Chapter 1
Elementary and Secondary Mathematics and Science Education

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HIGHLIGHTS

STUDENT ACHIEVEMENT

- **The general pattern for mathematics and science achievement test scores for upper-elementary and secondary school students has been one of decline or stagnation during the 1970s, followed by steady increase through the 1980s.** The overall scores show gains for all age groups in both mathematics and science during the 1980s. The 1992 average mathematics scores for all three National Assessment of Educational Progress (NAEP) age groups are at least as high or higher than the 1973 scores. The 1992 average science scores are higher than in 1970 for 9- and 13-year-olds, but are lower for 17-year-olds.
- **The average mathematics scores of male and female 9- and 13-year-olds did not differ in 1992, and the difference in scores for 17-year-old males and females is small.**
- **Gender differences in average science achievement test scores have diminished, but males score higher at each age level.**
- **Non-Hispanic white youth continue to score much higher than black or Hispanic youth on standardized tests of mathematics and science, but the differences decreased from the late 1970s to 1992.** Since the average scores of all groups have increased over this period, the convergence is real improvement and not a "leveling down" of scores toward greater equality.
- **While international comparisons of mathematics and science achievement rank U.S. students below most other industrial nations, students in some states are at about the same level as the average students in the higher achieving nations.**

CURRICULUM AND INSTRUCTION IN HIGH SCHOOLS

- **High school students are completing substantially more mathematics and science courses than in the early 1980s.** Enrollments have grown rapidly in more advanced courses like trigonometry, calculus, chemistry, and physics.
- **Student achievement scores show greater gains over the high school years among students who take more mathematics and science courses.** This pattern holds for students who start high school at lower levels of mastery, as well as for students who start high school at relatively high levels of mastery.
- **Students who complete higher levels of high school mathematics and science are less likely to drop out of college.**

TEACHERS AND TEACHING

- **Many mathematics and science teachers have very little training in mathematics and science, particularly among elementary and middle-grade teachers.** In 1993, less than 4 percent of elementary mathematics and science teachers had majored in mathematics or mathematics education, or science or science education. Only 11 percent of middle school mathematics teachers and 21 percent of science teachers majored in their fields of teaching specialization. Sixty-three percent of high school mathematics teachers and 72 percent of high school science teachers had in-field majors in 1993.
- **Many teachers are not well aware of reform recommendations advanced by their professional associations.** In 1993, 56 percent of grade 9–12 mathematics teachers felt well aware of the National Council of Teachers of Mathematics (NCTM) curriculum and evaluation standards, compared with 28 percent of the grade 5–8 teachers, and only 18 percent of the grade 1–4 teachers.

Introduction

Chapter Background

Science and mathematics education at the elementary and secondary levels has been the subject of major reform efforts for the past decade. Spurred, in part, by concerns over apparent test score declines, the weak preparation of high school graduates for college and work, and the unfavorable showing of U.S. youths in international comparisons, most states and many local districts and schools have sought to improve student outcomes.

In 1983, the National Science Board report *Educating Americans for the 21st Century* set forth the goal that

> By 1995, the Nation must provide, for all its youth, a level of mathematics, science, and technology education that is the finest in the world, without sacrificing the American birthright of equity and opportunity.

Twelve years later, it is clear that the United States has not achieved this goal and that much remains to be done. Nonetheless, it is also clear that much has been accomplished. During this period, the precollegiate mathematics and science curricula have been extensively reviewed and thoughtfully revised. Many state and local education authorities have increased the number of mathematics and science courses students must complete to graduate from high school, and these requirements are now beginning to specify more advanced courses.

A reform movement has been led by the professional associations of mathematics and science teachers, the National Council of Teachers of Mathematics (NCTM) and the National Science Teachers Association (NSTA). These and other allied organizations and government agencies have developed curriculum, evaluation, and pedagogy standards. The most distinctive—and ambitious—aspect of these standards is the emphasis placed on improving outcomes for all students through a common curriculum. The comprehensiveness and clarity of the NCTM and NSTA standards have made them especially attractive to state and local education authorities, who had already been making efforts to improve curriculum, instruction, and outcomes.

Of course, recommended curricula and pedagogy are not the same as implemented curricula and pedagogy, and many formidable obstacles to implementation are likely to arise at every level. One of the most important of these obstacles may be the limited amount of time that American elementary and secondary teachers have to plan and exchange ideas with colleagues. As a result, teachers within the same school may hold quite different ideas about what constitutes appropriate practice and may work at cross-purposes to one another. Another obstacle may be that incentives for students to work harder in school are often low, because college admission is available to almost all students who can afford it and employers almost never request information on high school grades or test scores.

Improved outcomes are thus, by no means, certain to follow upon even widespread consensus over goals. While national trends in learning outcomes remain the best gauge of success, an understanding of what is and is not working can be achieved only by systematically collecting data on the full range of mediating steps between intention and result. This chapter thus seeks to complement achievement trends with data on student coursetaking and on teachers and their opportunities for professional development.

Chapter Organization

This chapter presents indicators of changes in student performance, student coursetaking, school and teacher adoption of national standards in science and mathematics, and teacher preparation in science and mathematics. The first section of this report gives an overview of achievement trends by drawing on data from the National Assessment of Educational Progress (NAEP). Student performance increased somewhat during the 1980s, especially for minority groups. New information about state-by-state differences in performance shows that students in some regions of the United States perform as well as students in the highest performing countries in the world, whereas students in other regions perform at the same level as students in the poorest performing countries of the world. The first section also reviews preliminary results from recent efforts to assess achievement with instruments other than multiple-choice tests.

State and local efforts in the 1980s to improve precollegiate mathematics and science instructional outcomes focused largely on graduation requirements, with little attention to curriculum content and instructional methods. High school graduates at the end of the 1980s had completed more courses in mathematics and science than at the beginning of the decade. Have these trends continued in the 1990s? Are students taking more advanced courses, or have enrollments mainly increased in the lower-level courses? Does more coursetaking lead to higher performance on achievement tests? The second section of this chapter reviews recent coursetaking trends, as well as results from recent analyses of the National Education Longitudinal Study of 1988 (NELS: 88) survey of high school students, which examine the relationship of coursetaking in science and mathematics to student achievement score gains during the high school years.

How adequately are students prepared in science and mathematics for postsecondary education and work opportunities? The chapter addresses this question in two ways. The first involves an assessment of the relationship between high school coursework and postsecondary outcomes. The second approach entails an examination of responses from college teachers to questions soliciting their subjective assessment of how well the students are prepared.

Teachers contribute to and are directly affected by the reform efforts. The third section of this chapter presents indicators on whether teachers are aware of the new standards, whether they have adopted them for their own classroom instruction, and whether they have been trained sufficiently to teach students in the manner recommended by the national standards. Data from the 1993 National Survey of Science and Mathematics Education (NSSME) are the primary source of information used to assess these issues.

While the typical science or mathematics class is taught by one teacher, the worklife of teachers usually involves a variety of contacts with other teachers and school administrators. Reform proposals emphasize the importance of building strong colleague support systems to improve the dissemination of new ideas and critical feedback. Data from recent surveys of teachers suggest that high schools differ greatly in the levels of cooperation and coordination within their departments. These data also illustrate the extent to which teachers understand and try to implement reform measures and whether their understanding and efforts are associated with whether they maintain contacts with colleagues in their subject-area departments.

Student Achievement

Trends in Achievement: The National Assessment of Educational Progress (NAEP)

The best information on national trends in student achievement is NAEP. Since 1969, NAEP has administered mathematics, science, reading, and writing tests to national samples of 9-, 13-, and 17-year-olds on a periodic basis. Special, less frequent, assessments have been conducted in other subject areas, including U.S. history, geography, civics, and computer literacy. Mathematics achievement has been assessed seven times (1973, 1978, 1982, 1986, 1990, 1992, and 1994); science achievement has been assessed eight times (1970, 1973, 1977, 1982, 1986, 1990, 1992, and 1994).[1] NAEP offers several advantages over tests such as the Scholastic Aptitude Test (SAT) and the American College Test (ACT). Most important, NAEP assesses nationally-representative samples of students, whereas the SAT and ACT test-takers are a self-selected subset of students.

NAEP reports mathematics and science achievement scores in two general forms: the student's general proficiency level and the student's levels of achievement on various subscales, which refer to specific thinking skills and content knowledge. The general achievement results, in turn, are reported in two forms. One form provides an overall or average proficiency score ranging from 0 to 500.[2] The other divides the 0 to 500 scale into a set of "proficiency levels" characterized in terms of typical skills.

The NAEP content and skill subscales are constructed from subsets of the items and are thus distinct from the general proficiency scale scores. The content areas in mathematics are numbers and operations, measurement, geometry, data analysis, statistics and probability, and algebra and functions. Mathematical thinking skills include conceptual understanding, procedural knowledge, and problem solving.

Content areas in science include life science, physical science, and earth and space science. Science thinking skill areas include knowledge of everyday science facts and simple scientific principles, application of scientific facts and principles to solve problems, and ability to design a scientific inquiry.

In this chapter, trend data are presented on both the overall proficiency scores and the proficiency levels. Data collected in 1990 and 1992 on the mathematics content subscales are presented, but earlier trend data are not available for the subscales. The available subscale information for science is even more limited, thus, it is not presented here.[3]

The NAEP was originally designed to obtain accurate assessments of students across the United States and separately by region of country, type of community, student gender, and student race/ethnicity. The 1992 mathematics assessment was substantially expanded to allow for further breakdowns by state and some of those results are presented here. The science assessment was not included in the state-by-state assessment design, but the national trend data will continue to be collected in upcoming assessments.

Changes in Overall and Specific Mathematics and Science Proficiencies

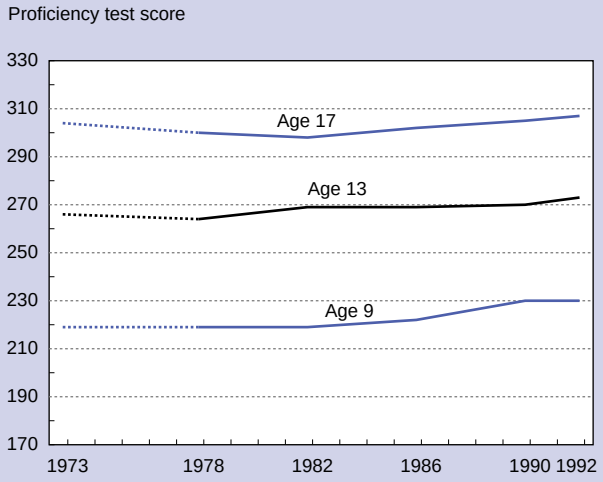
Since the NAEP began, the general pattern of overall proficiency scores for mathematics and science has been one of decline or stagnation during the 1970s, followed by a steady increase through the 1980s. (See figures 1-1 and 1-2 and appendix table 1-1.) Overall scores increased over the 1980s for all age groups in both mathematics and science. Indeed, for all three age groups, the 1992 mathematics scores were at least as high or higher than

[1]The 1994 data were not available when this report was written. The next assessments of both mathematics and science are scheduled for 1996.

[2]The full-sample standard deviations of the mathematics scores in 1992 were reported only by grade level and not by age. The standard deviations for 4th, 8th, and 12th grade students were, respectively, 32.4, 36.6, and 34.4 (NCES, 1993). The only published science test score standard deviations available are from the 1990 assessment, and they were presented by grade levels, rather than age. The science test standard deviations for 4th, 8th, and 12th grade students were, respectively, 31.4, 39.5, and 42.5 (Jones, Mullis, Raizen, Weiss, and Weston, 1993).

[3]The 1992 NAEP science assessment did not include enough items to construct reliable measures of either the content knowledge or thinking skill proficiencies. The published tabulations for the 1990 science assessment include only the content area data (Jones, Mullis, Raizen, Weiss, and Weston, 1993).

Figure 1-1.
Trends in average mathematics proficiency



..... extrapolated from previous NAEP analyses.

NOTE: Data are interpolated for years when NAEP not administered.

See appendix table 1-1.

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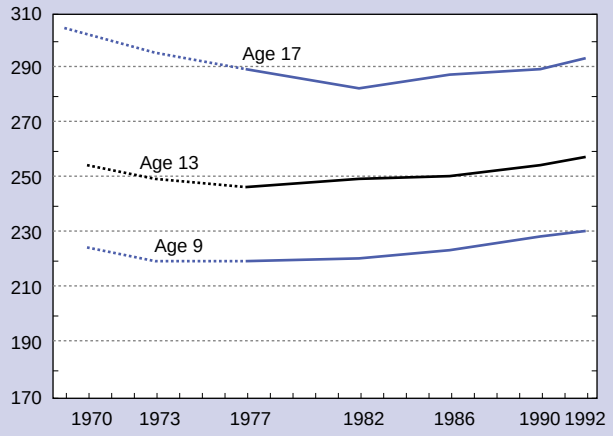
Figure 1-2.
Trends in average science proficiency



..... extrapolated from previous NAEP analyses.

NOTE: Data are interpolated for years when NAEP not administered.

See appendix table 1-1.

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the 1973 scores. The net gain of 11 points for 9-year-olds over the 19-year period was the largest. That gain actually occurred entirely from 1982 to 1992; scores for this group were steady from 1973 to 1982. The science scores for the 9-year-old population also show a statistically significant net gain from 1970 to 1992, but the change is only 6 points. Again, this increase occurred entirely from 1982 to 1992. The only net decline over the full span was in the science achievement of 17-year-olds.

One way to assess the significance of these changes is to compare them with the average gains per age-year that students realize. A rough estimate of these averages was obtained by dividing the difference between the age 17 and age 9 scores by the 8 years separating the two groups and averaging the quotients across the assessment years.[4] The average gain per age-year in mathematics was 9.9 points across the six assessments. This means that from 1982 to 1992, the 11-point gain in mathematics in the 9-year-old population translates into more than 1 age-year higher achievement. The average gain of 8.5 points per age-year in science was slightly lower. The 10-point gain among 9-year-olds from 1982 to 1992 thus represents about 1.2 age-year equivalents. In other words, if these growth assumptions are correct, 9-year-olds in 1992 were performing at levels that would have been slightly higher than those of the average 10-year-old in 1982.

Another way to make the results above more understandable is to tie the scores to particular competencies. The overall proficiency scores can be used to define cutpoints that index different knowledge and skill levels. (Detailed descriptions of the skill levels are included in appendix tables 1-2 and 1-3.) The highest level includes students who scored 350 or higher on the overall proficiency score. In mathematics, this score means that these students are able to solve multistep problems and to use algebra to solve problems. (See text table 1-1.) Virtually no changes in the percentages of students able to perform competently at this level have occurred since 1978 (the first year for which these cutpoints could be accurately assessed). Practically no 9- or 13-year-olds scored at this level, and only about 7 percent of 17-year-olds scored at this level.

Improvements are evident at the next highest level, however. The percentage of 17-year-olds scoring 300–349, demonstrating competence with "moderately complex procedures and reasoning," increased from 52 percent in 1978 to 59 percent in 1992. However, percentage of the 9- and 13-year-olds scoring at this level did not improve. All of the gains for these groups occurred with respect to the lower three levels of proficiency.

[4]The average age-year gains in mathematics are greater from age 9 to age 13 than from age 13 to age 17. The opposite is true for science. This pattern may reflect different real rates of cognitive growth in the two subjects. Alternatively, it may reflect curriculum coverage differences in mathematics and science. Almost all students study mathematics from early elementary school through the sophomore year of high school. The average high school student finishes high school with about three credits, and the loss of a fourth year of study roughly corresponds to the average difference of about 10 points less gain between age 13 and age 17 compared with the gain between age 9 and age 13. In contrast, science does not typically enter the curriculum until grade 6 or 7. Between age 9 and 13, then, many students will have had only 1 or 2 years of exposure to school science. While the average high school graduate completes a little over two science courses, he or she is still likely to receive relatively more exposure to science than the younger age group.

Text table 1-1.
Trends in the percentage of students at or above five mathematics proficiency levels

Proficiency level	Ability	Age	Assessment years 1978	1982	1986	1990	1992
Level 350	Multistep problem solving and algebra	9	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		13	1 (0.2)	0 (0.1)	0 (0.1)	0 (0.1)	0 (0.2)
		17	7 (0.4)	6 (0.4)	6 (0.5)	7 (0.6)	7 (0.6)
Level 300	Moderately complex procedures and reasoning	9	1 (0.1)	1 (0.1)	1 (0.2)	1 (0.3)	1 (0.3)
		13	18 (0.7)	17 (0.9)	16 (1.0)	17 (1.0)	19 (1.0)
		17	52 (1.1)	48 (1.3)	52 (1.4)	56 (1.4)	59 (1.3)
Level 250	Numerical operations and beginning problem solving	9	20 (0.7)	19 (1.0)	21 (0.9)	28 (0.9)	28 (0.9)
		13	65 (1.2)	71 (1.2)	73 (1.6)	75 (1.0)	78 (1.1)
		17	95 (0.5)	93 (0.5)	96 (0.5)	96 (0.5)	97 (0.5)
Level 200	Beginning skills and understandings	9	70 (0.9)	71 (1.2)	74 (1.2)	82 (1.0)	81 (0.8)
		13	95 (0.5)	98 (0.4)	99 (0.2)	98 (0.2)	99 (0.3)
		17	100 (0.1)	100 (0.0)	100 (0.1)	100 (0.1)	100 (0.0)
Level 150	Simple arithmetic facts	9	97 (0.3)	97 (0.3)	98 (0.3)	99 (0.2)	99 (0.2)
		13	100 (0.1)	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)
		17	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)

NOTE: Standard errors appear in parentheses.

SOURCE: I.V.S. Mullis, J.A. Dossey, J.R. Campbell, C.A. Gentile, C. O'Sullivan, and A.S. Latham, *NAEP 1992 Trends in Academic Progress,* Report No. 23-TR01 (Washington, DC: National Center for Education Statistics, 1994).

See appendix table 1-2.

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Essentially the same pattern of stability and improvements is evident in science: little or no gain at the higher levels and substantial gains at the middle and lower levels. (See text table 1-2.) The percentages of students at the higher levels of science achievement also are noteworthy. Among the 17-year-olds in 1992, 10 percent were able to "integrate specialized scientific information" and less than half were able to "analyze scientific procedures and data." While there are signs of progress, the Nation's schools clearly have a great deal of room for improvement in these vital skill areas.

