Chapter 1
Elementary and Secondary Education

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Highlights

Student Performance in Mathematics and Science

- **Student performance in mathematics and science, as measured by the National Assessment of Educational Progress (NAEP), has improved somewhat over the past 3 decades, but not consistently.** Improvements have occurred across all racial/ethnic subgroups.
- **Despite the improved performance overall, achievement gaps between various racial/ethnic subgroups persist and have shown no signs of narrowing since 1990.** For example, in NAEP's 2000 mathematics assessment of grade 12 students, 74 percent of white students and 80 percent of Asian/Pacific Islander students scored at or above a level deemed basic by a national panel of experts. In contrast, 31 percent of blacks, 44 percent of Hispanics, and 57 percent of American Indians/Alaskan Natives attained this level.
- **Achievement gaps between males and females have largely disappeared, especially in mathematics.** For example, in tests administered by the Program for International Student Assessment (PISA) in 2000, 15-year-old male and female students scored equally well in both mathematics and science literacy.
- **U.S. students are performing at or below the levels attained by students in other countries in the developed world.** U.S. students' performance on PISA was about average among Organisation for Economic Co-operation and Development (OECD) countries. Seven countries (Australia, Canada, Finland, Japan, New Zealand, South Korea, and the United Kingdom) had higher scores in both mathematics and science. Six countries recorded lower scores in both subjects: Brazil, Greece, Latvia, Luxembourg, Mexico, and Portugal.
- **In international comparisons, U.S. student performance becomes increasingly weaker at higher grade levels.** On the Third International Mathematics and Science Study (TIMSS), U.S. 9-year-olds scored above the international average; 13-year-olds, near the average; and 17-year-olds, below it. On advanced mathematics and science assessments, U.S. students who had taken advanced coursework in these subjects performed poorly compared with their counterparts in other countries.

Mathematics and Science Coursework and Student Achievement

- **Since the publication of *A Nation At Risk* 20 years ago, many states and school systems have increased their graduation requirements, including those for mathematics and science.**
- **Students are taking more science and mathematics courses in high school than their counterparts did in the past.** In 1998, high school graduates earned an average of 3.5 mathematics credits and 3.2 science credits compared with 2.6 and 2.2 credits, respectively, in 1982.
- **The proportion of high school graduates completing advanced mathematics and science coursework also increased over this period.** More students have been taking algebra in grade 8, better preparing them for more advanced coursework later in high school.

Curriculum Standards and Statewide Assessments

- **The No Child Left Behind (NCLB) Act of 2001 requires states to immediately set standards in mathematics and reading/language arts, and to set standards in science by academic year 2005. By 2002, nearly all states had established standards in these three subjects.**
- **Building on the testing requirements included in the 1994 reauthorization of the Elementary and Secondary Education Act, the NCLB Act requires periodic assessments in mathematics and science and mandates consequences for poor school and student performance.** States have developed a range of rewards, supports, and sanctions based on student test scores.

Curriculum and Instruction

- **Analyses of U.S. textbooks and curricula in science and mathematics indicate that more topics are covered, and with less coherence, in the United States than in other countries.** U.S. textbooks are longer and cover more topics, but do not generally cover topics more thoroughly, and the curricula often repeat content over more grades.
- **According to a 1995 TIMSS video study, U.S. mathematics lessons generally scored lower on various measures of lesson difficulty than lessons in some other countries, notably Japan.** However, a 1999 TIMSS-R video study, which did not include Japan, found that lesson difficulty in the U.S. was comparable to that in the five other countries that participated.

Teacher Quality

- **Some evidence suggests that college graduates who enter the teaching profession tend to have weaker academic skills.** Data from the 2001 Baccalaureate and Beyond Longitudinal Study indicate that recent college graduates who taught or prepared to teach were underrepresented among graduates with college entrance examination scores in the top quartile.

♦ **Teaching *out of field* (teachers teaching subjects outside their areas of subject-matter training and certification) is not uncommon.** In academic year 1999, 9 percent of public high school students enrolled in mathematics classes, 10 percent enrolled in biology/life sciences classes, and 16 percent of students enrolled in physical sciences classes received instruction from teachers who had neither certification nor a major or minor in the subject they taught. Comparable figures for public middle school students were higher.

♦ **The proportion of relatively new teachers is slightly higher in science and mathematics than in other subjects.** Research indicates that inexperienced teachers are generally less effective than more senior teachers.

♦ **High-poverty and high-minority schools both had a higher proportion of inexperienced science teachers than low-poverty and low-minority schools.** Moreover, these teachers were less likely than other new science teachers to participate in induction programs, which might help them adjust to their new responsibilities. Neither of these findings held true in mathematics, however.

Teacher Induction, Professional Development, and Working Conditions

♦ **A large majority of new mathematics and science teachers in public middle and high schools reported that they felt well prepared to teach mathematics and science in their first year of teaching.** Teachers who participated in induction and mentoring programs were even more likely to feel well prepared.

♦ **In recent years, beginning teachers' salaries have risen at a faster rate than the salaries of all teachers.** However, beginning teachers receive substantially lower salaries than the average starting salary offered to new college graduates in other occupations. In academic year 1999, salaries for mathematics and science teachers were similar to those for other teachers. Mathematics and science teachers in high-poverty public high schools earned less than their counterparts in low-poverty schools.

Information Technology in Schools

♦ **Almost all students now study in schools and classrooms with computers and at least some form of Internet access.** By fall 2001, an estimated 99 percent of public schools and 87 percent of instructional rooms had Internet connections. This represents a dramatic increase over 1994, when the comparable figures were 35 and 3 percent, respectively. Continuing differences in school access for students in different demographic groups concern student-computer ratios, teacher preparation for using information technologies (IT), and ways in which teachers use IT. These issues go beyond mere access to encompass quality and effectiveness in IT use.

♦ **Teachers cite inadequate teacher training as one barrier to effective IT use but rate other barriers as equally important.** These other barriers included lack of release time, lack of scheduled time for students to use computers, insufficient computers, lack of good instructional software, outdated computers with slow processors, and difficulty accessing the Internet connection. New teachers felt better prepared to use IT than did their more experienced colleagues.

♦ **Students' access to computers and the Internet at home is much more unequally distributed than their access at school.** According to 2001 data, home access to computers is nearly universal among children ages 10 to 17 in the highest income category, but limited to only about one-third of children in the lowest income category. As a result, reliance on school alone for access to computers is common for children in the lowest income category, but rare in the highest income category. Racial and ethnic differences in home access to computers and the Internet are also substantial.

Transition to Higher Education

♦ **The percentage of high school graduates who enrolled in postsecondary education immediately after graduation increased from 47 percent in 1973 to 62 percent in 2001.** The immediate enrollment rate increased more for females than for males, and more for blacks than for whites. Rates for Hispanics remained relatively constant between 1973 and 2001, resulting in a widening gap between Hispanics and whites.

♦ **Many college freshmen apparently lack adequate preparation for higher education; thus, remedial coursetaking is widespread, especially at 2-year institutions**. In 2000, undergraduate enrollment in remedial classes accounted for 12 percent of mathematics enrollment in 4-year institutions and 55 percent in 2-year institutions.

Introduction

Chapter Overview

Increasingly, nations need a skilled, knowledgeable workforce and a citizenry equipped to function in a complex world. Competent workers and citizens, in turn, need a sound understanding of science and mathematics; elementary and secondary schools are responsible for ensuring that they acquire this knowledge. Yet in the United States in recent decades, few parents, policymakers, legislators, or educators have been satisfied with student achievement in mathematics and science. This dissatisfaction has spawned numerous efforts to reform and improve schools.

Twenty years have passed since *A Nation At Risk* urged higher academic standards, better teacher preparation, and greater accountability for schools as ways of improving student achievement (National Commission on Excellence in Education 1983). Other reports and commissions subsequently set ambitious goals, among them that U.S. students would rank "first in the world in mathematics and science achievement by the year 2000" (U.S. Department of Education 1989). When 2000 arrived, another national commission concluded that U.S. students were "devastatingly far from this goal" (National Commission on Mathematics and Science Teaching for the 21st Century 2000).

Seeking to give school reform efforts new momentum, the Federal No Child Left Behind (NCLB) Act of 2001 introduced strong accountability measures for schools, requiring them to demonstrate progress in boosting student achievement. (This act became law in 2002.) The act specifies steps that states must take and timelines for their implementation; these steps included immediate development of standards for mathematics and development of standards for science by academic year 2005. (Academic year 2005 refers to the school year that begins in fall 2005.) The NCLB Act also requires school districts to assess student performance every year in grades 3 through 8, beginning in academic year 2005 for mathematics and in academic year 2007 for science. Schools that do not demonstrate progress in improving achievement for all students will initially receive assistance, but they subsequently will be subject to sanctions if they still fail to show improvement.

Chapter Organization

This chapter presents data on the developments, trends, and conditions that affect the quality of U.S. elementary and secondary mathematics and science education. It begins by summarizing the most recent available information on U.S. student achievement. The chapter then examines data on aspects of the education system thought to be linked to student performance, including course offerings, coursetaking, statewide curriculum standards, accountability systems, and instructional practices.

