, government official
MILITARY	career officer, enlisted man or woman in the Armed Forces
OPERATIVE	meat cutter, assembler, machine operator, welder, taxicab, bus or truck driver
PROFESSIONAL I	accountant, artist, registered nurse, engineer, librarian, writer, social worker, actor, actress, athlete, politician, but not including school teacher
PROFESSIONAL II	clergyman, dentist, physician, lawyer, scientist, college teacher
PROPRIETOR or OWNER	owner of a small business, contractor, restaurant owner
PROTECTIVE SERVICE	detective, police officer or guard, sheriff, fire fighter
SALES	sales person, advertising or insurance agent, real estate broker
SCHOOL TEACHER	elementary or secondary (not college)
SERVICE	barber, beautician, practical nurse, private household worker, janitor, waiter
TECHNICAL	draftsman, medical or dental technician, computer programmer

Sources: High School and Beyond Study, Digest of Education Statistics

to bachelors degrees take traditional mathematics courses than students with lower educational expectations. The differences are dramatic even at the first year mathematics level. Barely one half of the students who expect to terminate their education with a high school diploma have taken algebra I, whereas nearly all of the students (94%) who are aiming for a bachelors degree have taken that course. The students who intend to enter vocational training and those who expect to go to two year colleges take algebra I at a rate between these two extremes.

These differences in coursework are even more pronounced with respect to junior and senior level courses. The bulk of the students who anticipate graduating from a four year college have taken chemistry and intermediate mathematics in high school (Figures 37a & 37b). A third of them have also taken physics. By contrast, only one tenth of the students who do not plan on a four year college education have taken physics. The seniors who expect to terminate their education with high school or vocational school leave the traditional science and mathematics sequence early. As a result, courses such as physics and calculus are taken almost exclusively by students with high educational expectations.

Among the students bound for four year colleges, there is marked difference in the pattern of courses taken in high school by projected college major (See Figure 38). Seniors who look to major in engineering or the physical sciences are three times more likely to have taken trigonometry and four times more likely to have taken high school physics than the average student. These majors also score highest on achievement tests in mathematics, vocabulary and reading (see Table 16).