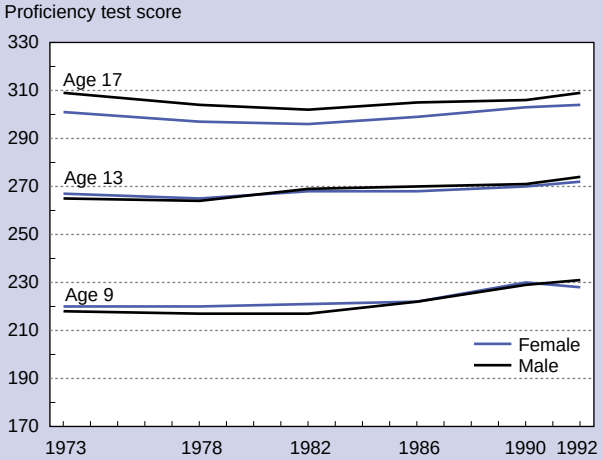
Changes in Overall and Specific Proficiencies by Sex and Race/Ethnicity

NAEP results are routinely reported for all students in the aggregate and separately for males and females and whites, blacks, Hispanics, and Asians.

Mathematics Proficiency Trends by Sex

Among the 17-year-olds in 1992, males scored about 5 points higher than females on the mathematics test. (See figure 1-3 and appendix table 1-1.) No significant difference in mathematics scores was found among 13-year-olds, and among 9-year-olds, the 3-point difference favoring males over females was small and barely significant. The mathematics trend from 1973 to 1990 indicates a reduction in the score gap between sexes among 17-year-olds and stability, or only very small differences, in the score gap between the sexes among 9- and 13-year-olds.

Figure 1-3.
Trends in average mathematics proficiency, by age and sex



NOTE: Data are interpolated for years when NAEP not administered.

See appendix table 1-1.

Science & Engineering Indicators – 1996

Comparing the percentages of males and females who attained the different levels of mathematics proficiency in 1992, the only significant difference between the sexes among the 17-year-olds was found at the highest level, "multistep problem solving and algebra." (See text table 1-3

Text table 1-2.
Trends in the percentage of students at or above five science proficiency levels

Proficiency level	Ability	Age	Assessment years 1977	1982	1986	1990	1992
Level 350	Integrates specialized scientific information	9	0 (0.0)	0 (0.1)	0 (0.1)	0 (0.0)	0 (0.1)
		13	1 (0.1)	0 (0.1)	0 (0.1)	0 (0.1)	0 (0.1)
		17	8 (0.4)	7 (0.4)	8 (0.7)	9 (0.5)	10 (0.7)
Level 300	Analyzes scientific procedures and data	9	3 (0.3)	2 (0.7)	3 (0.5)	3 (0.3)	3 (0.3)
		13	11 (0.5)	10 (0.7)	9 (0.9)	11 (0.6)	12 (0.8)
		17	42 (0.9)	37 (0.9)	41 (1.4)	43 (1.3)	47 (1.5)
Level 250	Applies general scientific information	9	26 (0.7)	24 (1.8)	28 (1.4)	31 (0.8)	33 (1.0)
		13	49 (1.1)	51 (1.6)	52 (1.6)	56 (1.0)	61 (1.1)
		17	82 (0.7)	77 (1.0)	81 (1.3)	81 (0.9)	83 (1.2)
Level 200	Understands simple scientific principles	9	68 (1.1)	71 (1.9)	72 (1.1)	76 (0.9)	78 (1.2)
		13	86 (0.7)	90 (0.8)	92 (1.0)	92 (0.7)	93 (0.5)
		17	97 (0.2)	96 (0.5)	97 (0.5)	97 (0.3)	98 (0.5)
Level 150	Knows everyday science facts	9	94 (0.6)	95 (0.7)	96 (0.3)	97 (0.3)	97 (0.3)
		13	98 (0.2)	100 (0.1)	100 (0.1)	100 (0.1)	100 (0.1)
		17	100 (0.0)	100 (0.1)	100 (0.1)	100 (0.2)	100 (0.0)

NOTE: Standard errors appear in parentheses.

SOURCE: I.V.S. Mullis, J.A. Dossey, J.R. Campbell, C.A. Gentile, C. O'Sullivan, and A.S. Latham, *NAEP 1992 Trends in Academic Progress,* Report No. 23-TR01 (Washington, DC: National Center for Education Statistics, 1994).

See appendix table 1-3. *Science & Engineering Indicators – 1996*

Text table 1-3.
Trends in the percentage of students at or above five mathematics proficiency levels, by sex

Proficiency level	Ability	Age	Assessment years 1978 Male	1978 Female	1992 Male	1992 Female
			Percent			
Level 350	Multistep problem solving and algebra	9	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		13	1 (0.2)	1 (0.2)	0 (0.2)	0 (0.3)
		17	10 (0.6)	5 (0.7)	9 (0.7)	5 (0.8)
Level 300	Moderately complex procedures and reasoning	9	1 (0.2)	1 (0.2)	1 (0.3)	1 (0.4)
		13	18 (0.9)	18 (0.7)	21 (1.1)	17 (1.4)
		17	55 (1.2)	48 (1.3)	60 (1.8)	58 (1.6)
Level 250	Numerical operations and beginning problem solving	9	19 (0.6)	20 (1.0)	29 (1.2)	26 (1.5)
		13	64 (1.3)	66 (1.2)	78 (1.6)	78 (1.1)
		17	93 (0.5)	91 (0.6)	97 (0.6)	96 (0.8)
Level 200	Beginning skills and understandings	9	69 (1.0)	72 (1.1)	82 (1. 0)	81 (1.1)
		13	94 (0.5)	95 (0.5)	99 (0.4)	99 (0.2)
		17	100 (0.1)	100 (0.1)	100 (0.0)	100 (0.0)
Level 150	Simple arithmetic facts	9	96 (0.5)	97 (0.3)	99 (0.3)	99 (0.3)
		13	100 (0.1)	100 (0.1)	100 (0.0)	100 (0.0)
		17	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)

NOTE: Standard errors appear in parentheses.

SOURCE: I.V.S. Mullis, J.A. Dossey, J.R. Campbell, C.A. Gentile, C. O'Sullivan, and A.S. Latham, *NAEP 1992 Trends in Academic Progress,* Report No. 23-TR01 (Washington, DC: National Center for Education Statistics, 1994).

See appendix table 1-2. *Science & Engineering Indicators – 1996*

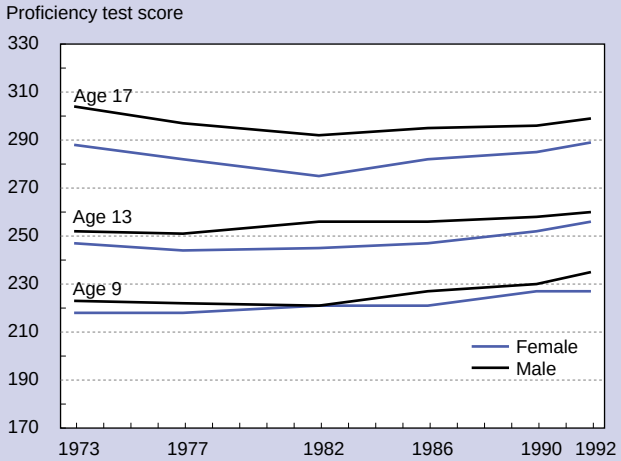
and appendix table 1-2.) None of the apparent differences among the 9- and 13-year-old males and females was statistically significant in 1992.

Science Proficiency Trends by Sex

In contrast to the pattern in mathematics, differences in the student science proficiency between the sexes in 1992 significantly favored males among the 17-year-olds, 13-year-olds, and 9-year-olds. (See figure 1-4 and appendix table 1-1.) The difference was largest among 17-year-olds and smallest among 13-year-olds. The trend lines show that the difference between the sexes among the 17-year-olds declined substantially from the early 1970s.

In 1992, a few differences existed in the percentages of males and females successfully attaining each of the five NAEP science proficiency levels. (See text table 1-4 and appendix table 1-3.) Among 9-year-olds, males had a small advantage over females at level 200 (knowledge of everyday facts) and at level 250 (simple principles). The latter gap actually represents an increase in the difference, by sex, from 1977 to 1992. The only significant male-female difference among the 13-year-olds was at the level tapping the students' abilities to analyze scientific procedures and

Figure 1-4.
Trends in average science proficiency, by age and sex



NOTE: Data are interpolated for years when NAEP not administered.

See appendix table 1-1.

Science & Engineering Indicators – 1996

Text table 1-4.
Trends in the percentage of students at or above five science proficiency levels, by sex

			Assessment years			
			1977		1992	
Proficiency level	Ability	Age	Male	Female	Male	Female
Level 350	Integrates specialized scientific information	9	0 (0.0)	0 (0.0)	0 (0.1)	0 (0.0)
		13	1 (0.2)	1 (0.1)	0 (0.1)	0 (0.2)
		17	12 (0.6)	5 (0.4)	14 (1.0)	7 (1.0)
Level 300	Analyzes scientific procedures and data	9	4 (0.3)	3 (0.3)	5 (0.6)	2 (0.3)
		13	13 (0.6)	9 (0.5)	14 (1.1)	10 (0.8)
		17	49 (1.1)	35 (1.0)	51 (2.0)	42 (1.7)
Level 250	Applies general scientific information	9	27 (0.9)	24 (0.9)	37 (1.7)	29 (1.1)
		13	52 (1.3)	45 (1.2)	63 (1.4)	60 (1.4)
		17	85 (0.7)	78 (1.0)	85 (1.4)	82 (1.4)
Level 200	Understands simple scientific principles	9	70 (1.2)	66 (1.1)	80 (1.4)	76 (1.2)
		13	87 (0.8)	85 (0.8)	93 (0.8)	93 (0.7)
		17	98 (0.2)	96 (0.3)	98 (0.6)	98 (0.7)
Level 150	Knows everyday science facts	9	94 (0.5)	93 (0.7)	98 (0.3)	97 (0.5)
		13	99 (0.2)	98 (0.2)	100 (0.2)	100 (0.2)
		17	100 (0.0)	100 (0.1)	100 (0.1)	100 (0.0)

NOTE: Standard errors appear in parentheses.

SOURCE: I.V.S. Mullis, J.A. Dossey, J.R. Campbell, C.A. Gentile, C. O'Sullivan, and A.S. Latham, *NAEP 1992 Trends in Academic Progress,* Report No. 23-TR01 (Washington, DC: National Center for Education Statistics, 1994).

See appendix table 1-3.

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data (level 300); this difference was unchanged from 1977. Among 17-year-olds, the gap at the highest level (integration) is sizable and appears to have changed little since 1977. At the next level (analyzes scientific procedures and data), the gap by sex is significant for 17-year-olds and has not significantly declined since 1977.

Mathematics Proficiency Trends by Race/Ethnicity

Gaps exist in the average mathematics proficiency levels of Hispanics and non-Hispanic blacks and whites.[5] (See figure 1-5 and appendix table 1-1.) The gaps between the lines indicate that blacks and Hispanics generally scored far below whites at all assessment years. (See *Trends in English Proficiency Among Hispanic Students*.) Despite the large gaps between the scores, the convergence of the lines indicates that the gaps are narrowing, as a result of the larger increases in the scores of black and Hispanic students compared with scores of white students. This convergence is a real improvement and not a "leveling down" of scores toward greater equality.

The race/ethnicity differences are not equal across proficiency levels. (See text table 1-5 and appendix table 1-2.) Among the 9-year-olds, the gaps are concentrated at levels 250 and 200. Virtually all 9-year-olds attained level 150 (simple arithmetic facts), and virtually none attained level 300 or higher. Among 13-year-olds, substantial race/ethnicity differences emerge at level 250 and 300. The same pattern holds for the 17-year-old group: the large gaps are at the higher proficiency levels, while the differences are relatively small at the lower levels.

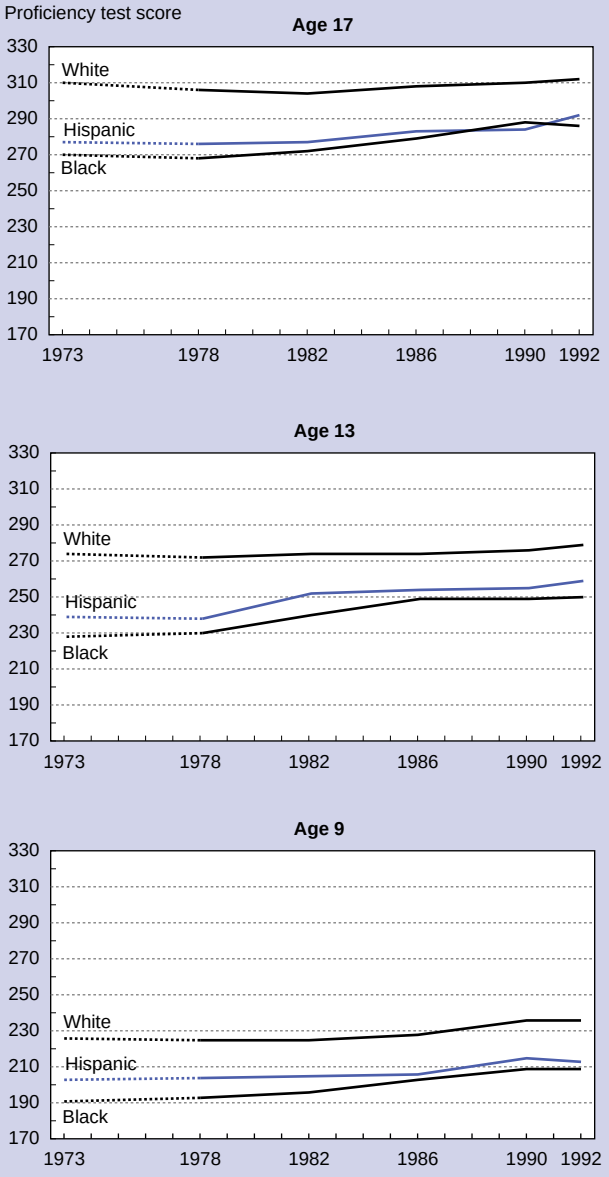
Black and Hispanic achievement did show large gains at all but the highest level from 1978 to 1992. (See text table 1-5.) While these rapid and large gains are encouraging, the large disadvantages at higher levels of performance should alert schools and parents to a serious concern.

Science Proficiency Trends by Race/Ethnicity

The race/ethnicity differences in science achievement are larger than those in mathematics. (See figure 1-6 and appendix table 1-1.) In 1992, the average for 17-year-old whites was 304, compared to 256 for blacks and 270 for Hispanics. Among 13-year-olds, the averages were 267 for whites, 224 for blacks, and 238 for Hispanics. The average 17-year-old black scored well below the average 13-year-old white, while the average 17-year-old Hispanic just equaled the average 13-year-old white.

The general pattern of large but diminishing differences among whites, blacks, and Hispanics that was seen in mathematics also exists in science. (See figure 1-6.) Since 1982, the convergence appears to be stronger for Hispanics than for blacks at ages 13 and 17 and about parallel for black and Hispanic 9-year-olds.

Figure 1-5.
Trends in average mathematics proficiency, by age and race/ethnicity



····· extrapolated from previous NAEP analyses.

NOTE: Data are interpolated for years when NAEP not administered.

See appendix table 1-1.

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Proficiency level breakdowns show the same general pattern that was evident in mathematics. (See text table 1-6 and appendix table 1-3.) Virtually no minority 17-year-olds scored at the highest level in 1992, compared with 13 percent of the 17-year-old white students. At the level of ability to do scientific analysis (level 300), no minority 9-year-olds are represented, compared with 4 percent of the white 9-year-olds. Only 2 and 3 percent of the black and Hispanic 13-year-olds, respectively, were proficient at this level, compared with 15 percent of the whites.

[5]Information on student race and ethnic identities is obtained directly from the students in the NAEP. Students are asked to identify themselves in terms of the following mutually exclusive categories: White, Black, Hispanic, Asian/Pacific Islander, and American Indian.

Trends in English Proficiency Among Hispanic Students

Part of the lower achievement among Hispanic youth may be attributable to high rates of immigration from Latin American countries since 1980 and lower levels of English proficiency among recent immigrants. While the achievement trends for Hispanics are positive, the numbers of Hispanic youth who speak Spanish at home and who have limited English proficiency increased from 1980 to 1990. The reason for this apparent anomaly may be that, despite the growth in absolute numbers, the proportion of native-Spanish speaking school-age individuals who have limited English proficiency has remained largely the same. Data from the U.S. Bureau of Census show that in 1980, 2.9 million persons aged 5 to 17 spoke Spanish at home. Of those, 44.5 percent were considered by the census respondent to speak English less than "very well." In 1990, the number of 5- to 17-year-olds who spoke Spanish at home reached 4.2 million. Despite the rapid increase, the 1990 census respondents indicated that a slightly lower percentage (39.3 percent) of the school-age youth spoke English less than "very well." Further breakdowns by state show that increases in percentages of limited-English-speaking students (three-quarters of whom speak Spanish as their mother tongue) were largely confined to California. The percentages of limited-English-speaking students decreased in Texas and New Mexico and increased only slightly from 1980 to 1990 in Arizona and New York (Smith, Rogers, Alsalam, Perie, Mahoney, and Martin, 1994, table 46-2).

The gaps at level 300 among 17-year-olds are less extreme but still very large.

The pattern of gains from the 1977 to the 1992 science assessments indicates that all of the significant gains over the period for minority youths were in the lower three levels of proficiency. (See text table 1-6.) The only group that did not realize any significant net gains at any proficiency level were 17-year-old Hispanic youths. However, proficiency scores of Hispanic 17-year-olds, which declined sharply in 1982, have been steadily improving. (See text table 1-6.)

Mathematics Content Area Proficiency by Sex and Race/Ethnicity

The 1990 and 1992 mathematics assessment introduced a set of content area scores to enable monitoring of progress within mathematics subjects, or content areas. These areas include numbers and operations; measurement; geometry; data analysis, statistics, and probability; algebra and functions; and estimation. (See appendix table 1-4 for NAEP descriptions of each area.)

The 2-year period between these assessments is not long enough to allow for significant changes in proficiency levels. However, it is sufficient time for determining whether exceptionally large or small subpopulation differences can be found on the various subscales. The comparisons by sex for 1992 12th-graders show significant differences favoring males in measurement, geometry, and estimation skills. (See figure 1-7.) As is true of the overall differences in mathematics proficiency between males and females, none of these differences is very large.

The race/ethnicity differences are also fairly constant across the various content areas. (See figure 1-7.) The black-white gap is largest in the areas of data analysis, statistics, and probability, where the group difference is 32 points. The main point to be made from this comparison of NAEP content areas is that the sex and race/ethnicity differences within content domains tend to be consistent with the overall mathematics proficiency differences among these racial-ethnicity groups.