Because of the critical role that teachers play in helping students meet high standards, the chapter also reviews data on mathematics and science teachers, including their academic ability, education, preparation, and experience; participation in teacher induction and professional development activities; salary levels; and working conditions.

The widespread use of computers and the Internet is changing education. This chapter therefore examines indicators of student and teacher access to information technologies (IT) at school and IT use in the classroom. And finally, it reviews data on high school students' transition into higher education and the prevalence of remedial education at the college level, a discussion that leads into the examination of college-level S&E in chapter 2.

Although this chapter focuses on overall patterns, it also looks at variation in access to education resources by school poverty level and minority concentration, and in performance by sex, race/ethnicity, and family background, when such data exist. In the conclusion, we bring together these data in summary form.

Student Performance in Mathematics and Science

Available data on U.S. student performance in mathematics and science present a mixed picture. Although data show some overall gains in achievement, most students still perform below levels considered proficient or advanced by a national panel of experts. Furthermore, sometimes substantial achievement gaps persist between various U.S. student subpopulations, and U.S. students continue to do poorly in international comparisons, particularly in the higher grades. This section describes long-term trends based on curriculum frameworks developed in the late 1960s, recent trends based on frameworks aligned more closely with current standards, and the performance of U.S. students relative to their peers in other countries.

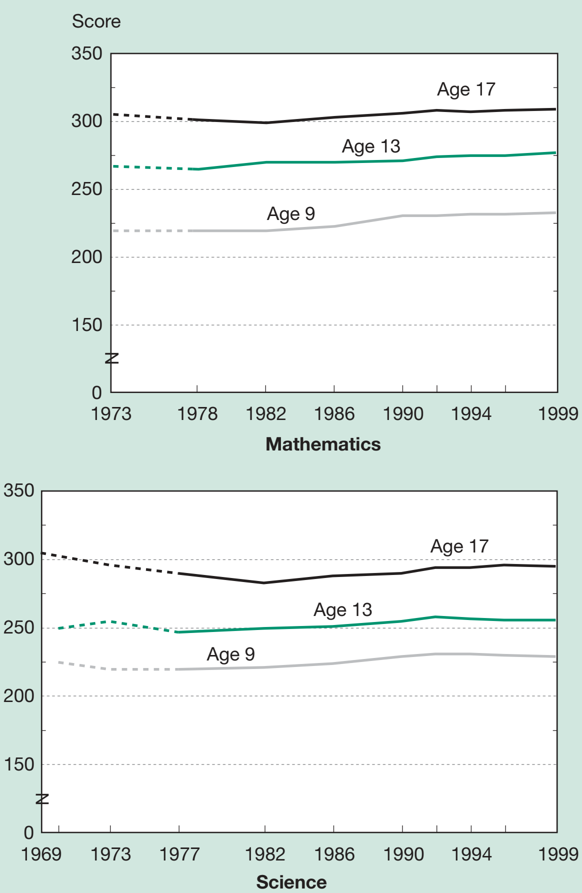
The National Assessment of Educational Progress (NAEP), also known as "The Nation's Report Card," has charted U.S. student performance for the past 3 decades (Campbell, Hombo, and Mazzeo 2000) and is the only nationally representative, continuing assessment of what students know and can do in a variety of academic subjects, including reading, writing, history, civics, mathematics, and science. NAEP consists of three separate testing programs. The "long-term trend" assessment of 9-, 13-, and 17-year-olds has remained substantially the same since it was first given in mathematics in 1973 and in science in 1969, and it thereby provides a good basis for analyzing achievement trends. [More detailed explanations of the NAEP long-term trend study are available in *Science and Engineering Indicators – 2002* (National Science Board 2002) and at http://www.nces.ed.gov/naep3/mathematics/trends.asp.] A second testing program, the "National" or main NAEP, is based on more contemporary standards of what students should know and be able to do in a subject. It assesses students in grades 4, 8, and 12. A third program, "state" NAEP, is similar to national NAEP, but involves representative samples of students from participating states. The NAEP data summarized here come from the long-term trend assessment and the national NAEP. Chapter 8 covers the considerable variation by state.

The most recent NAEP long-term trend assessment took place in 1999. Because the 1999 NAEP data have already been reported widely (including in the 2002 version of this report), this chapter only summarizes the main findings.

Trends in Mathematics and Science Performance: Early 1970s to Late 1990s

The NAEP trend assessment shows that student performance in mathematics improved overall from 1973 to 1999 for 9-, 13-, and 17-year-olds, although not at a consistent rate across the 3 decades (Campbell, Hombo, and Mazzeo 2000) (figure 1-1). In general, declines occurred in the 1970s, followed by increases in the 1980s and early 1990s and relative stability since that time.[1] The average performance of 9-year-olds held steady in the 1970s, increased from 1982 to 1990, and showed additional modest increases after that. For 13-year-olds, average scores improved from 1978 to 1982 with additional improvements in the 1990s. The average performance of 17-year-olds dropped from 1973 to 1982, rose from 1982 to 1992, and has since remained about the same, resulting in an overall gain from 1973 to 1999.

Figure 1-1
Trends in average scale scores in mathematics and science, by age: Selected years, 1969–99



NOTES: Student performance is assessed on a 0–500 point scale. Dashed lines represent extrapolated data. Test administration years are either labeled or are shown with tick marks.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *NAEP 1999 Trends in Academic Progress: Three Decades of Student Performance*, NCES 2000-469 (Washington, DC: U.S. Department of Education, 2000).

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Average student performance in science also improved from the early 1970s to 1999 for 9- and 13-year-olds, although again, not consistently over the 3 decades. Achievement declined in the 1970s and increased in the 1980s and early 1990s, holding relatively stable since that time. By 1999, increases had overcome the declines of the 1970s. In 1999, 9-year-olds' average performance was higher than in 1970. Among 13-year-olds, average performance in 1999 was higher than in 1973 and essentially the same as in 1970. By 1999, 17-year-olds had not recouped decreases in average scores that took place during the 1970s and early 1980s. This resulted in lower performance in 1999 than in 1969 when NAEP first assessed 17-year-olds in science.

The NCLB Act requires every student, regardless of poverty level, sex, race, ethnicity, disability status, or English proficiency, to meet challenging standards in mathematics and science. Patterns in the NAEP long-term trend data can show whether the nation's school systems are providing similar learning outcomes for all students and whether performance gaps between different groups of students have narrowed, remained steady, or grown.

Performance Trends for Males and Females

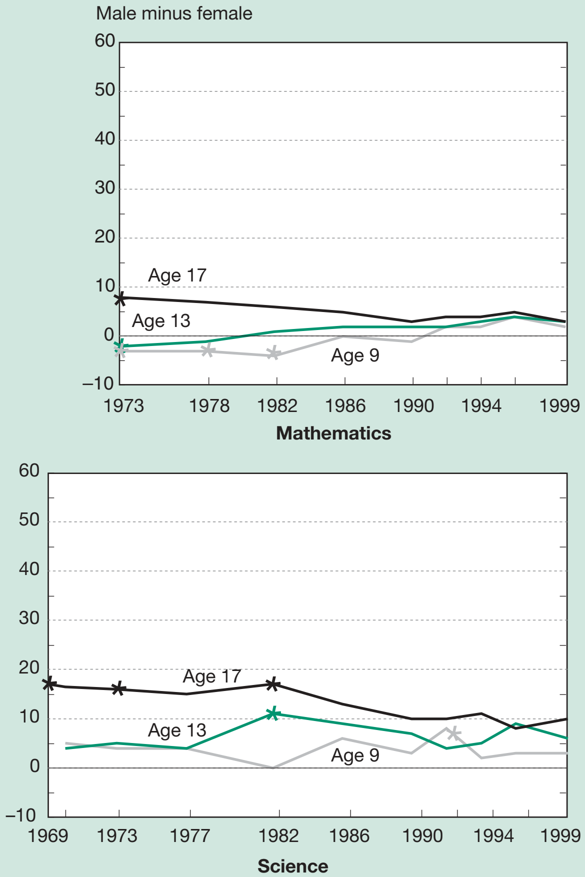
In general, the average performance of both males and females in mathematics improved from the early 1970s to the late 1990s, including the period from 1990 to 1999 (Campbell, Hombo, and Mazzeo 2000). For 9- and 13-year-olds, differences in average mathematics scores shifted from favoring females in the 1970s to favoring males by the 1990s (figure 1-2 and appendix table 1-1). Among 17-year-olds, the performance gap that favored males in 1973 had narrowed by 1999. By 1999, none of the apparent sex differences in mathematics performance were statistically significant. In science, average scores tended to favor males through 1999, although the apparent difference in 1999 for 9-year-olds was not statistically significant. The gender gap in science has remained relatively stable for 9- and 13-year olds, but it narrowed for 17-year-olds between 1969 and 1999.

Performance Trends for Racial/Ethnic Subgroups

In every racial/ethnic subgroup, a general trend of improved mathematics performance occurred over the past 3 decades. Scores for white, black, and Hispanic students, regardless of age, were higher in 1999 than in 1973 (Campbell, Hombo, and Mazzeo 2000). (Trends for other racial/ethnic groups are not reported because the samples for these

[1]The NAEP data are based on sample surveys. All trends and changes reported in this section are statistically significant at the .05 level.