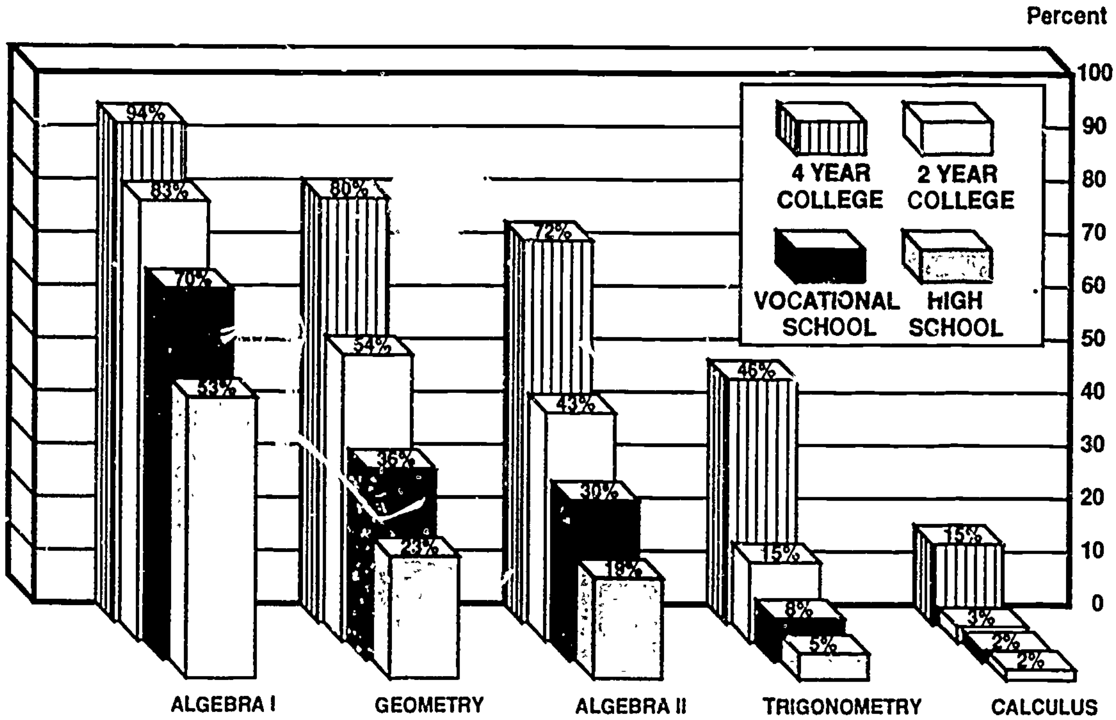

FIGURE 37a. Percent of seniors who have taken selected mathematics courses by level of educational aspiration, 1980.

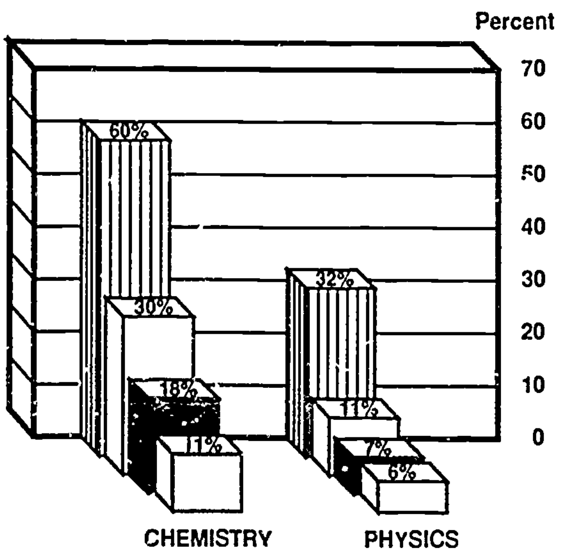

FIGURE 37b. Percent of seniors who have taken selected science courses by level of educational aspiration, 1980.

TABLE 16. Median standardized scores on achievement tests in mathematics, vocabulary and reading by anticipated college majors, 1980.

Anticipated Major	Mathematics	Vocabulary	Reading
STUDENTS EXPECTING AT LEAST A BACHELORS DEGREE			
Physical Sci.	63	61	62
Engineering	62	57	60
Mathematics	61	53	55
Life Sciences	58	58	60
Pre-professional	59	58	58
Computer Sci.	59	53	57
Health Sciences	53	52	55
Social Sciences	55	56	57
Business	55	53	55
Art and Music	52	53	55
Education	52	51	52
Nat'l Avg.	55	54	55
STUDENTS EXPECTING A TWO YEAR DEGREE			
Engineering	51	50	50
Computer Sci.	52	50	52
Health Sciences	47	49	50
Social Sciences	49	49	52
Business	49	48	50
Art and Music	49	48	48
Education	46	47	48
Nat'l Avg.	48	49	50