Changes in Student Background and Mathematics Achievement Score Trends

Mathematics achievement outcomes generally increased during the 1980s. Moreover, while large test-score differences among race/ethnicity groups remain, some of the differences appear to have diminished in recent years. Two very general factors explain these changes: (a) changes in students' social backgrounds and (b) changes in students' schooling experiences. Both factors are related to achievement scores, and both have probably changed in some important ways over the period. The 1994 RAND Corp. report *Student Achievement and the Changing American Family* (Grissmer, Kirby, Berends, and Williamson, 1994) tried to assess the relative strengths of these factors by analyzing several national data bases spanning the 1970s and the 1980s. The authors focused on achievement in two areas, mathematics and verbal skills, but they did not examine trends in science achievement.

One important change in schooling has been the shifts in student coursework, as documented in the next section of this chapter. Another set of changes, which are more recent and not as well documented, relates to the reform efforts discussed in the introduction and in the third section below.

At the same time, the background characteristics of students have also changed significantly. Some changes seem to favor student achievement, while others seem to work against it. (See text table 1-7.) From 1970 to 1990, the income of households in which the 15- to 18-year-olds lived increased only slightly, but their parents' average education levels increased dramatically over the 20-year span. Family size, which usually bears a negative relationship on achievement scores (Blake, 1989), declined in average size.

Text table 1-5.
Trends in the percentage of students at or above five mathematics proficiency levels, by race/ethnicity

			Assessment years					
			1978			1992		
Proficiency level	Ability	Age	White	Black	Hispanic	White	Black	Hispanic
Level 350	Multistep problem solving and algebra	9	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
		13	1 (0.2)	0 (0.1)	0 (0.1)	0 (0.2)	0 (0.3)	0 (0.1)
		17	8 (0.5)	0 (0.2)	1 (0.6)	9 (0.9)	1 (0.7)	1 (0.8)
Level 300	Moderately complex procedures and reasoning	9	1 (0.2)	0 (0.1)	0 (0.5)	1 (0.3)	0 (0.1)	0 (0.5)
		13	21 (0.7)	2 (0.5)	4 (1.0)	23 (1.3)	4 (0.7)	7 (1.2)
		17	58 (1.1)	17 (1.6)	23 (2.7)	66 (1.4)	30 (3.9)	39 (4.9)
Level 250	Numerical operations and beginning problem solving	9	23 (0.9)	4 (0.6)	9 (2.5)	32 (1.0)	10 (1.4)	12 (2.5)
		13	73 (0.9)	29 (2.1)	36 (2.9)	85 (1.1)	51 (2.7)	63 (2.7)
		17	96 (0.3)	71 (1.7)	78 (2.3)	98 (0.4)	90 (2.5)	94 (2.2)
Level 200	Beginning skills and understandings	9	76 (1.0)	42 (1.4)	54 (2.8)	87 (0.7)	60 (2.8)	65 (2.9)
		13	98 (0.3)	80 (1.5)	86 (0.9)	100 (0.2)	95 (1.4)	98 (0.7)
		17	100 (0.0)	99 (0.3)	99 (0.4)	100 (0.0)	100 (0.1)	100 (0.0)
Level 150	Simple arithmetic facts	9	98 (0.2)	88 (1.0)	93 (1.2)	100 (0.1)	97 (1.1)	97 (1.3)
		13	100 (0.0)	99 (0.4)	100 (0.3)	100 (0.0)	100 (0.1)	100 (0.0)
		17	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)	100 (0.0)

NOTE: Standard errors appear in parentheses.

SOURCE: I.V.S. Mullis, J.A. Dossey, J.R. Campbell, C.A. Gentile, C. O'Sullivan, and A.S. Latham, *NAEP 1992 Trends in Academic Progress*, Report No. 23-TR01 (Washington, DC: National Center for Education Statistics, 1994).

See appendix table 1-2.

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In contrast to these trends, two variables changed in ways that might be expected to reduce achievement. The average mother's age at the time of the child's birth decreased, and the proportion of students living with a single mother increased from 14 to 23 percent. Both of these variables are negatively associated with household income and parental education; they may also have negative effects on achievement even allowing for income and education. Younger mothers, for example, may not be as well prepared as older mothers for maternity, particularly if they lack strong social support from relatives or friends in their local community. The negative effects of single parenthood appear to be related to the emotional upheavals of marital dissolution and to the lack of the complementary adult authority that a father who is present normally represents (McLanahan and Sandefur, 1994).

Maternal employment is another variable often implicated in the dynamics of student achievement. (See text table 1-7.) The percentage of students whose mothers worked increased from 49 to 69 percent between 1970 and 1990. The effects of maternal employment on achievement outcomes are usually mixed though, with benefits accruing to female students but not to male students.

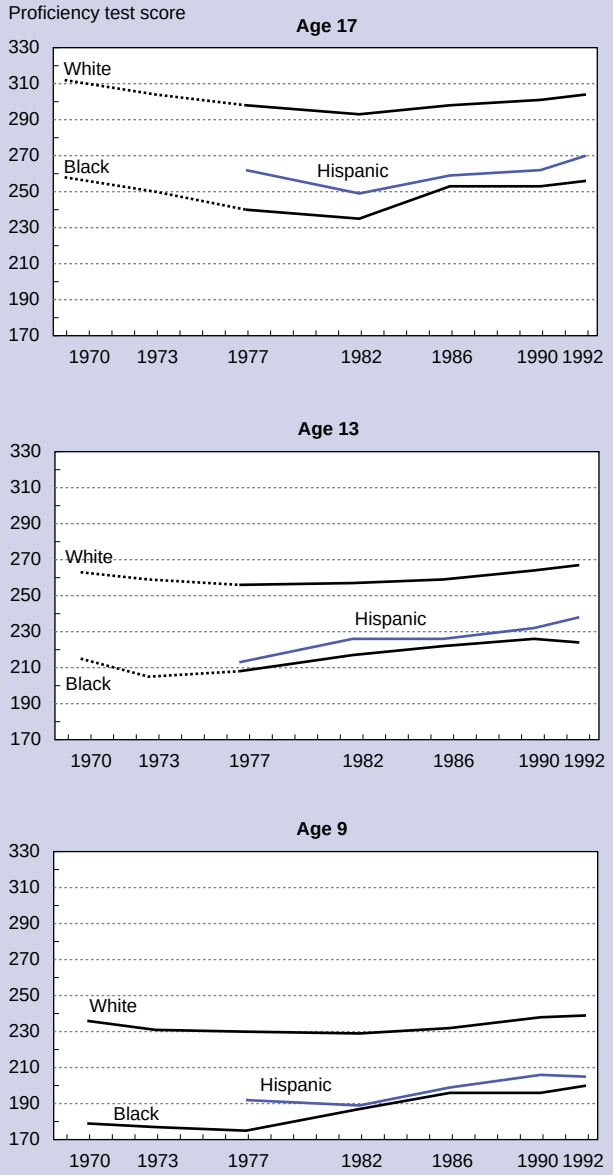
The 1994 RAND study estimated the effects of these social background variables on students' achievement scores using two large national data bases. The study used these estimates to calculate the extent to which the NAEP trends could be explained by changes in students' social backgrounds. The study found that only about one-third of the NAEP gains of black and Hispanic students in mathematics from 1975 to 1990 can be accounted for by the changes in family background. In contrast, virtually all of the mathematics gains of white students can be attributed to family background changes (Grissmer, Kirby, Berends, and Williamson, 1994, pp. 95–96).

Thus, while the family background resources of U.S. students improved from 1970 to 1990, the improvements were not sufficient to account for all of the gains made by black and Hispanic youths. The inability of family background variables to account for all the achievement gains made by minorities suggests that changes in the schooling experiences of these students have improved their outcomes over the 1970 to 1990 span. The RAND report does not pursue the identification of schooling variables that could explain the improvements. Further research is needed to give a fuller account of the gains in mathematics achievement by minorities.

International Comparisons of 9- and 13-Year-Olds

In 1991, the Educational Testing Service (which administers the NAEP), initiated the International Assessment of Educational Progress (IAEP), an international study of science and mathematics proficiency. Fourteen industrialized countries assessed nationally

Figure 1-6.
Trends in average science proficiency, by age and race/ethnicity



····· extrapolated from previous NAEP analyses.

NOTE: Data are interpolated for years when NAEP not administered.

See appendix table 1-1.

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representative samples of their 13-year-olds, while 10 assessed nationally representative samples of 9-year-olds. (The national averages for mathematics are shown in figure 1-8 and appendix table 1-5, and the science results are shown in figure 1-9 and appendix table 1-6.)

Comparing the overall averages for mathematics, U.S. students ranked at or near the bottom, with scores significantly lower than those of students from Korea, Hungary, Taiwan, the former Soviet Union, and Israel. (See figure 1-8.) U.S. 9-year-olds correctly answered about 58 percent of the items, compared with Korean youth, who correctly answered 73 percent. The U.S. 13-year-olds correctly answered about 55 percent of the mathematics items, compared with Koreans and Taiwanese who correctly answered 73 percent and Swiss, former Soviet, and Hungarian 13-year-olds who correctly answered about 70 percent. The U.S. 13-year-old students scored significantly lower than students from all nations except Slovenia, Spain, Ireland, and Scotland.

The range of mathematics test scores among U.S. students is relatively large compared with the scores of students in other nations. The highest U.S. scores were close to the highest scores of students from countries with the highest overall scores. However, the lowest scoring students in the United States are lower than their counterparts in all of the other countries.

A similar pattern is found in science. (See figure 1-9.) Korea and Taiwan are once more at the top of both age groups. The main difference between the science and the mathematics results is that the average science achievement of U.S. 9-year-olds is not significantly lower than that of any other nation, and it is significantly higher than the achievement of Slovenia and Ireland. Among the 13-year-olds, however, the average science achievement of U.S. students is not significantly higher than any country and is significantly lower than the achievement of Korea, Taiwan, Switzerland, and Hungary. As in mathematics, the top-scoring students in the United States compare closely with the top-scoring students in all but the highest-ranking nations.

Differences Among States in Mathematics Achievement

The NAEP expanded in 1992 to collect mathematics data on a state-by-state basis for fourth- and eighth-grade students. These data give an unprecedented look at how the states compare, and the trend data that will eventually be assembled should allow for very useful analyses of the effects of various policy initiatives.

The data for eighth-grade public school white students indicate some large achievement differences among states. (See figure 1-10 and appendix table 1-7.) States with the lowest scores among white students are concentrated in the South, including Mississippi, Louisiana, and Alabama. States with the highest scores among whites are found in the Upper-Midwest, as well as in Connecticut and New Jersey in the East. The difference between the highest and lowest states is 22 points.[6]

Comparable regional clusters are not apparent for eighth-grade public school black students, however. (See figure 1-11 and appendix table 1-7.) State-to-state differences in average black mathematics achievement also appear to be less than the state differences for whites. Black achievement is highest in Arizona, Wisconsin, Virginia, Indiana, Massachusetts, and West

[6]About 60 percent of the full-sample standard deviation (36.6) of individual student scores.

Text table 1-6.
Trends in the percentage of students at or above five science proficiency levels, by race/ethnicity

			Assessment years					
			1977			1992		
Proficiency level	Ability	Age	White	Black	Hispanic	White	Black	Hispanic
Level 350	Integrates specialized scientific information	9	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.1)	0 (0.0)	0 (0.0)
		13	1 (0.1)	0 (0.0)	0 (0.1)	0 (0.1)	0 (0.0)	0 (0.0)
		17	10 (0.4)	0 (0.2)	2 (0.6)	13 (0.9)	1 (1.1)	2 (1.2)
Level 300	Analyzes scientific procedures and data	9	4 (0.3)	0 (0.1)	0 (0.4)	4 (0.4)	0 (0.3)	0 (0.4)
		13	13 (0.5)	1 (0.4)	2.0 (0.8)	15 (1.0)	2 (0.8)	3 (1.3)
		17	48 (0.7)	8 (1.0)	18 (2.1)	55 (1.7)	14 (2.5)	23 (3.8)
Level 250	Applies general scientific information	9	31 (0.7)	4 (0.6)	9 (1.7)	39 (1.1)	9 (1.4)	12 (1.8)
		13	56 (0.9)	15 (1.7)	18 (1.8)	71 (1.3)	26 (2.8)	36 (2.9)
		17	88 (0.4)	40 (1.5)	62 (1.7)	90 (1.0)	56 (3.7)	68 (6.6)
Level 200	Understands simple scientific principles	9	77 (0.7)	27 (1.5)	42 (3.1)	86 (0.9)	51 (3.5)	56 (4.3)
		13	92 (0.5)	57 (2.4)	62 (2.4)	98 (0.4)	74 (2.8)	86 (2.6)
		17	99 (0.1)	84 (1.3)	93 (1.7)	99 (0.3)	92 (1.8)	95 (2.6)
Level 150	Knows everyday science facts	9	98 (0.3)	72 (1.8)	85 (1.8)	99 (0.1)	91 (1.8)	92 (1.7)
		13	100 (0.1)	93 (1.0)	94 (1.3)	100 (0.0)	98 (0.6)	100 (0.5)
		17	100 (0.0)	98 (0.3)	100 (0.2)	100 (0.0)	100 (0.3)	100 (0.0)

NOTE: Standard errors appear in parentheses.

SOURCE: I.V.S. Mullis, J.A. Dossey, J.R. Campbell, C.A. Gentile, C. O'Sullivan, and A.S. Latham, *NAEP 1992 Trends in Academic Progress*, Report No. 23-TR01 (Washington, DC: National Center for Education Statistics, 1994).

See appendix table 1-3.

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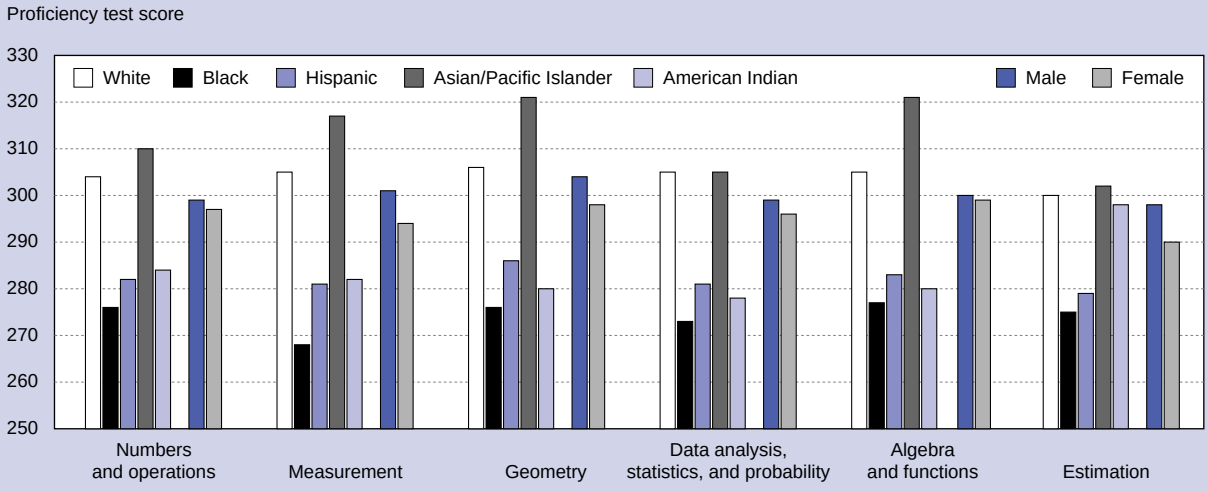
Figure 1-7.
Average proficiency in mathematics content areas for 12th-graders, by race/ethnicity and sex: 1992



See appendix table 1-4.

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Text table 1-7.
Selected family and demographic characteristics of 15–18-year olds

Variable	1970	1980	1990	Difference from 1970 to 1990
	1987 constant dollars			
Income	38,716	40,531	39,966	1,250
	Percent			
Mother's education				
Less than high school	38.2	27.4	17.1	–21.1
High school	44.7	46.8	47.1	2.4
Some college	10.4	15.1	20.0	9.6
College graduate	6.7	10.7	15.8	9.1
Father's education				
Less than high school	42.8	30.4	19.1	–23.7
High school	32.7	35.3	37.8	5.1
Some college	11.3	15.7	20.3	10.0
College graduate	13.2	18.5	22.8	9.6
Number of siblings				
0–1	48.2	58.7	72.5	24.3
2–3	33.7	32.7	23.5	–10.2
4 or more	18.0	8.6	4.0	–14.0
Age of mother at child's birth				
19 years or less	9.3	10.0	13.1	3.8
20-24 years	28.2	32.3	31.9	3.7
25-29 years	30.9	29.2	33.9	3.0
30 years or more	31.6	28.5	21.2	–10.4
Single mother	13.6	20.0	22.8	9.2
Mother working	49.3	59.3	68.6	19.3
Race				
Black	11.9	13.7	14.0	2.1
Other	88.1	86.3	86.0	–2.1

SOURCE: D.W. Grissmer, S.N. Kirby, M. Berends, and S. Williamson, *Student Achievement and the Changing American Family* (Santa Monica, CA: RAND, 1994).