Figure 1-2
Differences between male and female student average scale scores in mathematics and science, by age: Selected years, 1969–99



*Significantly different from 1999. Small differences between male and female scores are often not statistically significant. For example, the male/female differences were not statistically significant in 1999 for all three ages in mathematics and for 9-year-olds in science.

NOTES: Student performance on the long-term trend assessment is reported on a 0–500-point scale. Numbers represent the differences between males and females. Test administration years are either labeled or are shown with tick marks.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *NAEP 1999 Trends in Academic Progress: Three Decades of Student Performance,* 2000. See appendix table 1-1.

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groups are too small to analyze separately.) However, during the 1990s, although the performance of white students increased for each age group, the performance for blacks in each age group and for Hispanic 9- and 13-year-old students remained flat. The performance of Hispanic 17-year-olds increased from 1990 to 1999.

In science, scores for 9- and 13-year-olds from each racial/ethnic subgroup in 1999 were higher than in the year NAEP first assessed a particular subgroup (1970 for whites and blacks, 1977 for Hispanics) but held steady from 1990 to 1999. Among 17-year-olds, science performance trends varied. White students in that age group had lower scores in 1999 than in 1969, although the average score did increase between 1990 and 1999. The performance of black 17-year-old students was about the same in 1969, 1990, and 1999. Science scores of Hispanic 17-year-olds were higher in 1999 than in 1969 and increased from 1990 to 1999.

Despite improved performance overall from the 1970s to the late 1990s for all racial/ethnic subgroups studied, significant performance gaps persist among these subgroups (figure 1-3 and appendix table 1-2). In mathematics, the sizable gap between white and black students of all ages in 1973 narrowed until 1986 but remained relatively stable in the 1990s. Even larger performance gaps exist between white and black students in science. These gaps narrowed somewhat from 1970 to 1999 for 9- and 13-year-olds but remained essentially unchanged among 17-year-olds from 1969 to 1999. To place these gaps in perspective, in 1999 in mathematics, black students averaged about 30 points lower than did white students; in science, scores ranged from 39 to 52 points lower than those of white students, depending on the age level. These differences are roughly the same size as the differences between the average 13-year-old and 17-year-old in these subjects (figure 1-1).

Substantial gaps also exist between Hispanic and white students at each grade level for both mathematics and science. Among 9-year-olds, the mathematics gap favoring white students widened between 1982 and 1999. Hispanic-white mathematics performance differences for 13- and 17-year-olds persist but have lessened over the past 3 decades. In science performan ce, even larger gaps exist. For 9-year-olds, the science gap did not narrow overall. The 1977 science gap for 13-year-olds narrowed during the 1980s and early 1990s, but by 1999, it had returned to nearly the 1973 level. The score difference between 17-year-old white and Hispanic youth did increase at several points in time, but by the end of the 1990s, was at the same point as in the late 1970s. The white-Hispanic differences in average scale scores in 1999 ranged from 22 to 26 points in mathematics and from 30 to 39 points in science (figure 1-3).

Racial/ethnic subgroups differ in several characteristics generally agreed to influence academic achievement. For example, black and Hispanic students' parents have less education compared with the parents of white students, and black and Hispanic students are more likely to live in poverty (Peng, Wright, and Hill 1995). Economic hardship and low education levels can limit parents' ability to provide stimulating educational materials and experiences for their children (Hao 1995; and Smith, Brooks-Gunn, and Klebanov 1997). Appendix table 1-3 illustrates the persistent achievement gaps between students whose parents have different levels of education.

Recent Performance in Mathematics and Science

Thus far, this section has presented NAEP results based on the long-term trend assessments, which use the same items each time. The next analysis uses data from the national NAEP program, which updates instruments to

Figure 1-3
Differences between white and black student and white and Hispanic student average scale scores in mathematics and science, by age: Selected years, 1969–99

✱Significantly different from 1999.

NOTES: Student performance on the long-term trend assessment is reported on a 0–500-point scale. Numbers represent the differences between whites and blacks and whites and Hispanics. Test administration years are either labeled or are shown with tick marks.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *NAEP 1999 Trends in Academic Progress: Three Decades of Student Performance*, 2000. See appendix table 1-2.

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measure the performance of students based on more current standards. These assessments are based on frameworks developed through a national consensus process involving educators, policymakers, assessment and curriculum experts, and representatives of the public, then approved by the National Assessment Governing Board (NAGB).

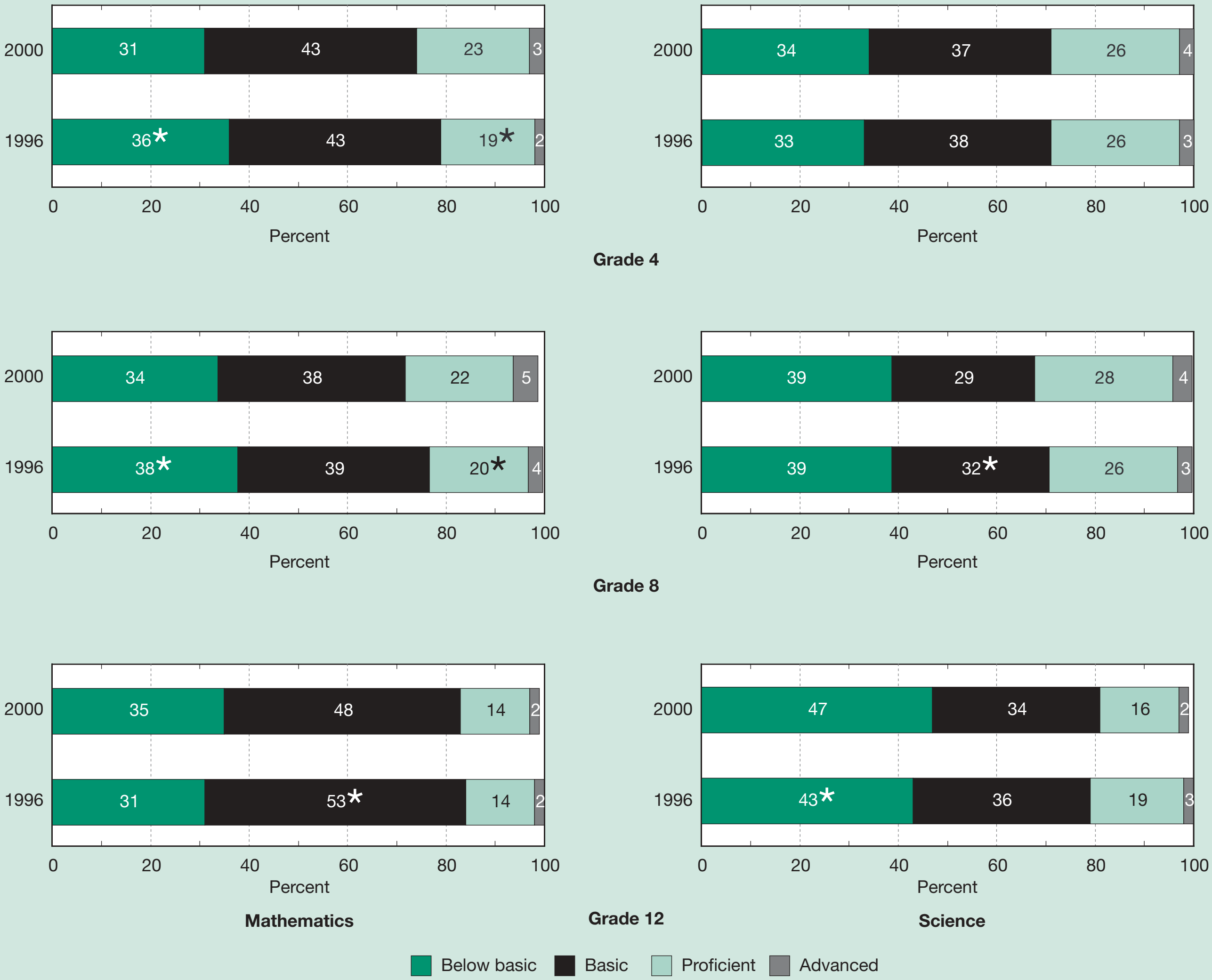
NAEP first developed a mathematics framework in 1990, then refined it in 1996 (NCES 2001c).[2] It contains five broad content strands (number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions). The assessment also tests mathematics abilities (conceptual understanding, procedural knowledge, and problem solving) and mathematical power (reasoning, connections, and communication). Along with multiple-choice questions, assessments include constructed-response questions that require students to provide answers to computation problems or describe solutions in sentence form.

NAEP developed the science framework in 1991 and used it in the 1996 and 2000 assessments (NCES 2003c). It includes a content dimension divided into three major fields of science (earth, life, and physical) and a cognitive dimension covering conceptual understanding, scientific investigation, and practical reasoning. The science assessment also relies on both multiple-choice and constructed-response test questions. A subsample of students in each school also conduct a hands-on task and answer questions related to that task.