Source: High School & Beyond Study

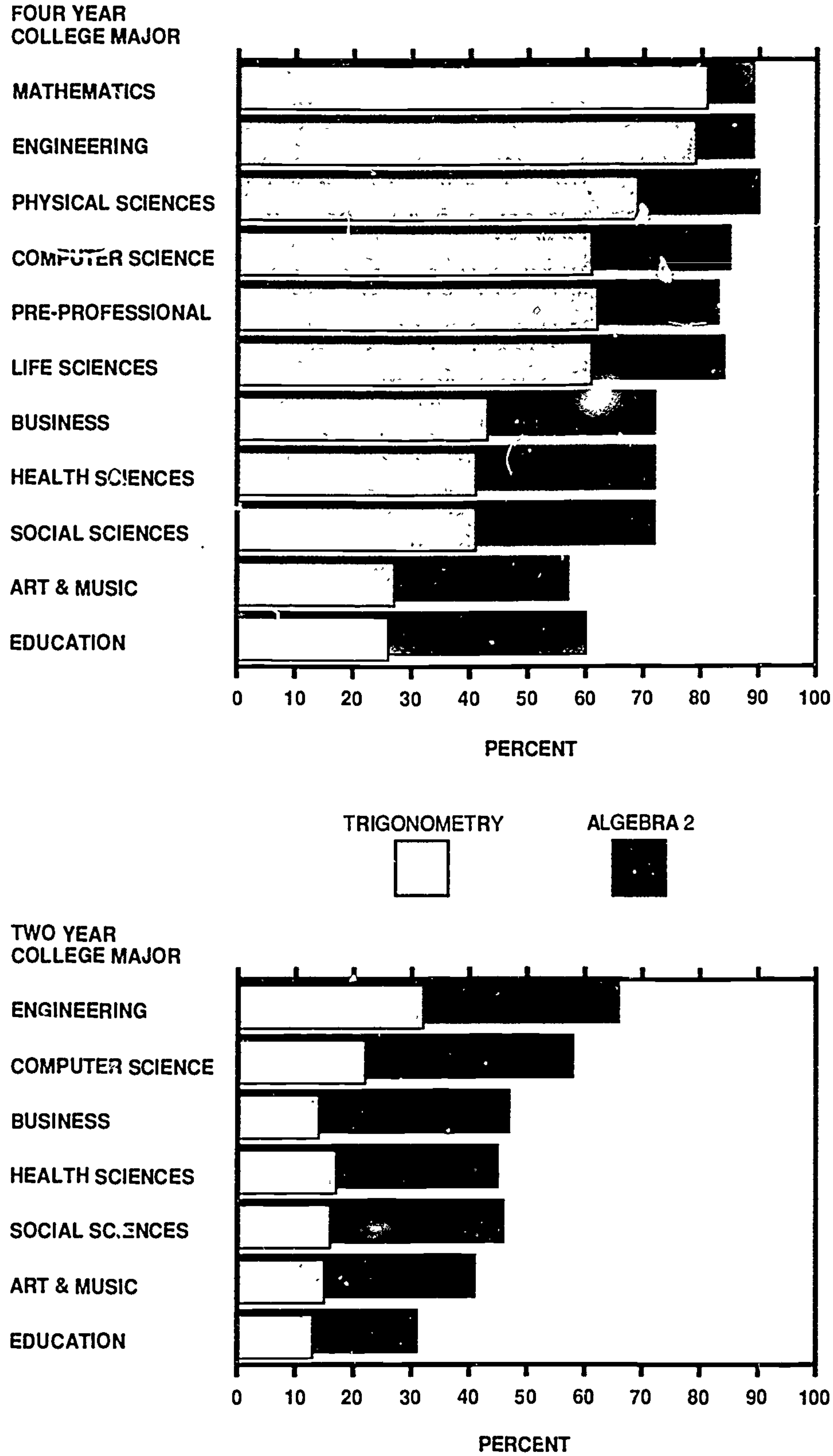

FIGURE 38. Percent of seniors who have taken trigonometry or Algebra II by anticipated college major, 1980. This figure is based on those students who aspire to a degree from either a two or four year college.