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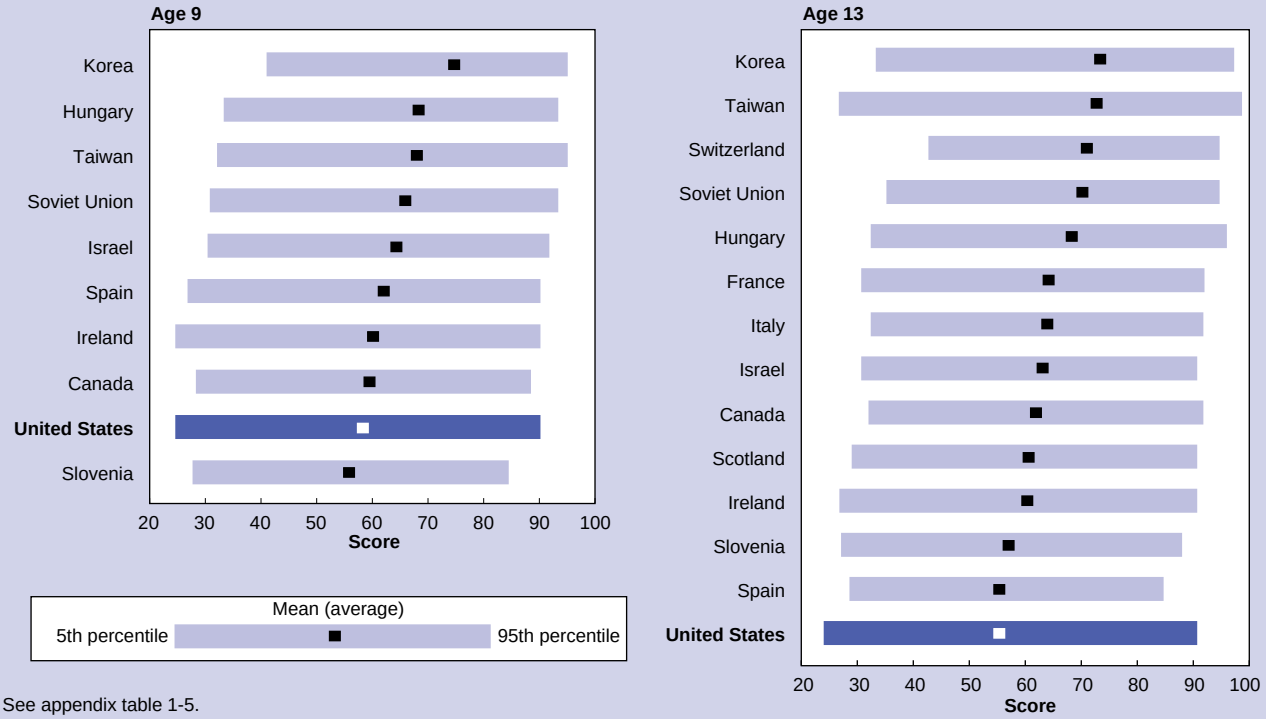
Virginia. Average achievement levels do not differ significantly among these states; the estimated averages range from around 240 to 250. At the other extreme, black mathematics achievement is lowest in Arkansas, Mississippi, Alabama, Louisiana, Michigan, and New York. Black achievement levels on the mathematics test average around 230 in these states.

The state-by-state mathematics averages for eighth-grade, public school Hispanic students follow the general pattern for the averages of non-Hispanic white students. Scores tend to be highest in the Midwest and lowest in the South. Scores in states where Hispanics are most populous (California, Texas, New Mexico, and Arizona) tend to lie in the middle of the national range for Hispanic eighth graders. (See figure 1-12 and appendix table 1-7.)

Differences among states can be accounted for by a variety of factors. State education policies and programs differ in ways that are likely to be important for student outcomes; states also differ in the levels of parental education. Since parental education has always been found to correlate strongly with children's achievement levels, some adjustment for this factor must be made before conclusions can be drawn regarding the impact of policy differences. A scatterplot of the 1992 NAEP eighth grade state-average mathematics achievement against the percentage of persons 25 years or older in the state with high school diplomas shows a clear positive relationship. (See figure 1-13 and appendix table 1-7.) It is also clear that some states do not follow the general pattern. Thus, differences among states with comparable levels of parent education are present and may be traceable to policy differences.

Figure 1-8.
IAEP mathematics scores for selected countries at 5th percentile, mean, and 95th percentile, by age: 1991



See appendix table 1-5.

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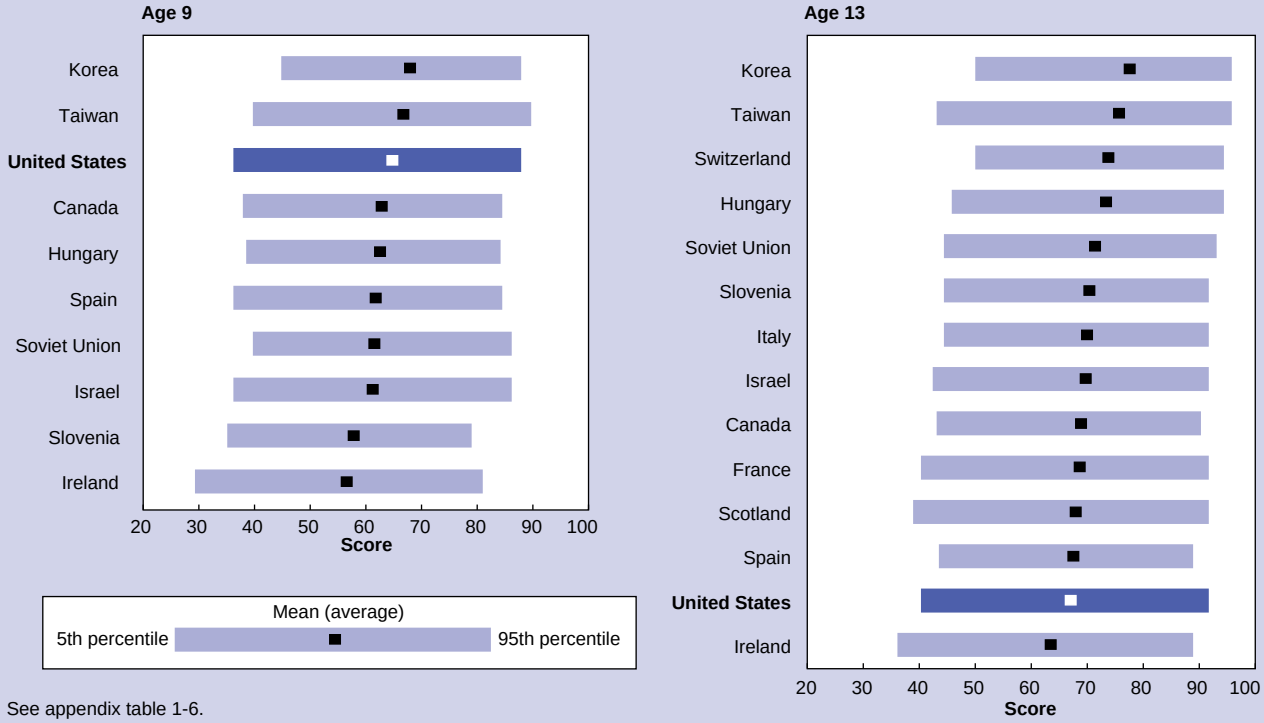
Figure 1-9.
IAEP science scores for selected countries at 5th percentile, mean, and 95th percentile, by age: 1991



See appendix table 1-6.

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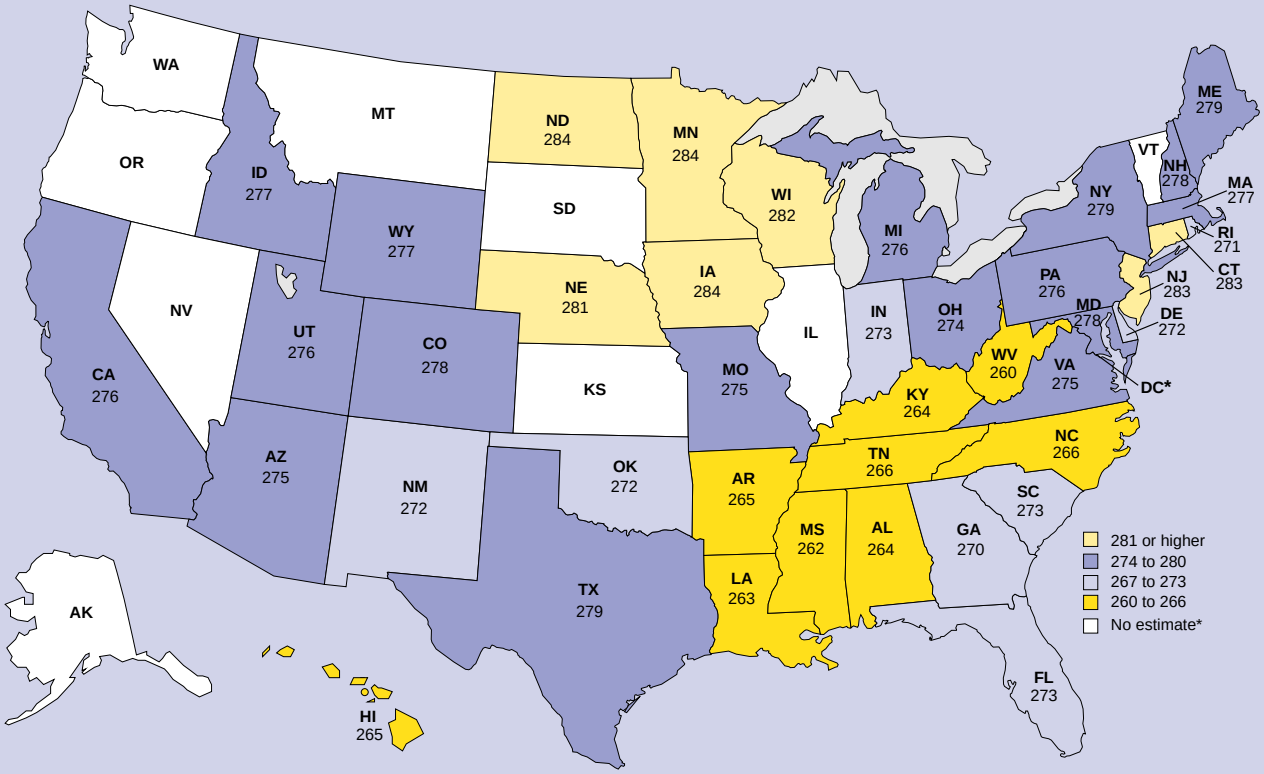
Figure 1-10.
Mean scores of eighth-grade public school white students on NAEP mathematics test: 1992



*This category includes states where there were too few sample cases for a reliable estimate and nonparticipants.

See appendix table 1-7.

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Comparisons of NAEP National and State-by-State Data with International Data

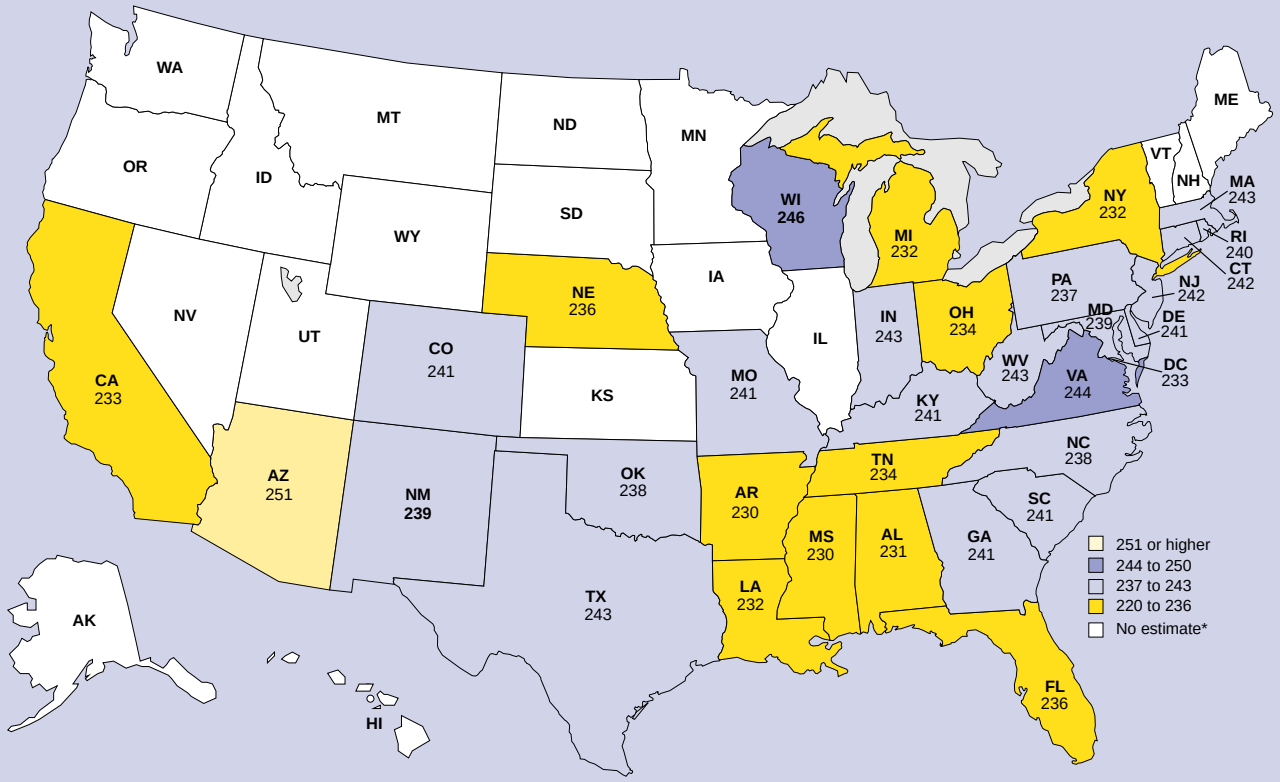
Another interesting set of comparisons can be made between the states and data from other countries. Because the IAEP mathematics tests included a number of items that were also included in the NAEP state-by-state mathematics assessment, it is possible to calculate comparable scores for states and countries. Despite the poor overall standing of U.S. students, some of the U.S. states achieved at levels that compare quite closely to the highest performing nations. (See figure 1-14.) Taiwanese students scored the highest, followed by Korea, but Iowa and North Dakota scored at levels equal to the Korean students, and Minnesota scored only slightly lower. At the other end of the scale, none of the industrial nations scored as low as the 15 lowest U.S. states. Mississippi scored at about the same level as the nation of Jordan, for example.

Experiments with Constructed Response Questions for Assessing Mathematics Achievement

Criticism of traditional multiple-choice and short-answer tests has grown in recent years. The NCTM has advocated tests that assess "authentic performance" and provide teachers with information on how students are thinking, instead of tests that simply determine whether various questions are answered correctly or incorrectly (NCTM, 1989).

Tests used by NAEP and large national sample surveys, such as NELS:88, have historically consisted entirely of multiple-choice items. The items are selected to represent knowledge and skills that a broad range of experts believe should be taught in mathematics and science classes at the grade levels being assessed. A number of observers have questioned whether the multiple-choice format is intrinsically unable to measure achievement on significant parts of the curricula schools should be implementing.

Figure 1-11.
Mean scores of eighth-grade public school black students on NAEP mathematics test: 1992



*This category includes states where there were too few sample cases for a reliable estimate and nonparticipants.

See appendix table 1-7.

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Two noteworthy experiments were conducted in recent years in an effort to assess whether the multiple-choice format leads to biased estimates of students' mathematical skills and knowledge. Both involved the use of "constructed response" formats, where students are asked to write an answer and show steps, rather than simply to choose from a set of response options. One of the experiments was administered with the 1992 NAEP assessment of mathematics; the other was administered with the 1990 and 1992 follow-up data provided by NELS:88.

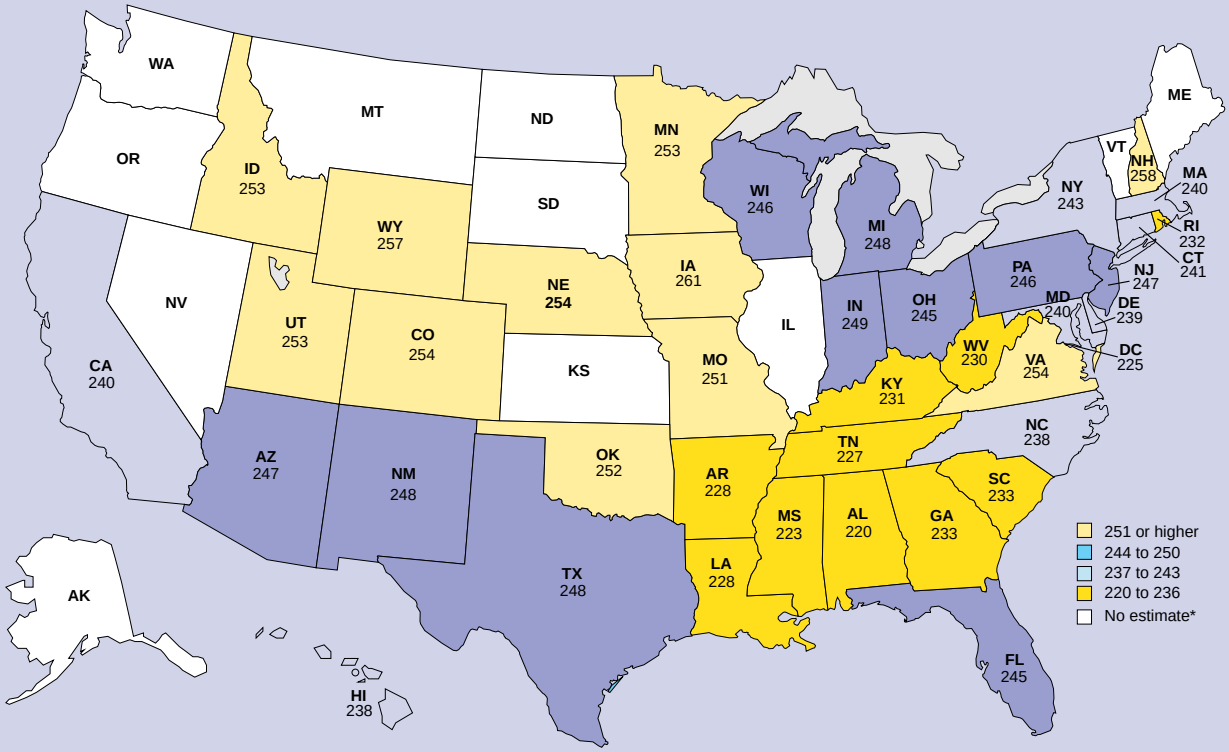
The results of these studies hold some important implications for future assessments. Rock and Pollack (1995) found that black and Hispanic youths score higher on the constructed-response tests than on the multiple-choice formats. Females score about the same as males on the constructed-response and multiple-choice formats in mathematics, but relatively worse on the constructed-response format in science. Further work is needed to explain these differences and to work out the implications for both assessment and evaluation research.

Curriculum and Instruction in High Schools

Trends in Completion Rates of High School Mathematics and Science Courses

The NAEP achievement data reviewed above showed a number of areas of improvement over the 1980s, and the recent RAND report found that most of the gains realized by black and Hispanic students in mathematics could not be attributed to improvements in minority students' family backgrounds. One factor contributing to the rise of achievement scores could be an increase in student coursework in mathematics and science. A number of large-scale studies have collected transcripts from national samples of high school graduates and have coded the coursework records into standardized schema that allow comparisons of students across the country. The baseline study was conducted in 1982. The High School and Beyond (HS&B) study collected the transcripts of approximately 14,000 students who first partici-

Figure 1-12.
Mean scores of eighth-grade public school Hispanic students on NAEP mathematics test: 1992



*This category includes states where there were too few sample cases for a reliable estimate and nonparticipants.

See appendix table 1-7.