Student performance on the national NAEP is classified according to three achievement levels developed by NAGB that are based on judgments about what students should know and be able to do. The basic level represents partial

[2]The revision to the 1990 framework reflects recent curricular changes, but assessments are connected to permit trend measurement through 2003. The 2005 assessment will have a new framework.

Figure 1-4
Students within each mathematics and science achievement level range, grades 4, 8, and 12: 1996 and 2000



*Significantly different from 2000.

NOTE: Percents may not sum to 100 because of rounding.

SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), *The Nation's Report Card: Mathematics 2000,* NCES 2001-517 (Washington, DC: U.S. Department of Education, 2001); and NCES, *The Nation's Report Card: Science 2000,* NCES 2003-453 (Washington, DC: U.S. Department of Education, 2003).

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mastery of the knowledge and skills needed to perform proficient work at each grade level. The proficient level represents solid academic performance at grade level and the advanced level signifies superior performance. Disagreement exists as to whether NAEP has appropriately defined these levels, but they do provide a useful benchmark for examining recent changes in achievement.[3]

The proportion of fourth and eighth grade students reaching at least the proficient level in mathematics increased by a few percentage points from 1996 to 2000, when just over one-fourth of fourth and eighth grade students scored at or above that level (NCES 2001c) (figure 1-4). Among 12th graders, only 17 percent reached that level. Approximately one-third of students at each grade level scored below the basic level in 2000. The proportion of fourth and eighth grade students scoring below the basic level decreased from 1996 to 2000, but the proportion for 12th graders increased.

In general, the 2000 science results mirror the mathematics results (NCES 2003c). Only a minority of students reached the proficient level, and at least one-third of students at each grade level did not reach the basic level. Among 12th

[3]A study commissioned by the National Academy of Sciences judged the process used to set these levels "fundamentally flawed" (Pellegrino, Jones, and Mitchell 1998), and NAGB acknowledges that considerable controversy remains over the setting of achievement levels (Bourque and Byrd 2000). NCES considers the achievement levels developmental and warns that they should be used and interpreted with caution (NCES 2001c). Because the levels are set by panels of experts separately by grade level and subject, meaningful comparisons across grades or subjects are not possible.

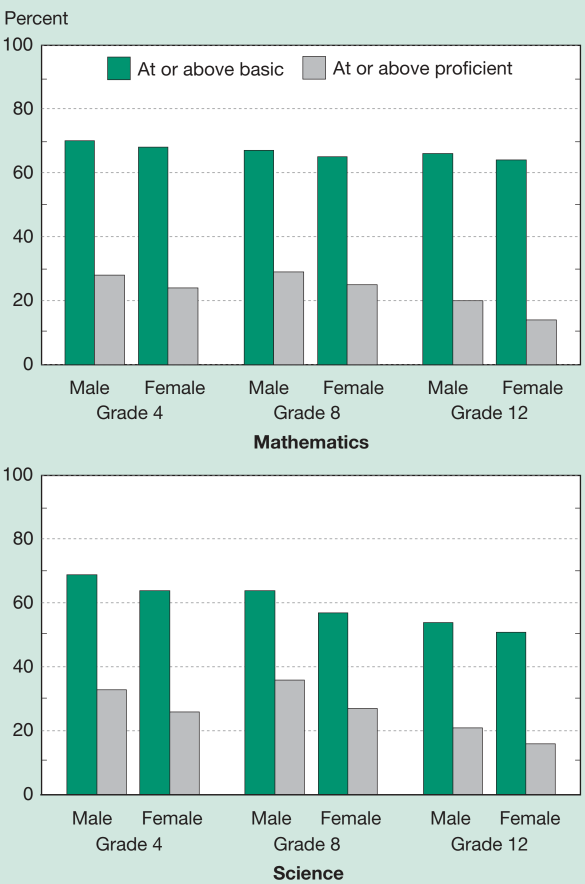
graders, that figure approached half, an increase from 1996. Across both subjects, very few students performed at the advanced level (only 2 to 5 percent).

Mathematics and Science Proficiency for Males and Females

Like the NAEP long-term assessment program, the national NAEP assessment reports results by subgroups, which allows comparisons of achievement levels among different subgroups. In 2000, similar percentages of males and females in each grade reached at least the basic level in mathematics (figure 1-5). However, more males scored at or above the proficient level. The 2000 mathematics results show improvement over 1996 for both sexes in the percentage scoring at or above the basic level in grade 4, but a decline in grade 12 (appendix table 1-4).

The 2000 science results show that a greater percentage of males than females in both grades 4 and 8 attained at least the basic level, and higher percentages of males at each grade level scored at or above the proficient level. The period between 1996 and 2000 saw no significant change in the proportion of females scoring at or above basic, or at or above proficient. Males in grade 12 registered a decline in the percentage at or above the basic level, and males in grade 8 registered an increase in the percentage at or above proficient (appendix table 1-4).

Figure 1-5
Students at or above basic and proficient levels in mathematics and science, grades 4, 8, and 12, by sex: 2000



SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), *The Nation's Report Card: Mathematics 2000*, 2001; and NCES, *The Nation's Report Card: Science 2000*, 2003. See appendix table 1-4.

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Mathematics and Science Proficiency by Racial/Ethnic Subgroups

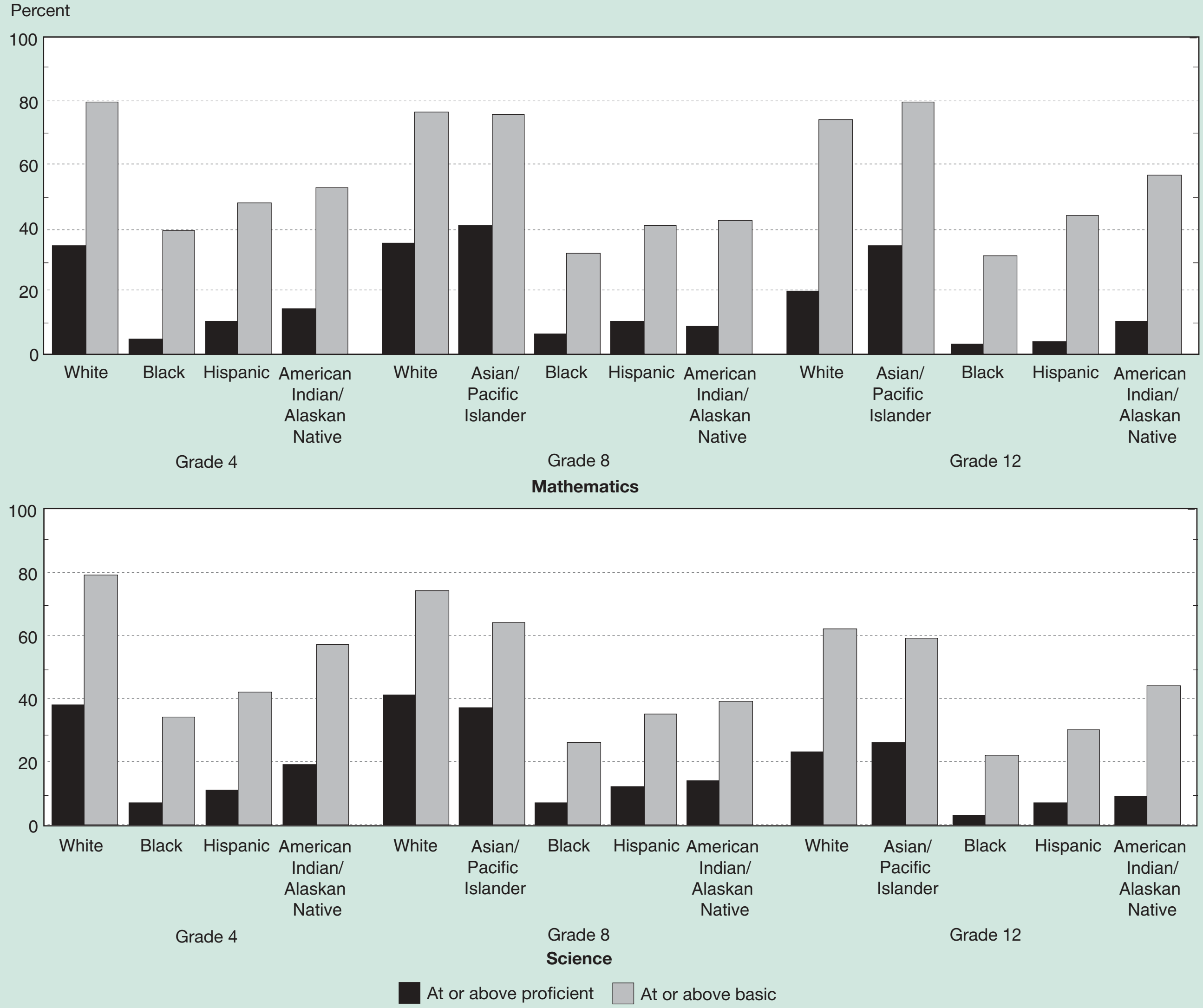
Variations in performance levels across racial/ethnic groups are more apparent than variations between males and females (figure 1-6). At each grade level in mathematics in 2000, higher proportions of white and Asian/Pacific Islander students (when scores for the latter group were reported) scored at or above the basic and proficient levels compared with black, Hispanic, and American Indian/Alaskan Native students. Among 12th grade students, 74 percent of white students and 80 percent of Asian/Pacific Islander students scored at or above the basic level compared with 31 percent of blacks, 44 percent of Hispanics, and 57 percent of American Indians/Alaskan Natives. Overall, black students had the lowest percentage scoring both at or above the basic level and at or above the proficient level. Only one statistically significant change occurred from 1996 to 2000: the proportion of white fourth grade students scoring at or above the proficient level in mathematics increased (appendix table 1-5). These differences in mathematics performance across racial/ethnic groups are evident even when children begin school (Denton and West 2002). Children from low-income and minority family backgrounds start kindergarten at a disadvantage in mathematics knowledge and skills. This disadvantage persists throughout kindergarten and into the first grade. By the first grade, black and Hispanic children are less likely than white children to solve addition, subtraction, multiplication, and division problems, and children from poor families are also less likely than those from nonpoor families to demonstrate proficiency in these areas.