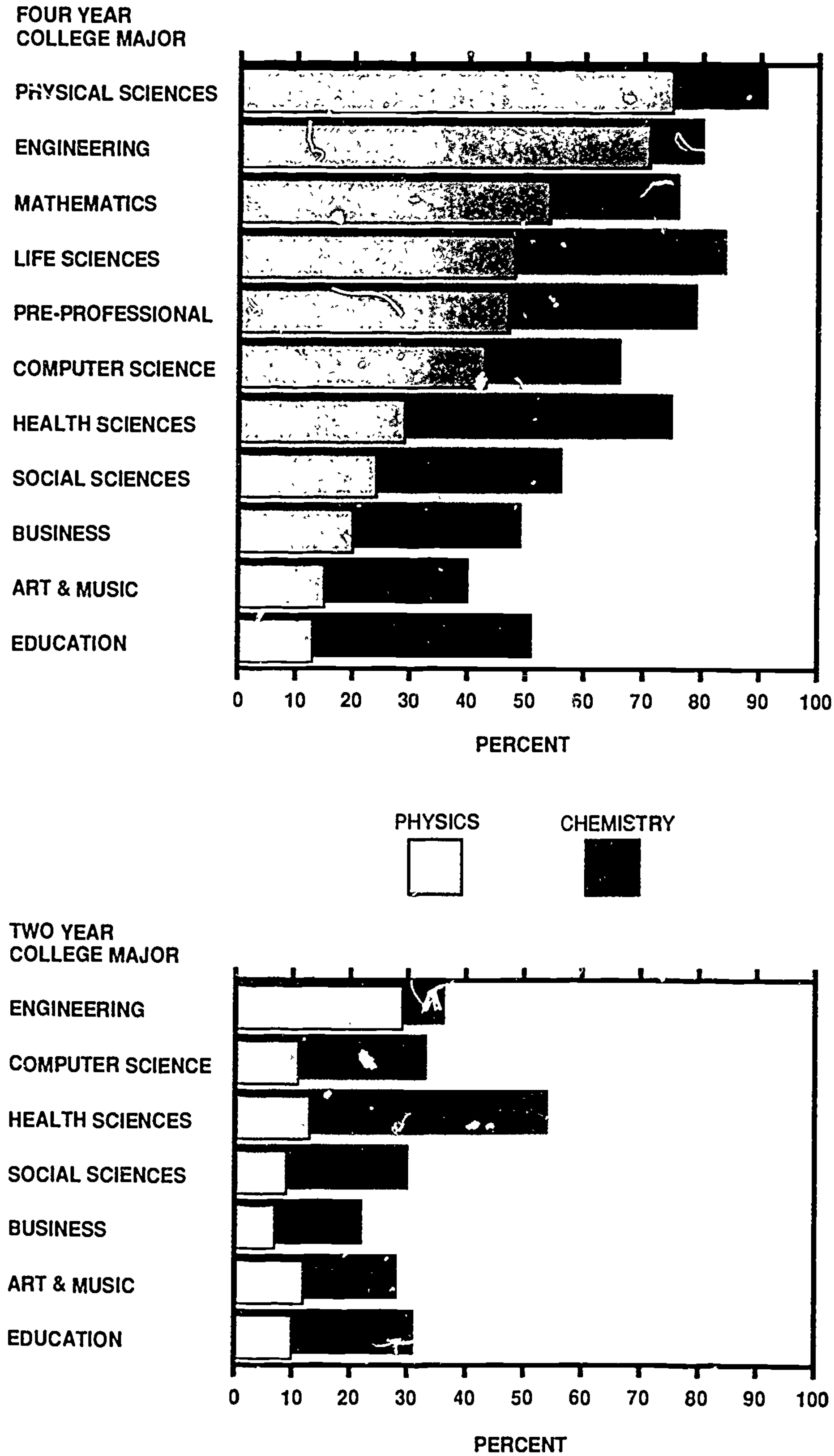

FIGURE 39. Percent of seniors who have taken chemistry or physics by anticipated college major, 1980. This figure is based on those students who aspire to a degree from either a two or four year college.

On the other end of the scale are students who intend to major in education, art or music. Few of these students have taken intermediate level high school science or mathematics. They also receive the lowest standardized scores on achievement tests in mathematics, reading and vocabulary. While majoring in art or music may not demand high competency in mathematics and science, it is rather disconcerting to note that education majors evidence the same lack of preparedness.

As discussed earlier, students intending to enter two year colleges are less likely than those bound for the four year colleges to have taken the traditional mathematics and science courses in high school. There is, however, some minor variation by intended major, with engineering students taking somewhat more high school mathematics and physics than other majors. However, the patterns are not pronounced and there is virtually no difference among the majors on achievement test scores.

Among the two year college bound. intended health science majors stand out as an anomaly. Over half of them have taken chemistry, a significantly higher proportion than any other two year college group. This probabaly reflects nursing pre-requisites. A detailed discussion of the relationships among college major, chemistry taking and student gender can be found in Chapter 3, section 4.

Students who expect to enter two year colleges represent a heterogeneous group with diverse skills and course taking patterns. As a group, however, they display many characteristics which are similar to students planning to enter vocational training. Their achievement test scores in mathematics, vocabulary and reading are almost identical. Likewise, large proportions of both of these groups leave the traditional high school mathematics sequence during intermediate courses, as depicted by Figure 37a. However, while students planning to enter vocational schools leave the mathematics sequence after algebra I, about half of those directed towards two year college hold on through geometry.

The following section explores the relationship between educational and occupational plans. The comparison among students expecting to enter four year colleges, community colleges and two year colleges will further illustrate the diversity of the latter group.