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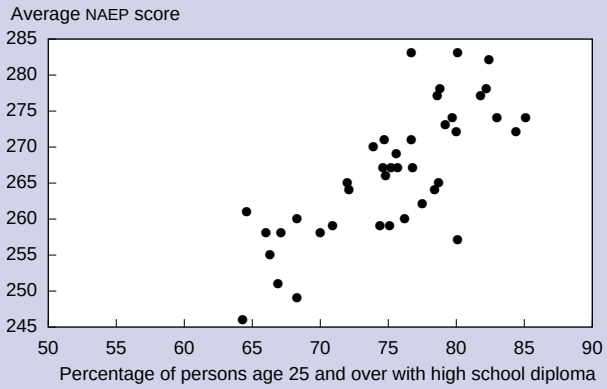
Figure 1-13.
Average mathematics achievement of eighth-grade students, by percentage of persons age 25 and over with high school diplomas for 41 states: 1992



See appendix table 1-7.

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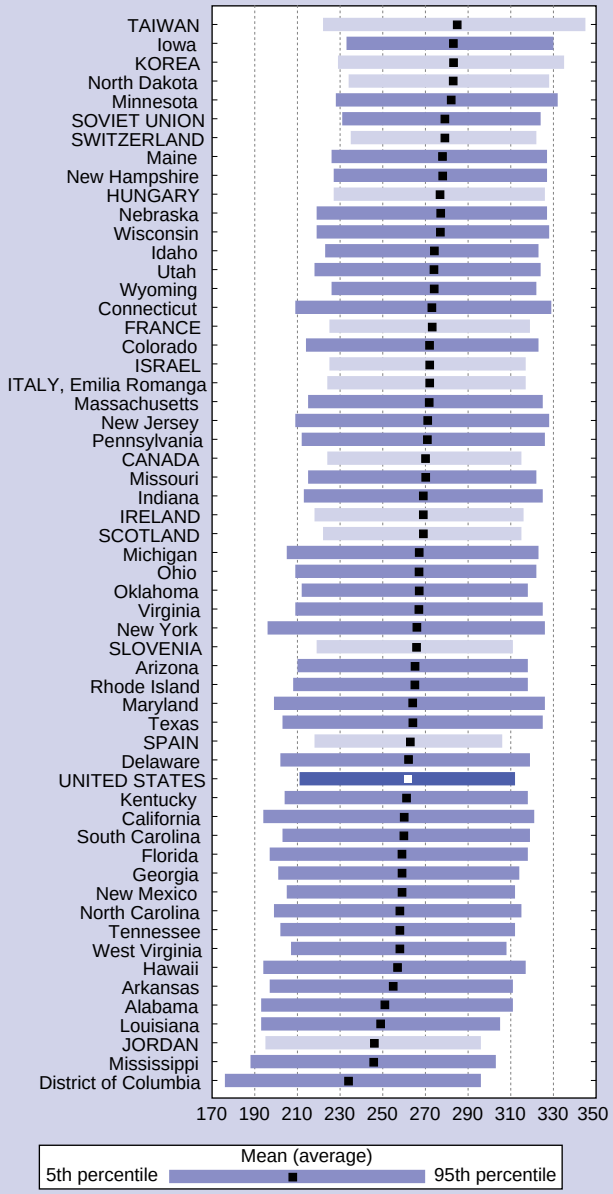
pated in the study in 1980, when they were high school sophomores. As a complement to the achievement data it collects, the NAEP has also collected transcripts for the 12th graders it assessed in 1987, 1990, and 1992. NELS:88, the successor to HS&B, also collected transcripts for the students in the fall of 1992, when most of the 1988 eighth-graders in the study had just graduated from high school.

Coursetaking Trends by Sex

High school mathematics and science coursetaking steadily increased from 1982 to 1992 for both males and females. (See figure 1-15 and appendix tables 1-8 and 1-9.) The percentage of students earning one or more credits in biology rose from about 75 percent of females and 78 percent of males in 1982 to over 90 percent of both by 1992. The increase in students completing a chemistry course was even steeper, rising from around 30 percent to over 50 percent 10 years later. While enrollment rates in physics are much lower than biology and chemistry, enrollments in physics also grew signifi-

Figure 1-14.
Mathematics proficiency scores for 13-year-olds in countries and public school eighth-grade students in U.S. states: 1991 or 1992



SOURCE: National Center for Education Statistics, *Education in States and Nations: Indicators Comparing U.S. States with the OECD Countries in 1988,* NCES 93-237 (Washington, DC: NCES, 1993).

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cantly, particularly among females. Female enrollment in physics grew from about 8 percent to almost 20 percent, but remained somewhat below the rate for males in 1992. This is the point where the largest gap by sex, in either science or mathematics, exists.

The growing percentages of students earning credits in geometry and algebra II paralleled the rapid growth in chemistry. (See figure 1-15.) In 1992, 70 percent of males and females completed geometry, and about 60 percent completed algebra II. Enrollment rates in trigonometry and calculus were much lower than in algebra and geometry, but large enrollment gains occurred in these more advanced subjects. By 1990, no gaps by sex were evident in either trigonometry or calculus.

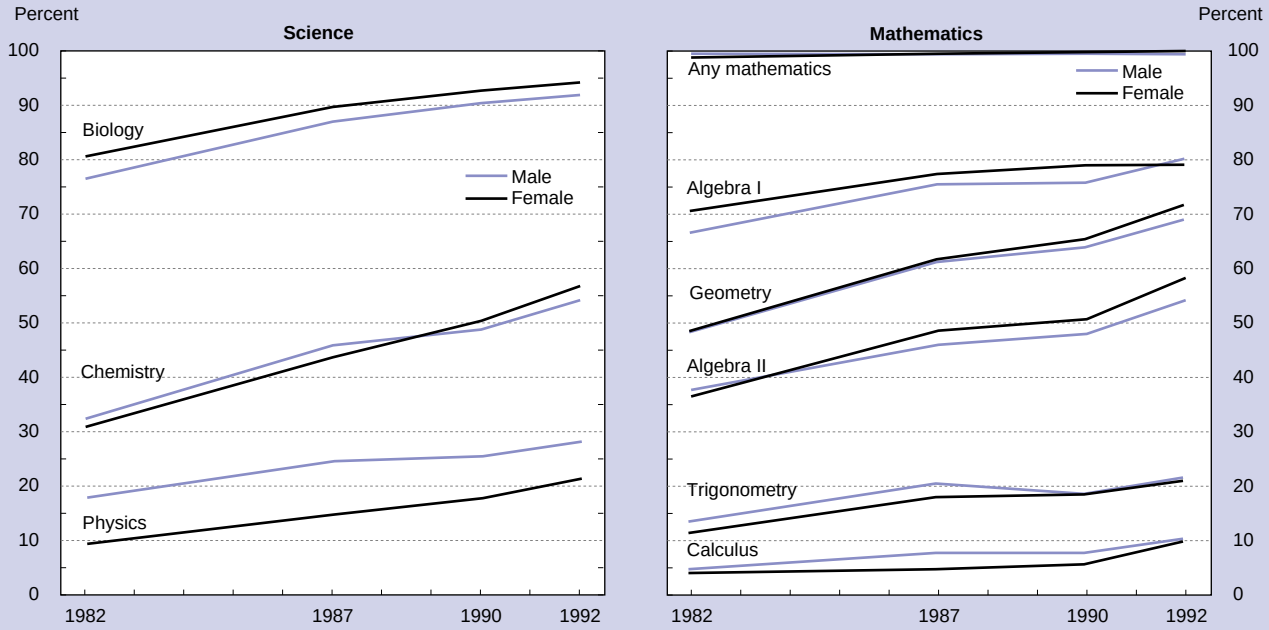
Coursetaking Trends by Race/Ethnicity

While the male-female differences in coursetaking have decreased and are now generally small, the differences among whites, blacks, and Hispanics are still substantial. The transcript data show that whites and minorities reached parity in the percentages of students completing algebra I and that the gaps declined considerably in geometry. (See figure 1-16 and appendix table 1-8.) All groups were more likely to complete algebra II, and the gap between coursetaking of white students and Hispanic students narrowed. The black and white increases, however, are roughly parallel. In 1992, about 60 percent of whites completed algebra II, while about 42 percent of black students did so. Similarly, the rates of completion for trigonometry increased for all students, but minority-white differences of about 8 percentage points in 1982 remained little changed by 1992. The apparent leveling of the black completion rates for algebra II and trigonometry from 1990 to 1992 are curious, but they are not large enough to speculate upon.

Blacks, Hispanics, and whites were equally likely to complete a course in biology by 1992, with over 90 percent of high school graduates completing it. (See figure 1-17 and appendix table 1-9.) The numbers completing chemistry increased substantially from 1982 to 1992, so that almost 60 percent of white graduates completed chemistry, and about 45 percent of blacks and Hispanics completed it. The 1992 completion rate for minorities was about equal to the 1987 completion rate for non-Hispanic whites. The race/ethnicity gaps also remained largely unchanged in physics, even though the course-completion rates increased.

The overall pattern of increasing course completion rates is one of the more striking changes in secondary education over the past decade. One factor contributing to this increase is the increased numbers of mathematics and science courses students must complete in order to fulfill state and local graduation requirements. This is probably not the only factor at work, however, because graduation requirements typically stipulate only the numbers and not the types of mathematics and science courses that must be completed. The increases in upper-level courses, such as calculus and physics, are more likely due to forces related to college entrance requirements and competition for places in selective institutions. More research is needed to gain a better understanding of this important trend.

Figure 1-15.
Percent of high school graduates earning credits in science and mathematics courses, by subject and sex: 1982–92



See appendix tables 1-8 and 1-9.

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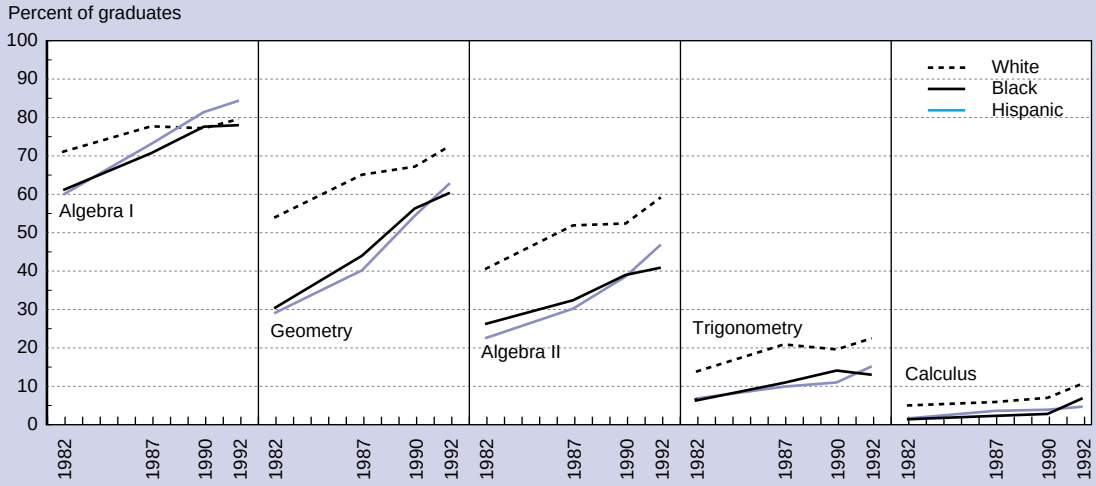
Figure 1-16.
Percent of high school graduates earning credits in mathematics courses, by race or ethnic origin: 1982–92



See appendix table 1-8.

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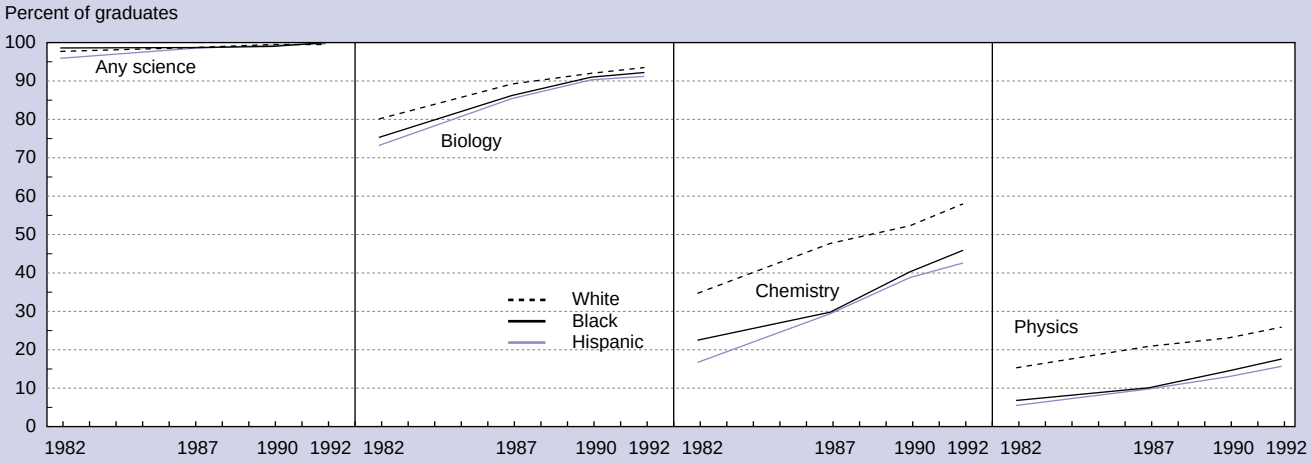
Coursetaking and Student Achievement

The NELS:88 data include mathematics and science achievement scores from 1988, when the students were in the eighth grade, and from 1990 and 1992, when most of the 1988 eighth-graders were sophomores and seniors. By analyzing both the students' background information and transcripts, it is possible to assess the relationships between coursetaking and achievement gains in order to ascertain how these relationships vary among students from different social backgrounds.

Just as near parity exists in the rates at which males and females complete the high school mathematics and science courses, the NELS:88 transcript data show that males and females complete about the same number of

Figure 1-17.
Percent of high school graduates earning credits in science courses, by race or ethnic origin: 1982–92



See appendix table 1-9.

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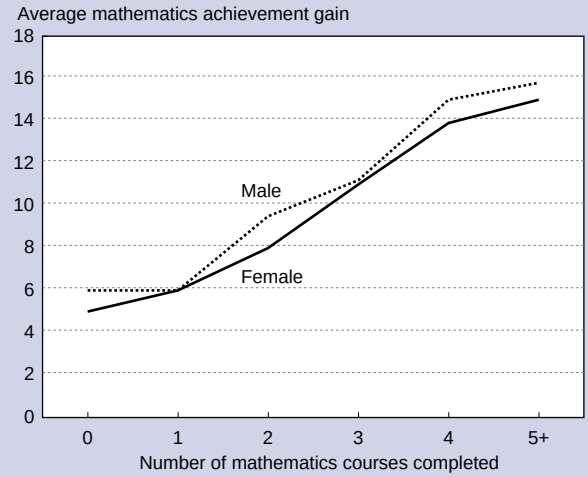
total credit units of mathematics and science during high school (Hoffer, Rasinski, and Moore, 1995). (See appendix table 1-10.) The association between achievement growth in mathematics from the end of the 8th grade to the end of the 12th grade and the number of mathematics courses students complete shows that achievement growth from 8th- to 12th-grade is greater the more mathematics courses the student completes during high school. (See appendix table 1-11 for source data.) (See figure 1-18.) The gap between the lines for males and females indicates the amount of additional gain that the higher group realized at that level of courses completed. These gaps are quite small and statistically insignificant, indicating that the achievement gains of males and females per additional mathematics course completed are about equal.

The general relationship between science achievement gains and science coursework is positive for both males and females. (See figure 1-19.) In contrast to mathematics, though, the gap between the slopes for males and females is sizable, roughly equal to the amount of gain per additional course completed. In other words, females who completed four science courses gained about the same amount of achievement as males who completed just three science courses.

Why do females gain less from their science classes? Probably partly because females in 1992 were still significantly less likely to complete a high school physics course. (See figure 1-15.) This coursetaking difference, however, would presumably affect students at the higher end of the course-count distribution and could not account for the lower achievement gains of females completing one or two science classes. Further research on this issue could examine both the transcript information on courses completed and grades earned in those courses, as well as the wealth of information NELS:88 has on achievement-related experiences outside of the courses students completed.

The relationship between achievement growth and coursetaking show that students from all race/ethnicity backgrounds realize greater achievement gains from additional coursework. (See figures 1-20 and 1-21 and appendix table 1-11.) The gains for black students are somewhat lower than for other students, and the differences appear to be particularly large in science. Hispanic youths also appear to realize lower achievement gains per additional science courses than whites or Asians.

Figure 1-18.
Average mathematics test score gain from 8th to 12th grade, by sex and number of mathematics courses completed during high school: 1992



See appendix table 1-11.

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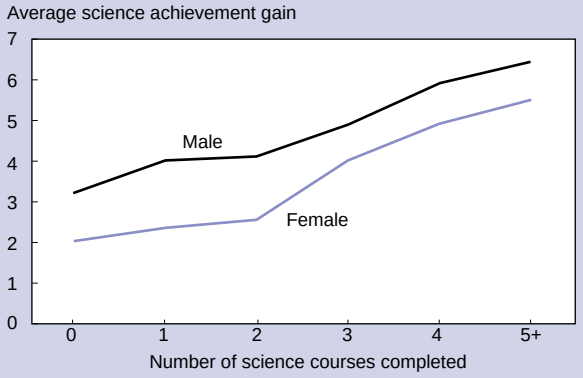
Figure 1-19.
Average science test score gain from 8th to 12th grade, by number of science courses completed during high school and student sex: 1992



See appendix table 1-11.

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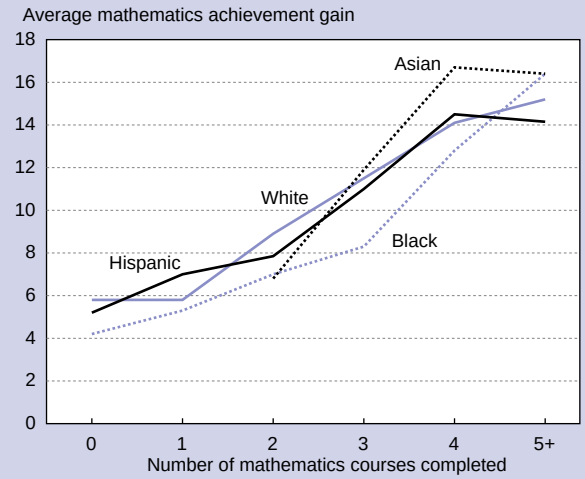
Figure 1-20.
Average mathematics test score gain from 8th to 12th grade, by number of mathematics courses completed during high school and race/ethnicity: 1992



NOTE: American Indian and Alaskan Native students are excluded because of small sample size (n = 96).