Similar racial/ethnic differences hold true for science. In 2000, higher percentages of white and Asian/Pacific Islander students scored at or above the basic level and at or above the proficient level at each grade level compared with their black, Hispanic, and American Indian/Alaskan Native counterparts. Black students at all grade levels were least likely to reach these performance goals. Only one statistically significant change occurred from 1996 to 2000, a decrease in the proportion of white 12th graders reaching or exceeding the basic level (appendix table 1-5).

Mathematics Achievement in High-Poverty Schools

Poverty is negatively associated with student achievement. Analyses of NAEP 2000 mathematics data show that fourth graders in schools with higher proportions of students eligible for the Free/Reduced-Price Lunch Program, a com-

Figure 1-6
Students at or above basic and proficient levels in mathematics and science, grades 4, 8, and 12, by race/ethnicity: 2000



NOTE: Special analyses raised concerns about the accuracy and precision of the national results for Asian/Pacific Islander fourth graders in 2000; therefore, the National Center for Education Statistics (NCES) did not publish these results.

SOURCES: U.S. Department of Education, NCES, *The Nation's Report Card: Mathematics 2000*, 2001; and NCES, *The Nation's Report Card: Science 2000*, 2003. See appendix table 1-5.

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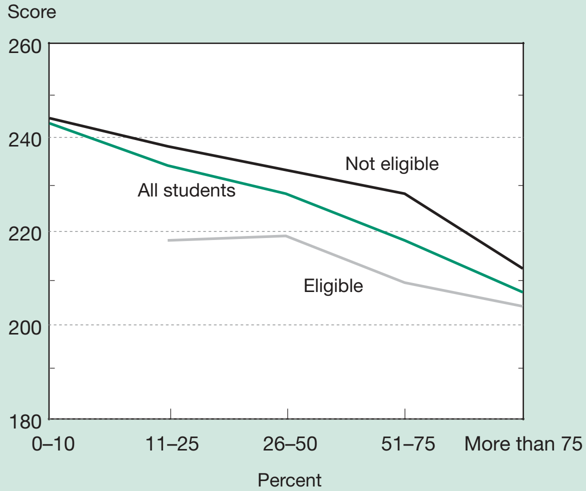
monly used indicator of poverty, tend to have lower scores (NCES 2002a) (figure 1-7).[4] This pattern occurred among eligible and not eligible students. These high-poverty schools also enrolled a greater percentage of black and Hispanic students and had higher rates of absenteeism, a lower proportion of students with a very positive attitude toward academic achievement, and lower levels of parent involvement in school activities (NCES 2002a).

[4]Similar analyses were not conducted using the grade 8 and grade 12 data. Using participation in the Free/Reduced-Price School Lunch Program as a proxy for poverty level is not reliable at higher grades because older students may attach stigma to receiving a school lunch subsidy and choose not to participate.

International Comparisons of Mathematics and Science Performance

Two international assessment programs collected data on student performance in mathematics and science during the past decade. The 1995 Third International Mathematics and Science Study (TIMSS) involved 41 nations and studied the performance of fourth and eighth grade students as well as students in their final year of secondary school (12th grade in the United States). Four years later, a repeat study focused on the performance of eighth graders (TIMSS-R) in 38 countries. In 2000, the Program for International Student Assessment (PISA), organized by the Organisation for Economic

Figure 1-7
Average scale scores in mathematics of fourth grade public school students, by eligibility for free or reduced-priced lunches: 2000



NOTES: Student performance is assessed on a 0–500-point scale. Sample size for the 0–10 percent group of eligible students was too small for a reliable estimate.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2002*, NCES 2002-025, Indicator 11 (Washington, DC: U.S. Department of Education, 2002).

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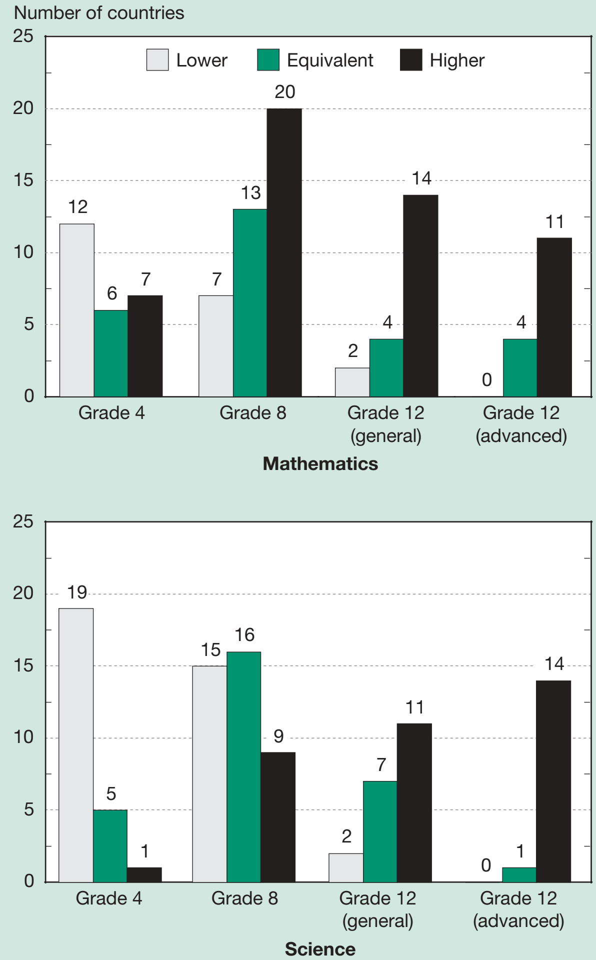
Figure 1-8
Countries whose TIMSS average scores in mathematics and sciences are lower, equivalent to, or higher than U.S. average score, grades 4, 8, and 12: 1995



TIMSS Third International Mathematics and Science Study

NOTE: In the United States, the advanced mathematics assessment was administered to students who had taken or were taking precalculus, calculus, or Advanced Placement (AP) calculus; the advanced science assessment was administered to students who had taken or were taking physics or AP physics.

SOURCE: U.S. Department of Education, National Center for Education Statistics, TIMSS, 1995.

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Co-operation and Development (OECD), assessed 15-year-olds from 32 countries in reading, mathematics, and science.

The design and purpose of the two assessment programs differ somewhat (Nohara 2001). TIMSS and TIMSS-R measured students' mastery of curriculum-based scientific and mathematical knowledge and skills. PISA assessed students' scientific and mathematical "literacy," with the aim of understanding how well students can apply scientific and mathematical concepts and thinking skills to real-life challenges and nonschool situations. The TIMSS and TIMSS-R findings have been reported extensively, including in the two most recent editions of *Science and Engineering Indicators* (National Science Board 2000 and 2002). Therefore, this section only briefly reviews the main findings from TIMSS and TIMSS-R, and devotes more coverage to the PISA findings.

Achievement of Fourth and Eighth Grade U.S. Students on TIMSS and TIMSS-R

In 1995, U.S. students performed slightly better than the international average in mathematics and science in grade 4, but by grade 8, their relative international standing had declined, and it continued to erode through grade 12 (figure 1-8). Of the 25 other countries participating in the fourth grade component of the assessment, 12 had lower average mathematics scores than the United States, 6 had equivalent average scores, and 7 had higher average scores. In science, 19 countries had lower scores, 5 had equivalent scores, and 1 had a higher score. Not all nations participated in every aspect of the TIMSS assessment.

U.S. eighth graders scored below the international average in mathematics but above the international average in science (NCES 1997b). However, nine countries outperformed the United States compared with only one in the fourth grade science assessment.

The fourth and eighth grade results from the 1995 TIMSS study suggest that U.S. students perform less well on international comparisons as they advance through school. TIMSS-R, by enabling comparisons between the relative international standing of U.S. fourth grade students in 1995 and U.S. eighth grade students 4 years later, tended to confirm this interpretation (NCES 2000b).