III. Occupational and Educational Expectations

Educational and occupational goals are highly related. As Figure 40 indicates, students planning to earn a bachelors degree are clearly directed towards professional occupations. At the other end of the spectrum, students terminating their education at the high school level will be concentrating in clerical, craft and unskilled labor areas.

Students considering vocational schools and two year colleges indicate the most varied profiles. Like the terminal high school graduates, many are aimed at clerical and craft operations. Others are directed at technical and business positions. Finally, a signifcant number, particularly among the potential two year college bound, aspire towards professional careers.

Students approach their educational and occupational goals in different fashions, as indicated by their plans for the first year after graduation. Table 18 presents students' first year plans according to the their educational expectations. To a large extent, these immediate plans are in line with students' long term goals. Three-quarters of the students bound for four year colleges intend to matriculate directly after graduation from high school. An additional 12% will begin their studies in the two year college arena, intending to transfer to a four year college later. Only 10% are delaying their college entrance to work or fulfill a military obligation.

The situation for those considering two year colleges and vocational schools is more mixed. While most students expecting to remain in college for two years anticipate entering the two year college system directly, a significant proportion apparently hope to receive

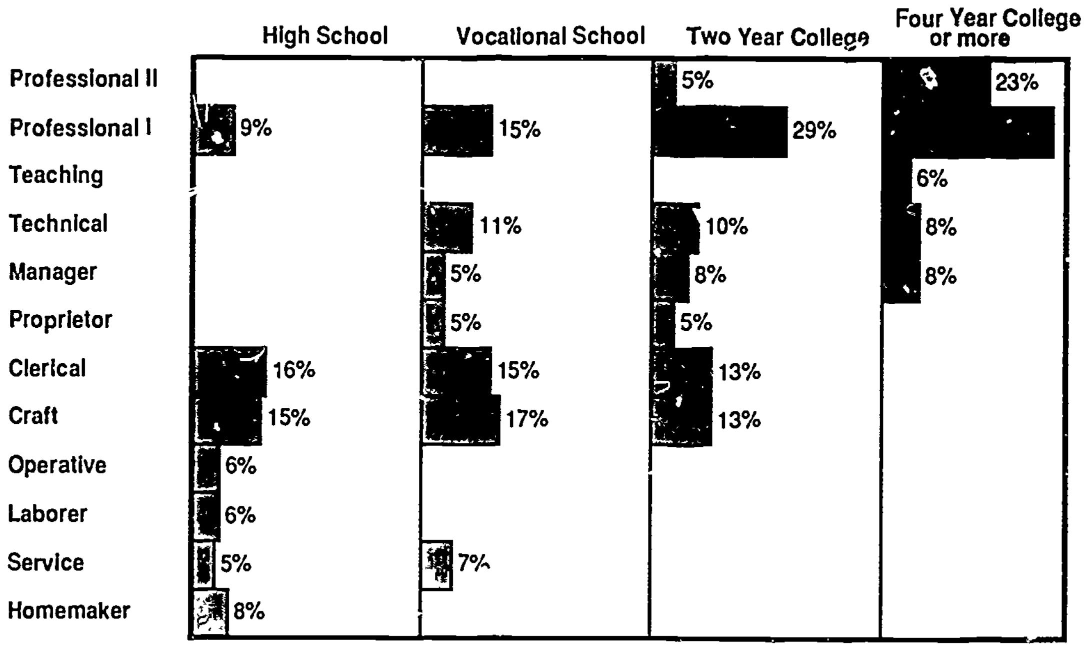

FIGURE 40. Predominant occupational goals by level of educational aspiration, 1980. Occupations cited by less than 5% of the students are not displayed. See Table 15 for a listing of the fields within each category.

TABLE 17. Median standardized scores on achievement tests in mathematics, vocabulary and reading by level of educational aspiration, 1980.

	High School	Vocational School	Two Year College	Four Year College
Mathematics	40	46	48	55
Vocabulary	44	46	49	54
Reading	43	48	50	55

Source: High School and Beyond Study

TABLE 18. Plans for the first year after high school by level of educational aspiration, 1980.