See appendix table 1-11.

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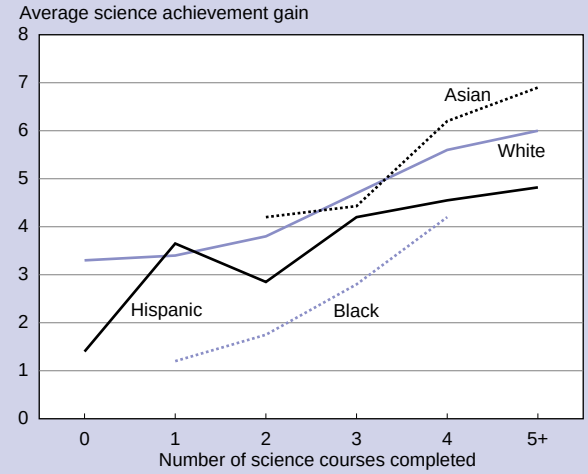
Figure 1-21.
Average science test score gain from 8th to 12th grade, by number of science courses completed during high school and student race/ethnicity: 1992



NOTE: American Indian and Alaskan Native students are excluded because of small sample size (n = 96).

See appendix table 1-11.

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As with the gaps by sex of students completing the same numbers of courses, the lower returns to minority youths may reflect their lower enrollments in more advanced mathematics and science courses. Minority youths are also concentrated in schools with fewer instructional resources (Oakes, 1990; Division of Research, Evaluation, and Communication, forthcoming), and, as a consequence, these students may get less out of nominally identical courses completed by white students attending better-endowed schools.

Relationship of Performance to Instruction

The differences among students in the kinds and numbers of courses they complete are strongly related to their patterns of achievement growth during high school. Nonetheless, coursetaking differences do not explain all of the variability in student outcomes. Common sense suggests that learning will also depend on a variety of factors that are likely to vary within courses. For example, some geometry teachers are much more demanding than others, and some geometry textbooks may defeat even the best teachers. The NELS:88 survey addressed the problem of how mathematics and science classes differ and what effect these differences have on student learning. Detailed information from the teachers of the sampled students were collected at three junctures: in 1988, when the sampled students were in the eighth-grade; in 1990, when most were high school sophomores; and in 1992, when most were high school seniors.

Several studies published in the past few years have examined these data (Horn, Hafner, and Owings, 1992; Hoffer and Moore, 1995; Kupermintz, Ennis, Hamilton, Talbert, and Snow, 1995; Hamilton et al., 1995). The Hoffer and Moore report examines the relationship of several instructional variables with achievement score gains from 1990 to 1992. While most variables show little connection with student achievement growth once differences in the levels of the courses are statistically controlled, a few interesting findings do appear. The reform recommendations in mathematics advocate placing

greater emphasis on problem-solving skills, and it turns out that teachers who claim to do so have students who gain more from the sophomore to the senior year.

The 12th-grade mathematics teachers of the NELS:88 students were asked to indicate the extent to which they emphasized various skills that typify "higher-order thinking" in mathematics. These include emphasis on

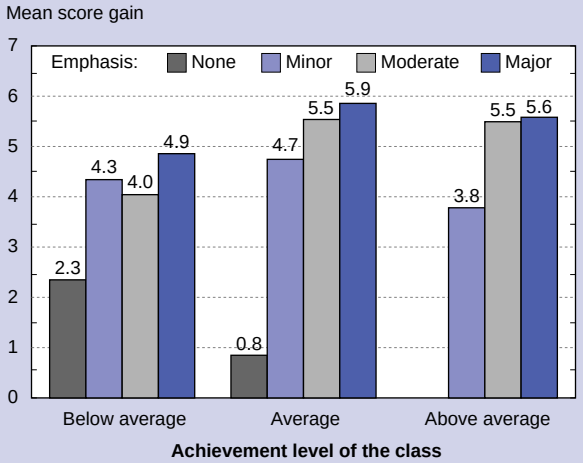
- Learning to represent problem structures in multiple ways (e.g., graphically, algebraically, numerically, etc.);
- Integrating different branches of mathematics (e.g., geometry and algebra) into a unified framework;
- Conceiving and analyzing the effectiveness of multiple approaches to problem solving;
- Raising questions and formulating conjectures.

Since the teachers' responses to these four questions proved to be highly correlated, the items were averaged together to create a common "emphasis on higher-order thinking" scale.

The emphases that teachers place on these kinds of skills are likely to vary with the ability level of the class, probably because students in higher-ability classes are more receptive to the cognitive challenges represented by these skills or because teachers hold lower expectations of students in lower-level classes. In any case, it is important to determine whether the emphasis on higher-order thinking skills is related to learning differences within ability groups.

The NELS:88 1992 teacher survey asked teachers to indicate whether the class in question was generally below average, average, or above average in comparison to the achievement level of all seniors in the school. The mathematics teachers' emphasis on higher-order thinking skills was positively related to the students' average mathematics achievement test score gains from 1990 to 1992. (See figure 1-22 and appendix table 1-12.) Moreover, the positive relationship appeared to hold for students in low-, average-, and high-ability classes. The mean achievement score gain for the students in below-average classes (level 1) was greater in classes with emphasis on higher-order thinking skills. Students gained slightly more than two points between the 10th and 12th grades, when no emphasis was placed on higher-order thinking. This gain increased to about five points when higher-order thinking skills received major emphasis. (The standard deviation of the NELS 1992 composite mathematics test used here is 15 points.) The mathematics gains of students in average-achievement level mathematics classes (level 2) show the most correlation with increased emphasis on higher-order thinking; the associated gains range from less than one point for no emphasis to nearly six points for major emphasis. Finally, while teachers of students in classes with above-average achievement levels (level 3) all placed at least minor emphasis on higher-order thinking skills, students in classes with a major emphasis gained an average of two points more than students in classes with a minor emphasis on higher order skills.

Figure 1-22.
Average mathematics test score gain by achievement level of class and emphasis on higher order thinking skills: 1990–92



SOURCE: S.J. Ingels, K.L. Dowd, J.D. Baldridge, J.L. Stipe, V.H. Bartot, and M.R. Frankel, *NELS: 88 Second Follow-up: Student Component Data File User's Manual,* NCES 94-374 (Washington, DC: National Center for Education Statistics, U.S. Department of Education, 1995).

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Because it is not entirely clear what the teachers meant when they indicated that they emphasized higher-order thinking skills, these results must be interpreted cautiously. However, these results do at least suggest that students respond well to the greater cognitive demands of a problem-solving approach in mathematics.

Computer Use in School and at Home

A key part of the instructional standards developed by NCTM and NSTA is that classes should make greater use of new technologies. For mathematics, this mainly amounts to the increased use of hand-held calculators. Once students learn basic principles, calculators can be used to reduce time spent on tedious drills. Calculators also have an important contribution in learning more advanced mathematics, particularly in helping students develop graphical representations of functions. Personal computers are more important to science education than to mathematics at the secondary grade level. The main scientific uses of computers are for compiling and analyzing data.

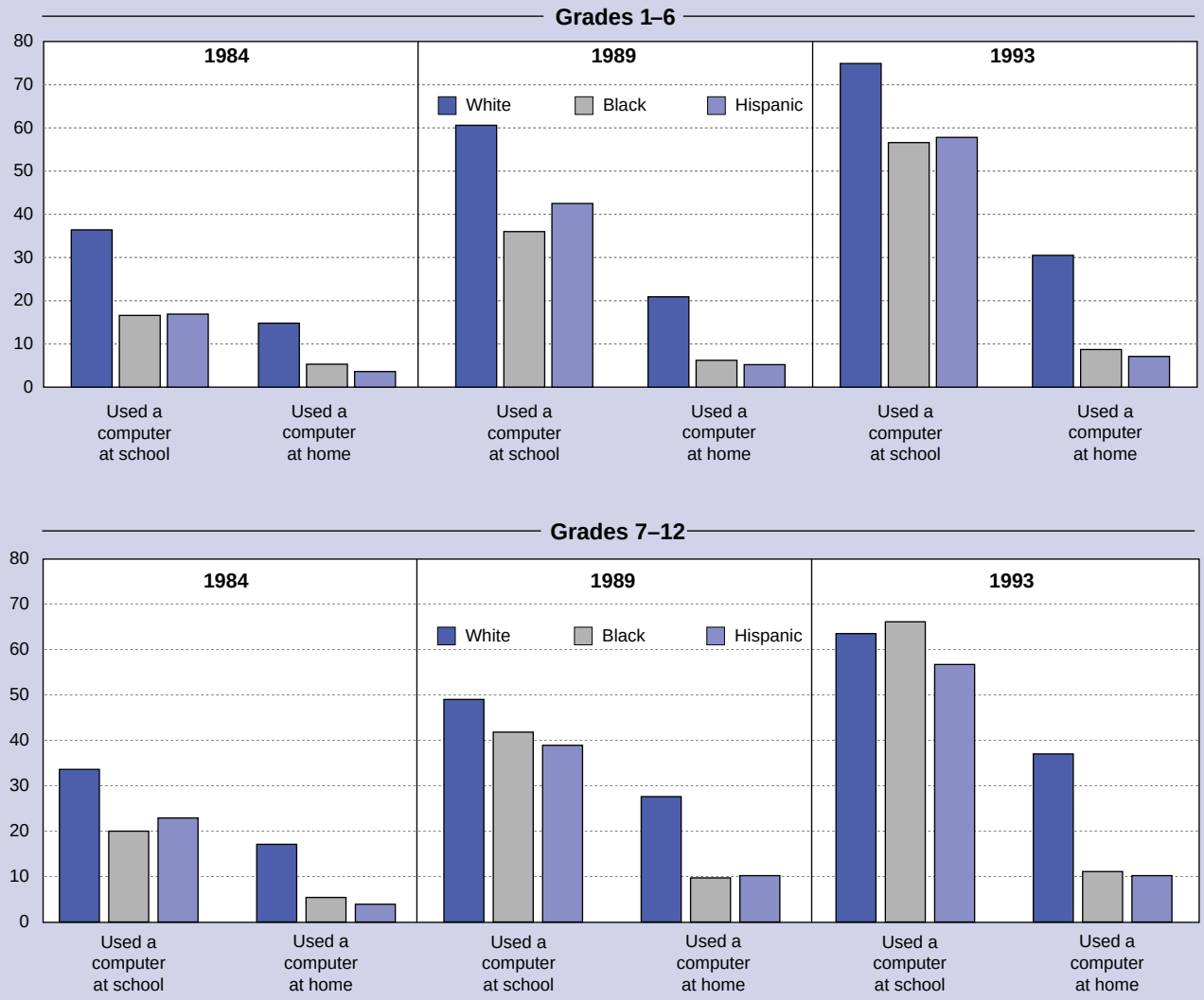
National data on the use of calculators and computers in schools show that both have grown rapidly in recent years. Data collected by the Current Population Surveys (CPS) of the U.S. Bureau of the Census show that 35 percent of all elementary and secondary students in 1984 had used a computer at home or school. This figure rose to 68 percent by 1993. Further breakdowns of the CPS

data show that the use of computers both at home and at school are correlated with race/ethnicity and family income. (See figure 1-23 and appendix table 1-13.) The correlations likely reflect the cost of owning and operating a computer. In 1993, 51 percent of high-income elementary students, versus 4 percent of low-income elementary students, used computers at home. Comparable differences are found among secondary students. Nonetheless, these large differences should not overshadow the large differences in school use between rich and poor students at both the elementary and secondary levels. Poor students' lack of familiarity with computers may place disproportionate numbers of low-income and minority youth at some disadvantage in postsecondary educational and occupational pursuits (Smith, Rogers, Alsalam, Perie, Mahonie, and Martin, 1994).

The Impact of High School Coursework in Science and Mathematics on Transitions to College and Work

The mathematics and science reform movement has emphasized the importance of requiring all students, not only those planning to attend college, to complete more science and mathematics during high school. The benefits of additional coursework are fairly transparent for students who attend college, but may be less obvious for those going directly into the labor force after high school. Proponents of these recommendations generally argue that additional coursework in these areas will improve the employment opportunities and productivity of students who go directly into the workforce, many of whom will work—or would work, if they had the skills—in jobs requiring some mathemat-

Figure 1-23.
Percentage of students who used a computer at school or at home, by race/ethnicity



See appendix table 1-13.

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ics, an understanding of basic scientific principles, and inquiry skills.

The evidence from national surveys on the benefits of more high school coursework in mathematics and science is mixed. Drawing on the HS&B students' high school transcripts, students can be classified into five levels of science and mathematics coursework completion:

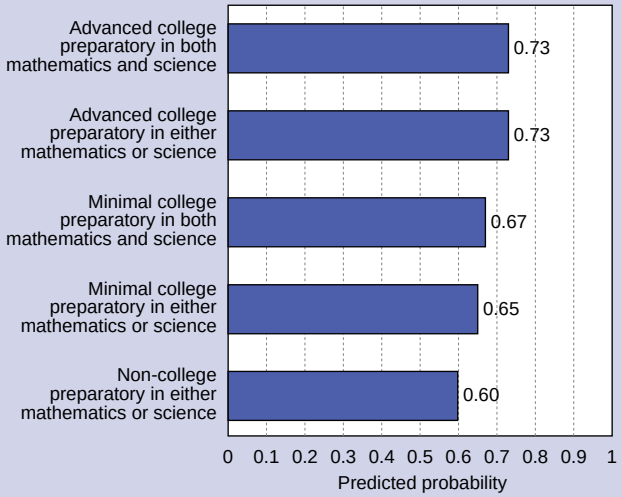
- General or limited completers (non-college-preparatory in either mathematics or science);
- Minimal college preparatory in either mathematics or science, but not both;
- Minimal college preparatory in both mathematics and science;
- Advanced college preparatory in either mathematics or science, but not both;
- Advanced college preparatory in both mathematics and science.

An analysis of the HS&B data shows that, among students who went to college after high school, completing higher levels of high school mathematics and science courses is positively related to the likelihood of continued 4-year college enrollment (or degree completion) 4 years after high school. These results are based on a regression model that statistically controls for individuals' social backgrounds and verbal achievement levels. (See figure 1-24.) Since many students who start college quit before completing a baccalaureate degree, the higher rates of enrollment may indicate that a stronger high school preparation in science and mathematics gives individuals an advantage in the college environment. Of course, motivational and other factors also affect student retention. But these results are based on controls for high school achievement levels that usually are highly correlated with motivational differences and are thus more strongly suggestive. (See Hoffer, 1995, for details on these analyses.)

The completion of advanced mathematics and science courses also appears to affect persistence in scientific, mathematical, or engineering (SME) majors in college. (See figure 1-25.) When students' social and high school academic backgrounds are controlled, students who completed higher levels of high school science and mathematics are much more likely to persist in SME majors. Note that these comparisons are among students who planned to major in an SME field and who actually enrolled in college in the fall after high school.

The evidence is much weaker for positive effects on labor market outcomes of non-college-goers. Gamoran's (1994) critical review of the research on this topic found some evidence that more rigorous academic programs of study in high school lead to higher rates of employment, higher wages, or higher-status jobs. The effects of completion of advanced mathematics and science courses on labor market outcomes are generally much weaker than the effects on students' cognitive skills. Many of those skills, particularly the quantitative ones, are likely to be acquired in the individuals' high school classes. One conclusion from this mixed body of research seems to be that the high school science and mathematics courses completed by non-college-goers are predictive of postsecondary labor market success only when the students' cognitive skills are improved by their courses.

Figure 1-24.
Predicted probability of continued college enrollment in 1986, by level of high school coursework in mathematics and science



NOTE: Predicted probabilities are calculated from logistic regressions of whether the student was enrolled in a science, mathematics, or engineering major field in 1986 on socioeconomic status, sex, race-ethnicity, 1980 science and mathematics achievements, 1982 reading and vocabulary achievements, and coursework dummies indicating the mathematics and science courses completed in high school.

SOURCE: T.B. Hoffer, "High School Curriculum Differentiation and Postsecondary Outcomes." In P.W. Cookson & B. Schneider (Eds.), *Transforming Schools* (New York: Garland Publishing, Inc., 1995), pp. 371–402.

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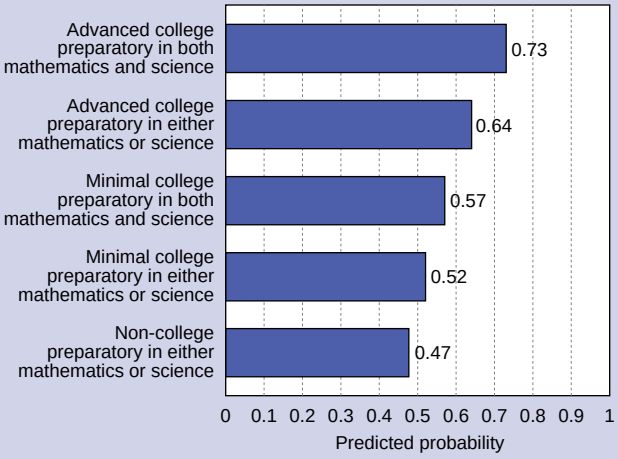
College Instructors' Views of Incoming Mathematics and Science Students' High School Preparation in Science and Mathematics

Techniques for teaching mathematics and quantitative reasoning vary greatly from country to country, but college instructors generally believe that high school students do not receive adequate preparation in mathematics and quantitative reasoning before college. While the majority of faculty representing 10 countries around the world agree that undergraduate students are not prepared when they reach college, the degree to which they agree differs quite markedly. (See text table 1-8.) In fact, of these 10 countries, the United States was least likely to perceive its students as adequately pre-

Figure 1-25.
Predicted probability of persisting in science, mathematics, and engineering majors in 1986, by level of high school coursework in mathematics and science



NOTE: Predicted probabilities are calculated from logistic regressions of whether the student was enrolled in a science, mathematics, or engineering major field in 1986 based on socioeconomic status, sex, race-ethnicity, 1980 science and mathematics achievements, 1982 readingand vocabulary achievements, and coursework dummies indicating the mathematics and science courses completed in high school.

SOURCE: T.B. Hoffer, "High School Curriculum Differentiation and Postsecondary Outcomes." In P.W. Cookson & B. Schneider (Eds.), *Transforming Schools* (New York: Garland Publishing, Inc., 1995), pp. 371–402.