Achievement of 12th Grade U.S. Students on TIMSS

TIMSS assessed the mathematics and science performance of students in their final year of secondary school (12th grade in the United States).[5] It included a test of general knowledge of mathematics and science for all students and a more specialized assessment for students enrolled in advanced courses. U.S. 12th graders performed below the 21-country international average on the TIMSS test of general knowledge in mathematics and science (NCES 1998).

U.S. students taking advanced mathematics and science courses also did not fare well in comparison with their international counterparts. The advanced mathematics assessment was administered to students in 15 other countries who were taking or who had taken advanced mathematics courses and to U.S. students who were taking or who had taken precalculus, calculus, or Advanced Placement (AP) calculus. Among students who participated in the advanced assessment, U.S. students registered lower average scores compared with their international counterparts, even though the United States tends to have fewer young people taking advanced mathematics and science courses relative to other countries. A total of 11 nations outperformed the United States, and 4 nations scored similarly. No nation scored significantly below the United States.

TIMSS administered the advanced science assessment, a physics assessment, to students in 15 other countries who were taking science courses and to U.S. students who were taking or had taken physics I and II, advanced physics, or AP physics. U.S. students performed below the international average, with 14 countries having average scores higher than the United States, and 1, Australia, having an average score equivalent to that of the United States.

Mathematics and Science Literacy of U.S. 15-Year-Olds on PISA

OECD first conducted PISA in 2000 and plans two additional assessments at 3-year intervals (NCES 2001d). Although PISA 2000 concentrated on reading, it did include some mathematics and science items.

PISA aims to measure how well equipped students are for the future by emphasizing items that have a real-world context. (See sidebar “Sample Mathematics and Science Items From PISA.”)

In both mathematics and science literacy, U.S. student performance did not differ from the average performance of students in the other OECD countries (appendix tables 1-6 and 1-7). Of the seven countries that had significantly higher average science scores, all also had higher average mathematics scores (Australia, Canada, Finland, Japan, New Zealand, South Korea, and the United Kingdom). In addition, Switzerland significantly outperformed the United States in mathematics. A common set of six countries had average scores significantly lower than the United States in both mathematics and science: Brazil, Greece, Latvia, Luxemburg, Mexico, and Portugal.

Subgroup Differences in Mathematics and Science Literacy

A recent report released by the U.S. Department of Education (NCES 2001d) considers PISA score differences by sex, parents’ education, parents’ occupation, parents’ national origin, and language spoken in the home. Findings reveal no statistically significant sex difference among U.S. 15-year-olds in mathematics. This was also true for 16 other countries that participated in PISA; however, males outperformed females in mathematics in 14 countries. In science literacy, male and female students in the United States, as in most other nations, performed equally well. This absence of sex differences in mathematics and science literacy in the United States is generally consistent with findings from the NAEP, TIMSS, and TIMSS-R assessments, all of which assess more curriculum- and school-based achievement.

PISA also collected information on parents’ education levels and occupation, both of which have been linked to student achievement (Coleman et al. 1966; NCES 2000b and 2001c; West, Denton, and Reaney 2000; and Williams et al. 2000). PISA data indicate that parents’ education level and occupation are more strongly associated with mathematics and science literacy in the United States than in some other countries, although links between parents’ education level and student achievement existed in all PISA countries (NCES 2001d). For example, in every country, students whose parents have college degrees outperformed students whose parents did not have a high school diploma. However, in only 12 of 29 countries, including the United States, students whose parents graduated from college scored higher in science literacy than students whose parents completed high school but not college. In the remaining countries, science performance did not differ between the subgroups of students with these two levels of parental education. A stronger association between parents’ occupation and student mathematics and science literacy existed in the United States compared with some other PISA countries. In Finland, Iceland, Japan, Latvia, and South Korea, the relationship between parents’ occupation and mathematics and science literacy was smaller than it is the United States; for mathematics, the relationship was also smaller in Canada and Italy. No country had a stronger relationship than the United States between parents’ occupation and student performance on PISA’s mathematics and science portions.

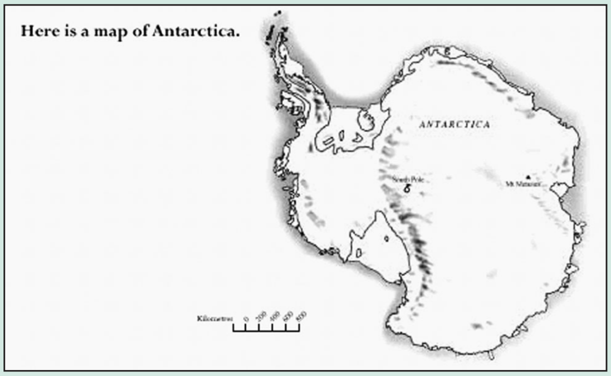
Students who are foreign born or who have foreign-born parents face challenges in adjusting to a new country and a

[5]NAEP has identified problems related to testing 12th grade students (NCES 2001c). Compared with students in fourth and eighth grades, they are less likely to participate, more likely to omit responses, and much less likely to indicate that they thought it either important or very important to do well on the test. If students do not try their best, NAEP may underestimate their achievement. Whether similar patterns exist in other countries is not known.

Sample Mathematics and Science Items From PISA

The examples below were included in the 2000 Program for International Student Assessment (PISA) mathematics and science assessment and include the item's level of difficulty and the proportion of both U.S. students and all students who received either full or partial credit.

Mathematics (level 3)



Directions: Estimate the area of Antarctica using the map scale.

Show your work and explain how you made your estimate. (You can draw over the map if it helps you with your estimation).

Difficulty level: middle-to-highest

Scoring: Students who provided the correct answer, between 12,000,000 and 18,000,000 square kilometers, received full credit. Students received partial credit if they showed evidence of using a correct method, such as drawing a square or circle to estimate the area, but provided an incorrect answer.

Proportion received full credit:

All OECD students: 20

U.S. students: 10

Proportion received partial credit:

All OECD students: 40

U.S. students: 38

Science (level 3)

Directions: Read the following section of an article about the ozone layer.

The atmosphere is an ocean of air and a precious natural resource for sustaining life on the Earth. Unfortunately, human activities based on national/personal interests are causing harm to this common resource, notably by depleting the fragile ozone layer, which acts as a protective shield for life on the Earth. Ozone molecules consist of three oxygen atoms, as opposed to oxygen molecules, which consist of two oxygen atoms. Ozone molecules are exceedingly rare: fewer than 10 in every million molecules of air. However, for nearly a billion years, their presence in the atmosphere has played a vital role in safeguarding life on Earth. Depending on where it is located, ozone can either protect or harm life on Earth. The ozone in the troposphere (up to 10 kilometers above the Earth's surface) is "bad" ozone, which can damage lung tissues and plants. But about 90 percent of ozone found in the stratosphere (between 10 and 40 kilometers above the Earth's surface) is "good" ozone, which plays a beneficial role by absorbing dangerous ultraviolet (UV-B) radiation from the Sun.

Without this beneficial ozone layer, humans would be more susceptible to certain diseases due to the increased incidence of ultraviolet rays from the Sun. In the last decades the amount of ozone has decreased. In 1974 it was hypothesized that chlorofluorocarbons (CFCs) could be a cause for this. Until 1987, scientific assessment of the cause-effect relationship was not convincing enough to implicate CFCs. However, in September 1987, diplomats from around the world met in Montreal (Canada) and agreed to set sharp limits to the use of CFCs.

Directions: At the end of the text, an international meeting in Montreal is mentioned. At that meeting lots of questions in relation to the possible depletion of the ozone layer were discussed. Two of those questions are given in the table below.

Can the questions listed below be answered by scientific research?

Circle Yes or No for Each

Question:	Answerable by scientific research?
Should the scientific uncertainties about the influence of CFCs on the ozone layer be a reason for governments to take no action?	Yes/No
What would the concentration of CFCs be in the atmosphere in the year 2002 if the release of CFCs into the atmosphere takes place at the same rate as it does now?	Yes/No

Difficulty level: lowest-to-middle

Scoring: Students who answered no to the first question and yes to the second question received full credit. All other answers received no credit, including those that answered only one question correctly.

Proportion received full credit:

All OECD students: 59

U.S. students: 64

SOURCES: NCES 2001d and OECD 2001.

new school system. According to PISA data, approximately 13 percent of U.S. students have parents who were both born outside the United States. In about half of the participating countries that reported this data (15 of 26), including the United States, students whose parents were both native-born scored significantly higher in mathematics. In the United States, no difference in science literacy by parent nativity existed, although differences did exist in 17 of 26 participating countries.