	High School %	Vocational School %	Two Year College %	Four Year College or more %
Working/Miliatry	87	53	27	10
Trade School	1	24	3	1
Junior College	1	14	44	12
College	1	3	21	75
Homemaker	4	2	1	--
Other	6	4	4	2

Source: High School and Beyond Study

TABLE 19. Percent of seniors planning to atter d either a two year or four year college in the first year after high school compared to actual enrollment data by race and ethnic background, 1980.

	Asian %	White %	Black %	Hispanic %
EXPECTED PLANS				
Junior College	29	27	22	37
Four Year College	71	73	78	63
ACTUAL ENROLLMENT				
Junior College	43	36	43	54
Four Year College	57	65	57	46

Sources: High School and Beyond Study; and Digest of Education Statistics

an associates degree from a four year institution. More than a quarter of these students, however, will delay their education by working for at least a year after graduating from high school. Most vocational school applicants will first enter the labor force, although some of t!. s may be combined with part-time vocational training.

Immediate plans, however, do not always hold up. Many students who intend to enroll in four year colleges directly, will in fact start out in a two year institution. Data on actual enrollment in two year and four year colleges provide a comparison between where students hope to be going to school and where they actually go (Snyder 1987). Table 19 provides data on students from various racial and ethnic backgrounds who expect to enter either two or four year institutions. Black and Hispanic students are least likely to fulfill their intentions of entering four year colleges directly and start out at two year schools instead.

IV. Conclusions

Given our increasingly technological society, it is crucial that the next generation of voters, decision makers and workers have at least some grasp of basic science and mathematics. An examination of the patterns of courses taken in high school in 1980 provide us with little confidence. While broad state requirements have escalated since that date, they have had a minimal impact on students taking intermediate and uppe level courses. The life goals of 17 year old students are, of course, subject to change. However, a limited education in high school restricts one's flexibility to change educa*ional and career paths later on in life. By taking more mathematics and science in high school, students open themselves to the widest range of future options; at the least, they will not have cut these options off so early in their lives.

Any evaluation of high school education is contingent on information regarding students' post-secondary school experiences. The following report will detail these graduates' lives after high school and shed more light on the strengths and inadequacies of science and mathematics education in the secondary school system.

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APPENDIX A
GEOGRAPHIC DIVISIONS

New England

- Connecticut
- Maine
- Massachusetts
- New Hampshire
- Rhode Island
- Vermont

Middle Atlantic

- New Jersey
- New York
- Pennsylvania

South Atlantic

- Delaware
- District of Columbia
- Florida
- Georgia
- Maryland
- North Carolina
- South Carolina
- Virginia
- West Virginia

East North Central

- Illinois
- Indiana
- Michigan
- Ohio
- Wisconsin

West North Central

- Iowa
- Kansas
- Minnesota
- Missouri
- Nebraska
- North Dakota
- South Dakota

West South Central

- Arkansas
- Louisiana
- Oklahoma
- Texas

Mountain

- Arizona
- Colorado
- Idaho
- Montana
- Nevada
- New Mexico
- Utah
- Wyoming

Pacific

- Alaska
- California
- Hawaii
- Oregon
- Washington

East South Central

- Alabama
- Kentucky
- Mississippi
- Tennessee

APPENDIX B
CORRECTING ERRONEOUS PHYSICS DATA

In the process of data analysis, several logical inconsistencies were found. There were a number of anomalies in the data on the specific mathematics and science courses that students reported taking. In particular, there appeared to be a number of seniors who misinterpreted the question about whether they had taken a course in physics. This Appendix describes those individuals who reported taking physics and whose data were changed to indicate that they had not taken physics. Thus, the physics data reported in this study does not agree exactly with other published reports based on the HS&B survey.

As noted in Chapter 3, students who take physics have a very strong background in mathematics. Over 80% of physics students completed algebra I & II and geometry. Two out of three completed trigonometry and over a quarter had taken calculus.

However, out of the 28,240 seniors in the survey, 347 (1.2%) reported that they completed none of the above five traditional mathematics courses and yet claimed to have completed a course in physics. Table B-1 indicates how these 347 problem cases compare with physics students and with other students who had reported taking neither physics nor any of the traditional mathematics courses.