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Text table 1-8.
Percent of all faculty who say that undergraduates in their institutions are adequately prepared in selected skills, by type of skill and country: 1992

Country	Mathematics and quantitative reasoning	Written and oral communication
Hong Kong	39	19
South Korea	37	59
Sweden	32	32
Russia	27	26
Mexico	23	24
Japan	22	30
Chile	22	17
Israel	19	15
Australia	18	20
United States	15	20

NOTE: Includes faculty of all disciplines and departments

SOURCE: E.L. Bayer, P.G. Altbach, and M.J. Whitelaw, *The Academic Profession: An International Perspective* (Princeton, NJ: The Carnegie Foundation for the Advancement of Teaching, 1994).

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pared for college-level mathematics coursework. Only 15 percent of the faculty in the United States believed their students were adequately prepared, while 39 percent of the faculty in Hong Kong, 37 percent of the faculty in South Korea, and 32 percent of the faculty in Sweden had similar perceptions. Close to one-fourth of the faculty in Russia, Mexico, Japan, and Chile believed that their students were prepared in mathematics and quantitative reasoning, while less than 20 percent of the faculty in Israel and Australia perceived their students as prepared.

Very often, however, students who are well prepared in mathematics tend to have poor written and oral communication skills. This phenomenon holds true in Hong Kong. While more than one-third of the faculty in Hong Kong believed that their students were prepared in mathematics, less than one-fifth perceived them to be prepared in written and oral communication. Chile and Israel had similar concerns, and only 20 percent of the faculty in the United States perceived their students were prepared in communication. About 30 percent of the faculty in Sweden, Russia, Mexico, and Japan indicated that their students seemed prepared in written and oral communication, and nearly 60 percent of the faculty in South Korea had similar perceptions.

Teachers and Teaching

Teacher Awareness of National Science and Mathematics Standards

Of all subject areas in the elementary and secondary curriculum, mathematics has been the most active in the effort to establish standards of what teachers should teach and what students should learn. The NCTM publications, *Curriculum and Evaluation Standards for School Mathematics* (1989) and *Professional Standards for Teaching Mathematics* (1991), have been held up as models of disciplinary reform. The movement to define standards in science is somewhat more diffuse, with three major efforts setting forth recommendations for the goals and methods of elementary and secondary science. The first was the American Association for the Advancement of Science's (AAAS) *Project 2061*, which defined the knowledge, skills, and attitudes that all elementary and secondary students should acquire and the project report, *Science for all Americans* (Rutherford and Ahlgren, 1990). The next efforts were NSTA's publication of *Scope, Sequence, and Coordination: The Content Core,* and The National Research Council's (NRC) publication of *National Science Education Standards* in 1993. Despite the variety of organizations involved in science reform, there is substantial agreement among them as to what should be taught and how.

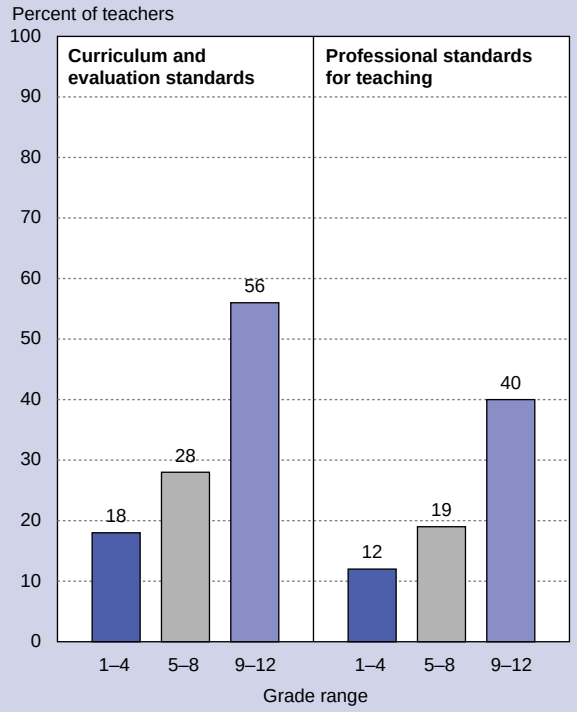
Two surveys of science and mathematics teachers in 1993 asked teachers about their familiarity with the reform recommendations. The National Survey of Science and Mathematics Education (NSSME) (Weiss, Matti, and Smith, 1994) surveyed a total of 6,120 science and mathematics teachers from 1,252 public and private elementary, middle, and high schools across the United States. A

much smaller survey of 612 mathematics and science teachers from 42 public high schools was conducted as part of the Longitudinal Study of American Youth (LSAY) (Miller, Hoffer, Brown, Pifer, and Nelson, 1993).

According to these surveys, in the spring of 1993, many teachers were not aware of the standards and recommendations presented in the publications listed above. The NSSME asked the mathematics teachers to indicate how familiar they were with the standards set forth in the two NCTM documents. High school mathematics teachers were more likely than their counterparts in the lower grades to be familiar with the recommendations—56 percent of the grade 9–12 teachers felt "well aware" of the *Curriculum and Evaluation Standards* report, compared with 28 percent of grade 5–8 teachers, and only 18 percent of the grade 1–4 faculty. (See figure 1-26.)

These data indicate that mathematics teachers generally are less familiar with NCTM's *Professional Standards for Teaching* report, which recommends innovative forms of classroom organization and pedagogy for mathematics. Elementary and middle school mathematics teachers were also less likely to report being "well aware" of these recommendations (12 percent and 19 percent, respectively) than were high school mathematics teachers (40 percent).

Figure 1-26.
Percent of mathematics teachers who are "well aware" of the NCTM standards documents, by grade range: 1993



SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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The 1993 LSAY survey of public high school teachers asked teachers in both mathematics and science very similar questions. Fifty-eight percent of the mathematics teachers reported that "I have read or am aware of the recommendations in the *[NCTM Curriculum and Evaluation] Standard*." This percentage closely matches with the NSSME data. The LSAY also asked science teachers if they were familiar with one or more of the science recommendations (NSTA, AAAS, or NRC). Forty-four percent indicated that they had read or were otherwise aware of at least one of these sets. Thus, it appears that at the time of the survey, the mathematics reform recommendations were gaining greater publicity than the science reforms at the high school level. The mathematics reforms were also more familiar to high school teachers than to elementary and middle school teachers.

Characteristics of High School Science and Mathematics Departments

The NCTM and NSTA reform proposals call most directly for changes in the content and delivery of instruction. These changes can be encouraged by the kind of training prospective and experience teachers receive in colleges and universities. However, even the best preparation of individual teachers will not translate into improved programs unless changes in school organization are also effected. The typical organizational model is the "top-down" bureaucratic form of control, whereby decisions of what will be taught and how it will be taught are decided by state, district, or school administrators. In contrast, a professional model of control allows teachers to decide on content and methods. Many observers believe that the professional model is essential to the effective implementation of the reform ideas. This is mainly because bureaucratic control is considered insufficiently flexible to adapt to the shifting exigencies of classrooms and the need to search constantly for more effective ideas and methods. What many advocate instead is an expanded role for the subject-area department as a problem-solving and monitoring mechanism and as a site for teachers' professional development.

Research directed toward describing and analyzing how secondary school subject-area departments work is just beginning. One research program being conducted at Stanford University, under the direction of Milbrey McLaughlin and Joan Talbert, has involved in-depth studies of a diverse set of 16 high schools and their teachers. A second study, directed by Charles Bidwell, Anthony Bryk, and Barbara Schneider, is underway at the University of Chicago and National Opinion Research Center. This study builds on the LSAY survey to gather data about the extent of faculty professional ties, both within and across subject-area departments, and the consequences of those ties for student outcomes.

Among the important findings of the Stanford project are that departments can be positive influences on the orientations and practices of many high school teachers,

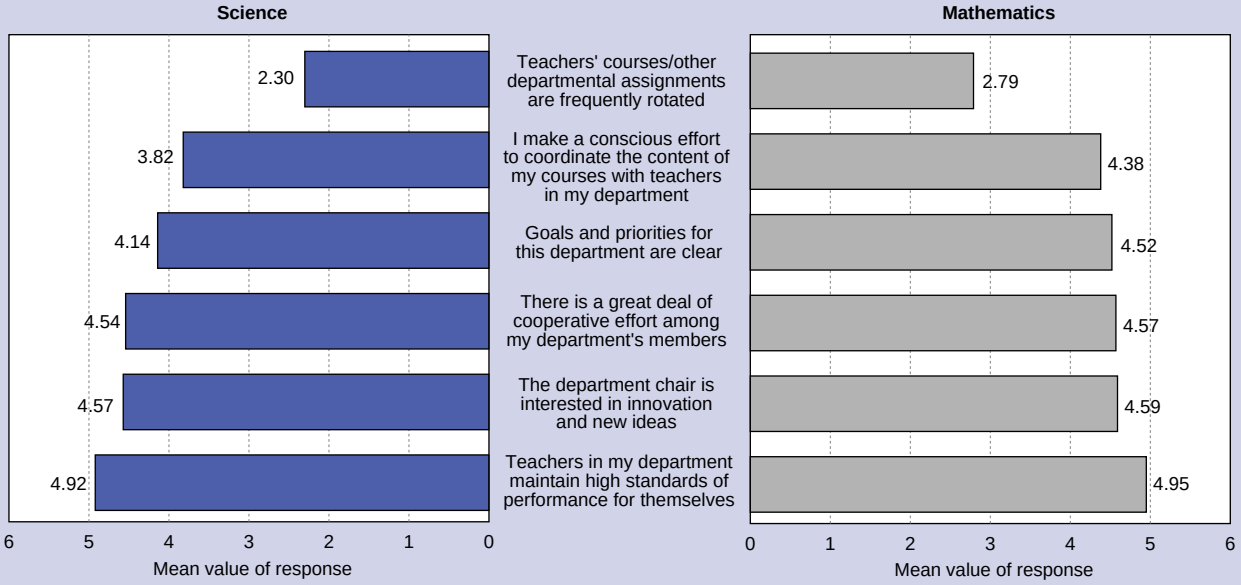
but that most teachers work in schools and departments that are not effective learning environments. In the absence of strong department- or school-based professional communities, some teachers find professional communities in subject-area networks outside their schools (McLaughlin and Talbert, 1993; Talbert and McLaughlin, 1994). Findings from the Chicago study suggest that science and mathematics departments can encourage professional development and instructional reform, but that cohesive departments do not necessarily promote strong professional orientations. The orientation of the departmental leadership appears to be especially important in determining the direction of influence. Both studies conclude that mathematics and science departments that embrace the new standards for teaching and learning are powerful settings for teacher learning and educational change.

One important dimension of subject-area departments was found through data collected in 1993 from the mathematics and science teachers in the LSAY high schools. The data show that teachers generally have favorable perceptions of their departmental colleagues and chairs. However, the teachers vary substantially in their perceptions of their department's leadership, the members' performance expectations for students, cooperation among members, and consensus over goals. Mathematics and science teachers generally agree that their department chairperson "is interested in innovation and new ideas." (See figure 1-27.)

Mathematics teachers tend to agree more strongly than science teachers that goals and priorities for their departments are clear. The lower clarity of goals and priorities reported by science teachers does not seem to reflect lower levels of cooperation or commitment to high standards of science teachers, compared with mathematics teachers. (See figure 1-27.) These are almost identical in mathematics and science. Instead, what seems to account for the differences is the nature of the subject matter, at least as traditionally defined. Mathematics teachers are more likely to agree "that they make a conscious effort to coordinate the content of their courses with teachers in their department" and that "if another teacher took over their courses, the basic content would stay the same." All of these departmental differences are likely tied to the fact that mathematics tends to be more sequential, with more standardized subject contents than the sciences.

Some of these characteristics of high school departments are related, albeit very modestly, to the teachers' self-reported awareness of the reform proposals in their fields. (See text table 1-9.) As might be expected, teachers who report stronger agreement with the statement that their department chair is interested in innovation are more likely to report that they are aware of the reform recommendations in their field. Interestingly, science—but not mathematics—teachers who are aware of reforms tend also to agree more strongly that goals and priorities in their departments are clear. This may

Figure 1-27.
Mean value of responses to questions about teachers' perceptions of their departments:



NOTE: Level of agreement with teachers' statements about their departments is measured on a 6-point scale, ranging from 1 = "strongly disagree" to 6 = "strongly agree."

SOURCE: J.D. Miller, T.B. Hoffer, K.B. Brown, L. Pifer, and C. Nelson, *Longitudinal Study of American Youth: Base Year Through Year 5 Data CD-ROM and Documentation* (Chicago: Chicago Academy of Sciences, 1993).

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Text table 1-9.
Correlation (gamma coefficient) between teachers' awareness of science or math reform recommendations and their level of agreement with statements about their subject area departments: 1993

Statement	Science	Math
Chair is interested in innovation	0.16	0.15
Department goals are clear	0.12	0.03
Teachers in my department maintain high standards	0.11	0.02
There is a great deal of cooperative effort in my department	0.06	0.08

NOTES: The measures of teachers' awareness is an ordinal scale, with levels 1 = "Not aware or sure;" 2 = "Yes, I have heard of these, but I don't know the specifics;" 3 = "Yes, I have read or am aware of these recommendations." Level of agreement with the statements about their departments is measured on a 6-point scale, ranging from 1 = "strongly disagree" to 6 = "strongly agree." The gamma coefficients measure the strength of the linear association between ordinal measures and ranges from 0 (no association) to 1 (perfect linear association).

SOURCE: J.D. Miller, T.B. Hoffer, K.B., Brown, L. Pifer, and C. Nelson, *Longitudinal Study of American Youth: Base Year Through Year 5 Data CD-ROM and Documentation*, special tabulations, 1993.

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reflect some impact of the reforms; all of the recommendations in science call for greater integration of course goals across the traditional subdisciplinary boundaries.

In addition to asking the teachers about their awareness of the reform recommendations, the 1993 LSAY survey asked about the extent to which the reforms have changed the curriculum and teaching practices in the high school. It is reasonable to suppose that the extent to which reforms are being followed, and the extent to which they are seen to be beneficial, would depend on the characteristics of the subject-area departments. Among teachers who reported that they were aware of the reform recommendations, there were moderately strong correlations between the chairperson's interest in innovation and the teacher's agreement with the statements about whether the science or mathematics program in the school had been modified in line with reform recommendations, whether the teachers were experimenting with recommended teaching techniques, and whether the department had benefited from the reform recommendations. (See text table 1-10.) This correlation suggests that the chairperson's leadership can be instrumental in gaining favorable outcomes from the reform efforts. Further research is needed to explore these relationships, but the data provide interesting indications about the links between departmental functioning and the teachers' perceptions of the success of reform initiatives.

Qualifications for Teaching Mathematics and Science

The mathematics and science standards have brought forth increased interest in the preparation teachers receive in their fields. To give students a challenging learning environment and appropriate instruction for the development of valuable analytical skills, teachers themselves must have a firm grasp of powerful scientific and mathematical concepts. The teachers' educational background, specifically whether they have an undergraduate or a graduate major in the field of instruction, is the most

Text table 1-10.
Correlations between high school teachers' reports about their departments and the extent to which they agree with statements about reform in their schools: 1993

		Teacher agrees that			
Agreement with statements about his/her department	Department	I have modified my teaching	This school has modified the curriculum in line with recommendations	Most teachers are following standards	Program has benefited from recommendations
The department chair is interested in innovation	Science	0.12	**0.35	**0.35	**0.38
	Mathematics	*0.15	**0.22	**0.22	**0.28
Goals and priorities for this department are clear	Science	0.01	*0.21	*0.21	*0.22
	Mathematics	0.08	**0.19	**0.24	*0.25
The teachers in my department maintain high performance standards	Science	0.15	*0.19	**0.29	**0.25
	Mathematics	0.02	**0.19	**0.24	*0.16
There is a great deal of cooperative effort in my department	Science	0.06	0.18	*0.21	*0.24
	Mathematics	0.01	**0.23	**0.20	0.11

* = p<0.05; ** = p<0.01

NOTE: Estimates are based on responses from 116 science teachers and 194 math teachers who indicated that they have read or are aware of the reform recommendations in their field.

SOURCE: J.D. Miller, T.B. Hoffer, K.B. Brown, L. Pifer, and C. Nelson, *Longitudinal Study of American Youth: Base Year Through Year 5 Data CD-ROM and Documentation*, special tabulations, 1993.

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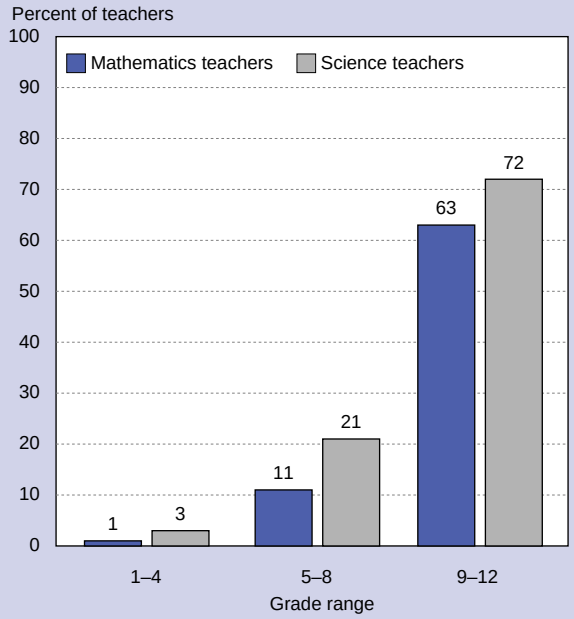
widely used index of teachers' understanding of and expertise in their field.

Educational backgrounds of mathematics and science teachers vary directly, and quite dramatically, with the grade or grades taught. (See figure 1-28.) In 1993, less than 4 percent of elementary mathematics and science teachers had majored in mathematics or mathematics education, or science or science education. Although that figure is low, it is not surprising, considering that most elementary teachers teach all or most academic subjects, rather than specialize in science or mathematics. However, middle school teachers—who typically do have specialized teaching assignments—also show high rates of out-of-field majors. Only 11 percent of middle school mathematics teachers had a mathematics or mathematics education major, while 21 percent of science teachers majored in science or science education. And although high school teachers are much more likely to have majored in their fields, a substantial number of these teachers had not. Thirty-seven percent of high school mathematics teachers did not have an undergraduate or a graduate major in mathematics or mathematics education, and 28 percent of high school science teachers did not major in science or science education.

A similar pattern emerges in the numbers of college science courses completed by teachers in each grade range completed. (See figure 1-29.) Fifty percent of elementary school science teachers completed fewer than six semesters of college science. This compares with 28 percent of middle school science teachers and only 1 percent of high school science teachers. At the other end of the distribution, 28 percent of the high school science teachers had completed more than 20 college semester courses in their field, compared with 8 percent of the middle school science teachers and 1 percent of the elementary science teachers.