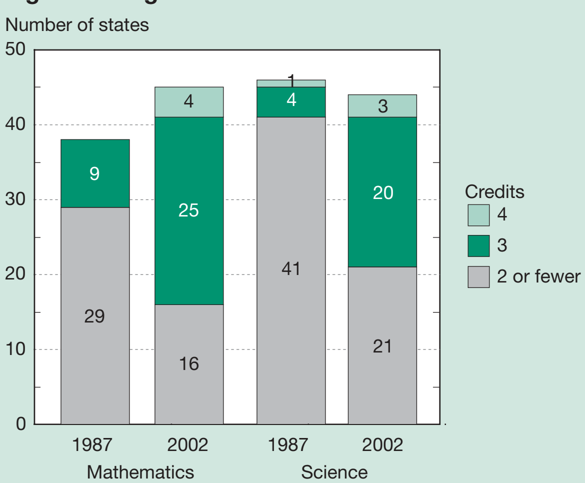
U.S. schools educate many students who speak a language other than English at home. In 19 of the 28 nations that reported data on students' home language, including the United States, students who spoke the language of the assessment at home scored better in mathematics literacy than students who did not. U.S. students registered a greater difference in mathematics performance by home language than the average OECD difference. In science, in 21 of 28 participating nations, including the United States, students who spoke the language of the assessment at home scored better than those who did not. Many PISA items impose a fairly high reading (and sometimes writing) load, which contributes to home language effects.

Mathematics and Science Coursework and Student Achievement

A Nation At Risk attributed the disappointing performance of U.S. students, in part, to "extensive student choice" in high school coursetaking (National Commission on Excellence in Education 1983). The report called for strengthened curricular requirements and graduation standards. In subsequent years, many states and school systems increased their graduation requirements (Blank and Engler 1992 and Clune and White 1992), including requirements for mathematics and science (figure 1-9). In addition to specifying the number of courses students must complete to graduate, some states also introduced requirements for particular courses, most commonly algebra, biology, and physical sciences (CCSSO 2002).

Increases in student coursetaking in mathematics and science followed. (See sidebar "Requirements and Coursetaking.") High school graduates now earn more mathematics and science credits overall and take more advanced courses.[6] When students complete challenging courses, their overall achievement improves. (See sidebar "Coursetaking and Achievement.")

Figure 1-9
Mathematics and science credit requirements for high school graduation: 1987 and 2002



NOTE: Totals do not sum to the number of states because some have no requirement or leave decisions to local districts.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *Digest of Education Statistics 1987,* ED 282 359 (Washington, DC: U.S. Department of Education, 1988); and Council of Chief State School Officers, *Key State Education Policies on PK–12 Education: 2002* (Washington, DC, 2002).

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This section looks at overall coursetaking patterns with a specific look at early enrollment in algebra. It then examines patterns in advanced course offerings and in students' advanced coursetaking behavior.

Coursetaking

In 1982, high school graduates earned an average of 2.6 mathematics credits and 2.2 science credits (1 credit equals 1 year of a daily 1-hour course). By 1998, those numbers grew to 3.5 and 3.2 credits, respectively (NCES 2001a). This expansion of academic coursetaking included all racial/ethnic groups and both male and female students.

Requirements and Coursetaking

Increasing requirements appears to affect coursetaking behavior, especially among lower achieving students. Clune and White (1992) examined the coursetaking patterns of graduates from high schools that enrolled mostly lower achieving students and were located in four states that had adopted higher-than-average graduation standards during the 1980s. These students exhibited better academic coursetaking patterns than their peers around the nation. In schools with more demanding requirements, the average number of credits earned in academic subjects increased, as did the average difficulty level of the classes. Research by Chaney, Burgdorf, and Atash (1997) using NAEP data suggests that more demanding requirements have a greater impact on coursetaking by lower achieving students than on coursetaking by higher achieving ones. Students with low grade-point averages were more likely to take geometry, algebra, physics, and chemistry if they attended a school that required 3 credits in science, whereas coursetaking among high achievers was not related to schools' graduation requirements.

The National Education Commission on Time and Learning (1994) found that minority and at-risk students did fail more courses after the introduction of stronger graduation requirements. Other studies found that increasing requirements led to students taking more academic courses, but increases in coursetaking in advanced courses were not as great as those in introductory or basic courses (Blank and Engler 1992; Chaney, Burgdorf, and Atash 1997; Clune and White 1992; and Finn, Gerber, and Wang 2002).

[6]In drawing conclusions from transcript data, one must keep in mind the fact that courses with the same titles may vary considerably from school to school in terms of content and demand on the student.

Coursetaking and Achievement

The association between coursetaking and achievement has been well documented (Campbell, Hombo, and Mazzeo 2000; Chaney, Burgdorf, and Atash 1997; Cool and Keith 1991; Hoffer, Rasinski, and Moore 1995; NCES 2001c and 2003b; Rock and Pollack 1995; and Schmidt et al. 2001). A 1995 study that analyzed data from the National Education Longitudinal Study (NELS) and that controlled for student background characteristics reported a positive relationship between the total number of mathematics and science courses completed and gains in achievement test scores from grade 8 to grade 12 (Hoffer, Rasinski, and Moore 1995). Other studies that also use the NELS data report similar findings; for example, see Lee, Croninger, and Smith 1997.

Completion of advanced coursework may be more important than completion of a greater number of courses. Students who complete higher level mathematics and science courses have, on average, higher achievement scores in these subjects. Studies that controlled for prior achievement indicate that the association does not simply result from stronger students selecting (or being selected for) the more demanding courses. Meyer (1998) found that taking advanced mathematics courses led to achievement gains for all students on assessments conducted as part of the High School and Beyond Study of 1980 high school sophomores, including college-bound and non-college-bound students and students with varying levels of mathematics skills. On the other hand, lower level courses contributed little to students' mathematics performance.

The benefits of completing advanced mathematics and science courses extend beyond improved test scores to include success in both postsecondary education and the labor force. Analyzing the High School and Beyond data, which were derived from tracking a national sample of 1980 10th graders for 13 years, Adelman (1999) found the rigor of students' high school curricula to be the best predictor of earning a bachelor's degree, and the best indicator of curriculum rigor was the most advanced mathematics course taken. Finishing a course beyond algebra II in high school more than doubled the odds that a student who entered postsecondary education would complete a bachelor's degree. Among students who successfully completed rigorous mathematics courses, race/ethnicity and socioeconomic status had little or no impact on their likelihood of completing college.

A recent study examined the relationship between advanced mathematics coursework and earnings 10 years after high school graduation (Rose and Betts 2001). The findings revealed a positive association only partly explained by the ultimate level of education attained. The authors credited cognitive gains from studying higher level mathematics with making students more productive, speculating that students "learn how to learn" from advanced mathematics coursework.

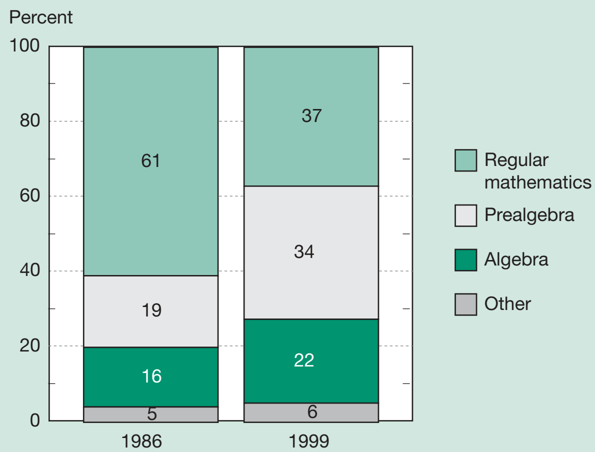
The proportion of high school graduates completing advanced mathematics and science coursework also increased over this period. From 1982 to 1998, the percentage of students completing at least one advanced mathematics course (defined as more challenging than algebra II or geometry) grew from 26 to 41 percent. In science, the proportion completing at least one advanced course (defined as more challenging than general biology) increased from 35 to 62 percent.

Algebra is considered a *gatekeeper* course for the more advanced mathematics and science courses (Oakes et al. 1990; and Schneider, Swanson, and Riegle-Crumb 1998). Compared with their peers who do not take algebra in grade 8, students who begin studying algebra during that year are more likely to complete algebra III, trigonometry, and calculus (Atanda 1999).

NAEP data indicate that the proportion of students who take algebra early increased between 1986 and 1999 (figure 1-10). In 1986, 16 percent of 13-year-olds enrolled in algebra and an additional 19 percent enrolled in prealgebra; by 1999, these figures had risen to 22 and 34 percent, respectively.

Nevertheless, a study using TIMSS data showed that about 20 percent of 1995 U.S. eighth graders attended schools that offered none of the more challenging eighth grade mathematics courses: enriched mathematics, prealgebra, algebra, or geometry (Cogan, Schmidt, and Wiley 2001). One in three eighth graders in the United States attended schools that did not offer them an algebra class. Lack of access to rigorous coursework likely has negative effects on achievement. Two measures of the difficulty of a mathematics class (time spent on various topics and combining the challenges posed by course content and textbook content) were both positively related to students' average

Figure 1-10
Distribution of 13-year-olds, by type of mathematics course: 1986 and 1999



NOTES: Numbers for 1986 are significantly different from 1999. Percents may not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, Long-Term Assessment, 1999.

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TIMSS assessment score in this study (Cogan, Schmidt, and Wiley 2001).

In the nation as a whole, enrollment size and concentration of minority students were both related to students' access to challenging mathematics content: more eighth graders had access to three of the more difficult mathematics courses (enriched mathematics, prealgebra, and algebra) as the size of eighth grade enrollment increased and as the percentage of minorities in the school decreased.