TABLE B-1. Median and quartile standardized test scores on achievement tests in mathematics, reading and vocabulary. Students are those who have completed physics, those who have not completed physics or any of the traditional courses in mathematics, and those identified as problem cases, 1980.

	Physics Students	Problem Cases	No Physics and No Math	All Students
		MATHEMATICS		
25th P	53	36	38	43
Median	60	40	42	49
75th P	64	44	45	57
		READING		
25th P	50	34	36	43
Median	57	38	43	50
75th P	62	45	48	57
		VOCABULARY		
25th P	49	37	[illegible]9	43
Median	56	40	[illegible]3	49
75th P	63	44	48	56

Source: High School & Beyond

TABLE B-2. Overall grades as reported by students who have completed physics, those who have not completed physics or any of the traditional courses in mathematics, and those identified as problem cases, 1980.

	Physics Students %	Problem Cases %	No Physics and No Math %	All Students %
90-100	29	2	2	12
85-89	28	9	10	21
80-84	20	13	14	21
75-79	15	40	34	26
70-74	5	21	24	14
65-69	2	12	13	6
60-64	1	2	2	1
< 60	-	1	1	-
Mean	86	76	76	81
25th P	80.1	70.5	71.3	75.4
Median	85.8	76.2	75.9	80.3
75th P	90.2	79.1	79.6	84.9

Source: High School & Beyond

The problem cases group is almost a full standard deviation below the overall student body on the tests of mathematics, vocabulary and reading ability. There is virtually no overlap between the 347 problem cases and physics students' scores. In fact, the "347" do even poorer on these tests than other students who reported taking neither physics nor any of the traditional mathematics courses. Further confirming data can be found in Tables B-2 and B-3. The 347 problem cases as a group are barely passing while physics students as a group have a grade point average in the A-/B+ range. Not surprisingly, the "347" have very low educational expectations.

TABLE B-3. Educational expectations as reported by students who have completed physics, those who have not completed physics or any of the traditional courses in mathematics, and those identified as problem cases, 1980.

	Physics Students %	Problem Cases %	No Physics and No Math %	All Students %
H.S.	6	53	46	20
Voc.	9	25	33	22
2-yr	7	7	10	12
4-yr+	78	15	11	46

Source: High School & Beyond

In short, given the reading and vocabulary abilities of the problem cases, it is easy to believe that they misread or misinterpreted the question on physics. Conversely, given the mathematics preparation and ability of this group it is very difficult to believe that they would have enrolled in a physics course. Thus, for all of the data analyses used in this report, these 347 individuals were re-coded to indicate that they had not taken physics.

APPENDIX C
METHODOLOGICAL NOTES

Achievement Test Scores

Two achievement tests in mathematics and two in vocabulary were administered as part of the HS&B study. There was a high correlation between the scores on the two mathematics tests as well as on the two vocabulary tests. The standardized scores for both mathematics tests were correlated at .63 and for both vocabulary tests the scores were correlated at .70. The tests did have different numbers of items. In the case of mathematics, one test was comprised of 25 items and the other 8 items. In the case of vocabulary, one test was comprised of 15 items and the other 12 items. To further improve the reliability and stability of these measures, the two test scores in mathematics and those in vocabulary were combined with only the average scores reported. This procedure was used throughout the report and had the effect of changing the standard deviation from 10 to 9, although the mean for the distribution stayed at 50.

Missing Responses

The high school seniors who participated in the HS&B Study were asked which of five traditional mathematics courses they had taken. They were also asked whether they had taken two specific courses in science - chemistry and physics. Some students did not respond either YES or NO to these questions but left them blank instead. Analyses of the data indicate that these students closely resemble students who responded "NO" to the questions about specific courses and differ from those students who reponded "YES" to those items. Thus, these missing data were changed to "NO."

Statistical Package

The HS&B data were analyzed using the P-STAT statistical package. This package computed the medians and quartiles reported in the tables and figures. It should be noted that P-STAT works with an ordered distribution of value points. In such an ordered distribution, the median equals the central point in an odd-numbered distribution and a weighted value between two middle points in an even-numbered distribution. P-STAT does not interpolate when the requested quantile falls a certain fraction into a group of equal values.

END

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