The NSSME survey also asked the mathematics and science teachers to evaluate themselves in terms of how well prepared they felt they were to cope with various instructional tasks. A substantial proportion of teachers felt less than well prepared for most instructional tasks. (See figures 1-30 and 1-31.) Almost all mathematics teachers at all levels felt well prepared to present applications of mathematical concepts, but a large number of high school teachers did not feel well prepared to use manipulatives, cooperative groups, and computers, and to teach students from a variety of cultures and students with learning disabilities. (See figure 1-30.) Although the

Figure 1-28.
Percent of science and mathematics teachers with undergraduate or graduate majors in science or mathematics fields, by grade range: 1993



NOTE: "Field" includes any science or science education major for science teachers and any mathematics or mathematics education major for mathematics teachers.

SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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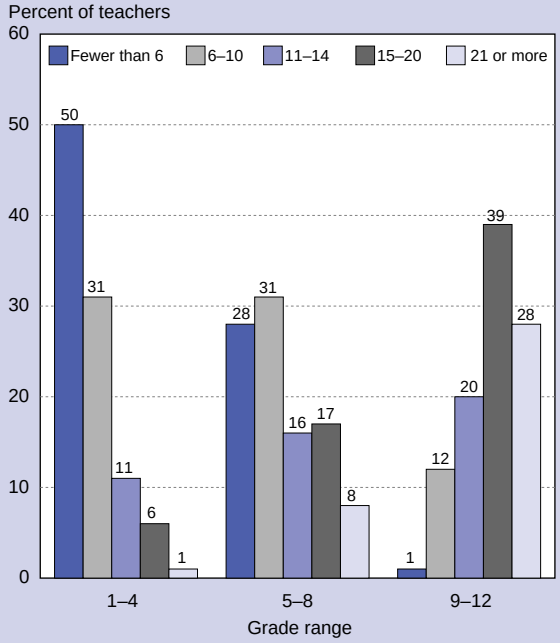
Figure 1-29.
Percentage of science teachers completing different numbers of semesters of college science coursework, by grade range: 1993



NOTE: The highest number of semesters a teacher could indicate for each of the four categories—life science, chemistry, physics/physical science, and earth/space science—was "8", therefore these figures underestimate the total for any teacher who completed more than eight courses in a particular category.

SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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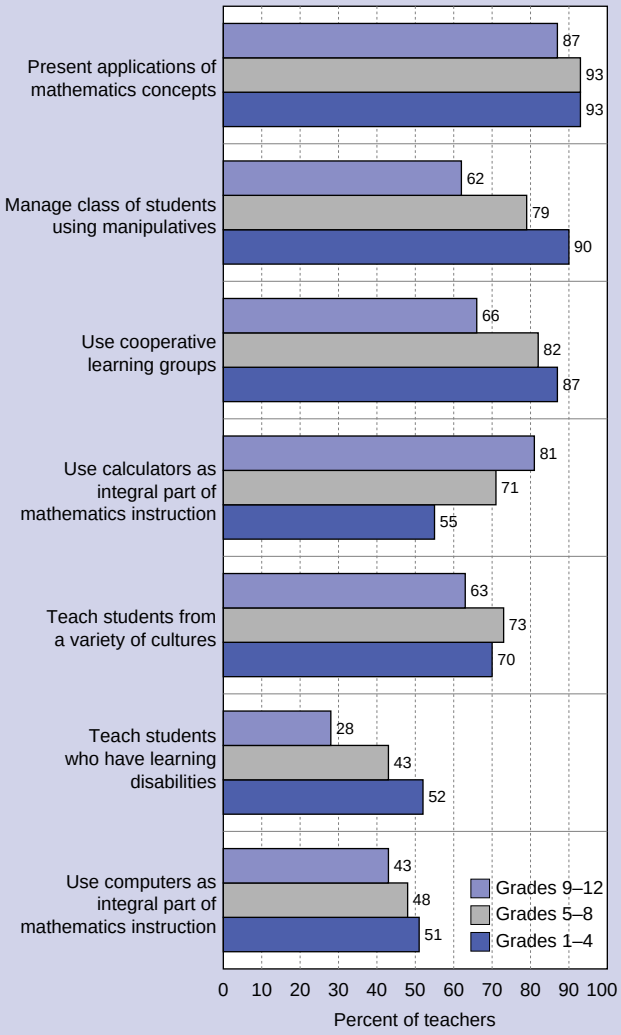
Figure 1-30.
Percent of mathematics teachers considering themselves well prepared for mathematics teaching tasks, by grade range: 1993



SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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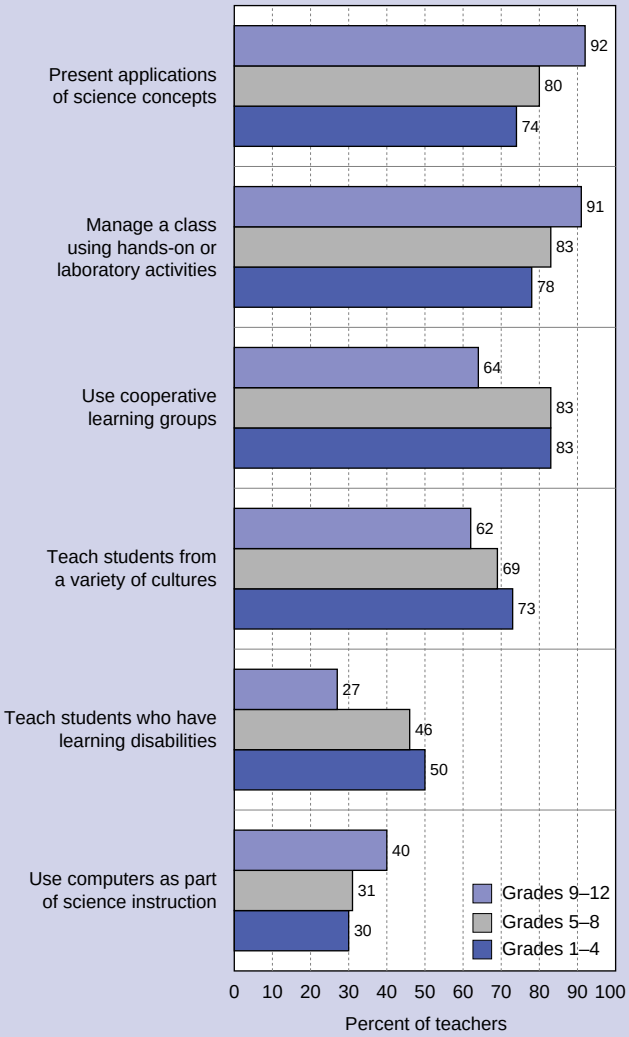
Figure 1-31.
Percent of science teachers considering themselves well prepared for science teaching tasks, by grade range: 1993



SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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use of calculators in elementary education is recommended by the NCTM standards, only 55 percent of the elementary teachers felt prepared to incorporate calculators as an integral part of their classes.

Similar patterns exist for the science teachers. (See figure 1-31.) One noteworthy exception is that, of the three grade ranges, the high school science teachers felt most comfortable with hands-on work, while elementary teachers felt the least prepared. This is the reverse of the pattern among mathematics teachers in the use of manipulatives. Significantly, only 40 percent of high school science teachers and 31 percent of the middle school science teachers felt well prepared to use computers as part of science instruction. If the recommendations of the reform proposals to use computers for teaching scientific research are realized, then, it is clear that great effort is needed to prepare science teachers for that instructional role.

Qualifications, Experience, and Student Achievement

Teacher education credentials and years of experience are widely used in determining salary and assignments. Based on his review of several studies of the relationships between teacher characteristics and student outcomes, Hanushek (1989) concluded that teacher

education and experience have no effect on student achievement. However, a critical reanalysis of Hanushek's review by Hedges, Laine, and Greenwald (1994) has disputed these results and the methods by which they were derived. Based on their reanalysis, the authors concluded that teacher experience does, in fact, have a significant positive effect on student achievement, but that teacher education does not have any significant effect.

Although teacher education generally has not shown any positive effect on student achievement, some shortcomings have been identified in how teacher education is typically measured (Monk, 1994). Teacher education has usually been measured in terms of the teacher's educational attainment (bachelor's, master's, or doctoral degree). But recent research suggests that more specific measures of the teachers' educational backgrounds, particularly the numbers of college courses teachers have completed in the subjects they teach, may have a significant positive effect on student learning (Chaney, 1995).

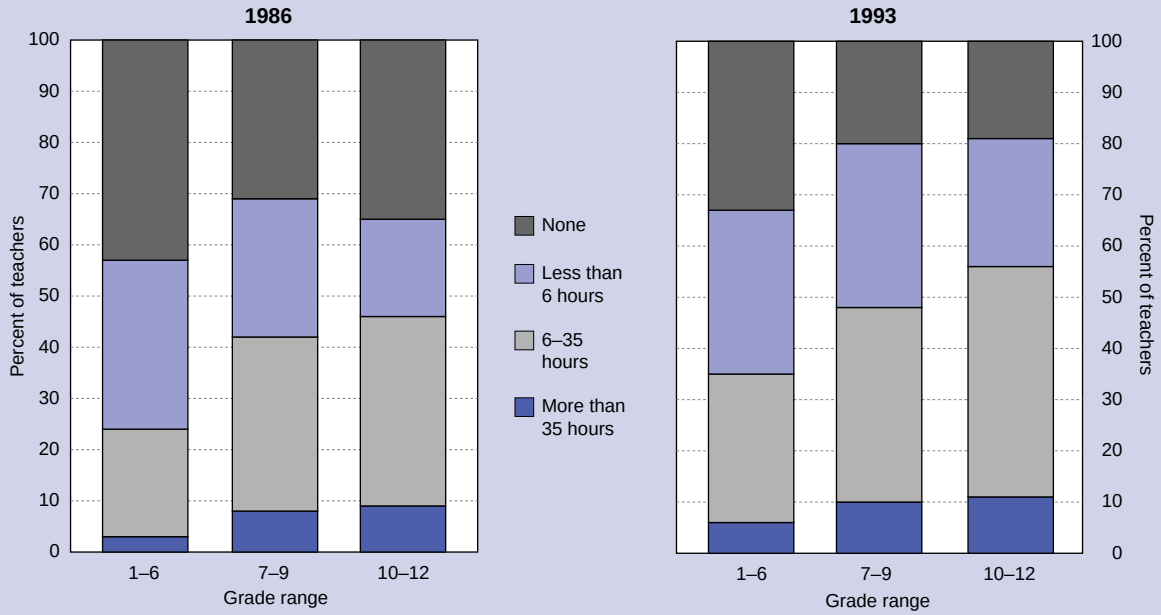
Recent Training

In-service education and college coursework serve as valuable links between advances in a field and teachers' growth and progress in that field. To keep up to date with new teaching techniques and instructional methods, teachers are offered workshops periodically throughout the year. Also, evening and summer college courses in education and specific teaching disciplines are available to teachers who wish to attend. Because the time teachers spend on in-service education and advanced college coursework may have a direct relationship with the effectiveness of their instructional practices, it serves as yet another measure by which teacher preparation may be evaluated.

Between 1986 and 1993, the percentage of teachers participating in in-service education increased substantially. (See figure 1-32.) While only 65 percent of grade 10 to 12 mathematics teachers had some type of in-service education in 1986, more than 80 percent did in 1993. (See text table 1-11.) However, despite the increase over this 6-year period, in 1993 many teachers still did not spend a substantial amount of time in in-service education. Even among high school mathematics and science teachers—many of whom are specialists in their field—only one-half spent 6 or more hours on in-service education during 1993.

The amount of time high school mathematics teachers spend on in-service education varies substantially. Mathematics teachers who do not teach advanced classes, and who, in many cases, may be more in need of in-service education as a means of strengthening content knowledge, are less likely to receive it. In 1993, high school teachers who did not teach any advanced mathematics courses were more likely to have spent no time on in-service education during the previous 3 years than teachers teaching one or more advanced courses. (See figure 1-33.) Furthermore, 63 percent of the high school

Figure 1-32.
Total amount of time mathematics teachers spent on in-service education in mathematics during previous 12 months: 1986 and 1993



See appendix table 1-14.

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Text table 1-11.
Amount of time science and mathematics teachers spent on science or mathematics in-service education in the past 3 years, by subject of class taught and grade range: 1993

Subject of class taught	Amount of time	Grade range 1–4	5–8	9–12
Science	None	26 (2.8)	17 (1.9)	12 (1.5)
	Fewer than 6 hours	30 (1.8)	22 (2.6)	14 (1.8)
	6–15 hours	22 (2.1)	27 (4.2)	18 (3.0)
	16–35 hours	14 (1.9)	14 (2.8)	19 (1.4)
	More than 35 hours	9 (1.8)	20 (2.4)	38 (3.1)
Mathematics	None	17 (1.5)	15 (1.5)	10 (1.8)
	Fewer than 6 hours	22 (2.0)	22 (3.5)	14 (2.8)
	6–15 hours	29 (2.4)	23 (2.5)	21 (1.8)
	16–35 hours	18 (2.4)	24 (2.5)	24 (2.6)
	More than 35 hours	15 (2.0)	17 (2.0)	31 (2.5)

NOTE: Standard errors appear in parentheses.

SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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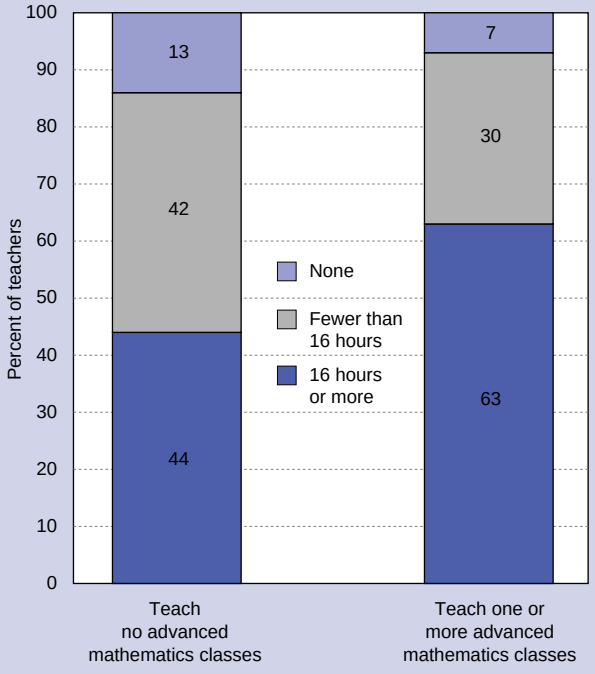
Figure 1-33.
Amount of time high school mathematics teachers spent on mathematics in-service education in the past 3 years, by teaching assignment: 1993



SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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mathematics teachers teaching one or more advanced courses spent 16 hours or more on in-service education, compared with only 44 percent of those teaching no advanced courses.

Recent college coursework in mathematics or science is also strongly related to the grade level taught. (See text table 1-12.) As shown, elementary mathematics and science teachers are more likely than middle and high school teachers to have taken their most recent college course prior to 1983. Likewise, high school mathematics and science teachers are more likely than elementary and middle school teachers to have taken their most recent course in their field between 1989 and 1993. Although these numbers do not take into account how recently the teachers graduated from college, they do reflect an indication that high school mathematics and science teachers are more continually enrolled in college courses within their field than their counterparts in lower grades.

Conclusion

The findings of recent studies reviewed in this chapter show several positive trends and reasons for optimism about the future of science and mathematics education at the precollegiate levels. Aggregate achievement levels show small but steady increases in both subjects, and the gaps between racial and ethnic groups have diminished over the last decade. These gains coincide with dramatic increases in the rates at which high school students are completing courses in the main content areas of the mathematics and science curricula: algebra, geometry, trigonometry, biology, chemistry, and physics. Data from the NELS:88 survey confirm that students who complete more of these courses do better on standardized tests of mathematics and science achievement. In addition, when

Text table 1-12.
Mathematics teachers' most recent college coursework in field: 1993

Subject and year	Grade range 1–4	5–8	9–12
	Percent of teachers		
Science or science education			
1989–93	26 (3.0)	41 (2.8)	55 (3.2)
1983–88	20 (2.1)	18 (1.6)	21 (1.5)
Prior to 1983	53 (2.5)	41 (3.0)	24 (3.8)
Mathematics or mathematics education			
1989–93	38 (2.6)	44 (3.3)	45 (2.2)
1983–88	22 (1.9)	20 (3.1)	24 (2.7)
Prior to 1983	40 (2.3)	36 (3.8)	31 (1.8)

NOTE: Standard errors appear in parentheses.

SOURCE: I.R. Weiss, M.C. Matti, and P.S. Smith, *Report of the 1993 National Survey of Science and Mathematics Education* (Chapel Hill, NC: Horizon Research, Inc., 1994).

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high school students are followed up after graduation, national data show that students who completed higher levels of mathematics and science in high school are more likely to survive in college, once enrolled.

Researchers do not yet have a clear sense of why test scores have increased and why participation in the mathematics and science curricula have soared over the past decade or so. Clearly, this has been a period of considerable ferment in the mathematics and science professional educational communities. The leading professional associations of science and mathematics teachers have developed curriculum, evaluation, and instruction standards, and these are reaching substantial segments of the secondary and elementary teaching workforces. State and local educational authorities have also been actively involved, most consistently in the area of high school graduation requirements, but also in the definition of curriculum and evaluation standards. But these factors are not quite the whole story. As this chapter has shown, most teachers are not thoroughly familiar with the reform recommendations of their professional associations. And while states, districts, and schools are requiring more mathematics and science courses for students to graduate, much of the growth in coursetaking has been in subjects that graduation requirements are not likely to affect, such as chemistry and trigonometry.

Nor are the leading indicators wholly positive. While racial and ethnic achievement gaps have diminished, they remain enormous. This is particularly true at the more advanced levels of mastery, which are, of course, the most crucial for college entry and success and for associated post-collegiate professional opportunities. Another cause for concern is the apparent disparity between the achievement trends and the mathematics and science course-completion trends reported here. Achievement levels have increased slightly, while coursetaking has increased greatly. This suggests that students may be getting less out of courses that are nominally the same. Also, while many teachers are familiar with reform proposals, most are not. Perhaps more importantly, a substantial number of mathematics and science teachers continue to lack solid collegiate or graduate training in their fields.

These shortcomings and areas of ambiguity are important lines for further research. That research should not, however, be confined to national overviews. The national data are useful in drawing attention to general problems, but state and local inquiries are needed to determine, first, whether a national problem holds in the particular state or locality and, second, how the problem developed at that level and how it might be redressed by those ultimately responsible for it.

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