Advanced Mathematics and Science Courses Offered in High Schools

Student coursetaking is constrained by the courses schools offer. Advanced courses are not equally available in all schools. Oakes et al. (1990) reported that as the proportion of low-income and minority students increased, the relative proportion of college preparatory and advanced courses decreased. For example, schools serving students from primarily high-income families offered approximately four times the number of sections of calculus per student as schools serving large proportions of students from low-income families.

The 1990, 1994, and 1998 NAEP assessments collected information on the courses high schools offered (appendix tables 1-8 and 1-9). Much larger percentages of graduates attended schools that offered advanced courses compared with the proportion of graduates who actually completed these courses. For example, although 86 percent of 1998 graduates attended schools that offered calculus, only 12 percent of graduates completed it (appendix tables 1-8 and 1-10). Compared with 1990, greater percentages of graduates in 1998 attended schools that offered precalculus/analysis, statistics/probability, and calculus.[7] Schools did not widely offer International Baccalaureate (IB) precalculus or AP statistics courses, but the majority (64 percent) of students could take AP/IB calculus courses. (The AP and IB programs provide students in participating high schools with advanced coursework across a variety of subjects, allowing them to potentially earn college credit while in high school. Starting in 1998, AP and IB coursetaking were reported separately by the National Center for Education Statistics.)

Precalculus/analysis and AP/IB calculus courses were more commonly available to students in urban and suburban than in rural schools. Course offerings in precalculus/analysis, calculus, and AP/IB calculus tended to increase as student enrollment increased. Significant differences in course offerings by school poverty level occurred only for precalculus and statistics/probability.

Advanced science courses were more widely available than advanced mathematics courses (appendix tables 1-8 and 1-9). In 1990, 1994, and 1998, more than 90 percent of high school graduates attended schools that offered advanced biology, chemistry, and physics, or all three. High schools attended by 27 percent of 1998 graduates offered AP/IB physics, schools attended by 39 percent offered AP/IB chemistry, and schools attended by 46 percent offered AP advanced biology.

Despite an overall prevalence of advanced science offerings, availability varied by school characteristics. Students attending urban and suburban schools were more likely to be offered advanced science courses, particularly AP/IB courses compared with students in rural schools. However, there was no statistically significant difference in chemistry offerings by location or in physics offerings for students in rural schools compared with suburban ones. School size was related to offerings for all seven advanced science categories, with the likelihood of attending a school offering advanced courses rising with school size. A particularly pronounced association occurred in the AP/IB categories. In AP/IB chemistry and AP/IB physics, a link existed with school poverty, with students in low-poverty schools more likely to be offered these courses.

Advanced Mathematics and Science Coursetaking in High School

In the 1990s, as more high schools offered more courses, students increased their advanced coursetaking in mathematics. (Mathematics courses considered "advanced" include trigonometry/algebra III, precalculus/analysis, statistics/probability, and calculus.) In conjunction with the 12th grade NAEP assessments, the National Center for Education Statistics collected information on courses completed by 1990, 1994, and 1998 high school graduates. In 1998 (compared with 1990), larger proportions of students completed precalculus/analysis (23 versus 14 percent), statistics/probability (4 versus 1 percent), and calculus (12 versus 7 percent) (appendix table 1-10).

Only a few students completed AP/IB courses. For example, in 1998, only 6 percent of high school graduates completed an AP/IB calculus course. Male and female graduates were equally likely to have taken advanced mathematics courses in high school, including AP/IB courses. However, considerable racial/ethnic differences existed in advanced mathematics course participation. In general, Asians/Pacific Islanders were most likely to take advanced courses, followed by whites, then blacks and Hispanics; the latter two groups exhibited similar advanced coursetaking patterns (appendix table 1-10).

Advanced course participation also varied by type of school attended. High school graduates from urban and suburban schools were more likely to complete precalculus and AP/IB calculus than students from rural schools, but no significant differences existed by school location for the remaining categories of advanced mathematics courses. Course participation in AP/IB calculus was higher in medium and large schools than small ones, but participation in

[7]Statistical weights are not available to generate national school estimates from the sample of high schools. Instead, student weights can be used to estimate what students were offered at their schools. This means, for example, that rather than report that urban schools offered more advanced mathematics courses, it would be reported that students attending urban schools were offered more advanced courses.

other course categories did not differ significantly by school size. The completion of advanced mathematics courses decreased as school poverty increased for precalculus, statistics/probability, calculus, and AP/IB calculus but not for trigonometry/algebra III.

For science, increased advanced coursetaking also occurred from the beginning of the 1990s to the end of the decade (appendix table 1-11). (Science courses considered "advanced" include advanced or AP/IB biology, any chemistry, and any physics.) Compared with 1990, larger proportions of 1998 high school graduates completed courses in advanced biology, chemistry, and physics. Relatively low participation in AP/IB science courses occurred in 1998, with 5 percent of graduates completing an AP/IB course in biology; 3 percent, one in chemistry; and 2 percent, one in physics.

In contrast to mathematics, sex differences existed in advanced science coursetaking. In 1998, female high school graduates were more likely than males to take advanced biology, AP/IB biology, and chemistry, although males were more likely to have completed a physics course (including an AP/IB course). For racial/ethnic groups, a pattern of participation existed similar to that for mathematics. Smaller proportions of blacks and Hispanics tended to complete advanced science courses compared with whites and Asians/Pacific Islanders.

Consistent with mathematics findings, high school graduates from urban and suburban schools were generally more likely than their counterparts from rural schools to have completed advanced science courses. A significant relationship with school size existed for AP/IB biology and AP/IB chemistry, with participation rising with enrollment. As school poverty increased, fewer students completed courses in chemistry and physics.

Curriculum Standards and Statewide Assessments

One response to evidence of disappointing achievement by U.S. students has been the movement—accelerating since the early 1990s—to define and implement higher standards for student learning. The National Council of Teachers of Mathematics (NCTM) issued and revised mathematics standards in 1989 and 2000 (NCTM 1989 and 2000), the American Association for the Advancement of Science (AAAS) published *Benchmarks for Science Literacy* (AAAS 1993), and the National Research Council (NRC) issued the National Science Education Standards (NSES) (NRC 1996). These standards documents recommend that schools cover fewer topics in greater depth, use inquiry-based methods, and focus on understanding of concepts in addition to basic skills. During the 1990s states used such guiding documents to develop their own standards and curriculum frameworks, to create new assessment instruments, and to reform teacher education.

This section reports on state curriculum standards and testing and accountability policies.

State Curriculum Standards and Policy on Instructional Materials

The NCLB Act requires states to immediately set standards in mathematics and reading/language arts, and to set standards in science by academic year 2005. In 2002, 49 states and the District of Columbia had content standards for mathematics (as well as for English/language arts), and 47 states had standards for science (CCSSO 2002). Many states have recently revised or are in the process of revising their standards, curriculum frameworks, and instructional materials. By 2002, exactly half the states had set a regular timeline for reviewing and modifying their standards (Editorial Projects in Education 2003).

Standards documents vary greatly in detail, degree of focus, specificity, clarity, and level of rigor. Evaluations of standards have used different criteria and methods (Achieve, Inc. 2002b; AFT n.d.; and Finn and Petrilli 2000). States also prescribe instructional materials to varying degrees. In spring 2002, 21 states had no policy prescribing textbooks and another 4 had a policy of local choice. Of states that restricted textbook choice, eight produced a list of approved books and materials for local choice, five selected textbooks, and nine combined selection and recommendation (CCSSO 2002).

Accountability Systems and Assessments

Assessment Programs in Mathematics and Science

Building on the testing requirements included in the 1994 reauthorization of the Elementary and Secondary Education Act, the NCLB Act requires all schools to conduct mathematics and reading assessments during academic year 2002 in at least one grade of three different grade spans (grades 3–5, 6–9, and 10–12). By academic year 2005, states must test students in grades 3–8 in these subjects every year and must test all students once during the grades 10–12 span. States must also conduct science assessments in one grade of the same grade spans by academic year 2007. The act prescribes rigorous assessments aligned with state standards but does give states wide latitude in setting school performance standards. The NCLB Act also requires states to participate in the NAEP assessments for the subjects in which the state tests in order to provide policymakers and the public with common benchmarks for judging the rigor of their own state's standards, assessments, and performance requirements.

By 2002, many states had already developed and administered tests based on their curriculum standards and frameworks. For example, in academic year 2002, 19 states and the District of Columbia required students to take mathematics and reading tests in the grades identified by the NCLB Act (Doherty and Skinner 2003).

The NCLB Act requires states to publish achievement data and other indicators of performance (such as attendance and completion rates) at the school level, and disaggregated by key demographic characteristics such as income, race/

ethnicity, and English proficiency status. A total of 29 states and the District of Columbia rated all schools or identified all low-performing schools in academic year 2002, but only 12 states relied solely on student test scores for these evaluations (Editorial Projects in Education 2003). The other 17 states and the District of Columbia used test scores along with other information such as attendance rates, graduation rates, and coursetaking data.

Consequences and Sanctions

Recently implemented state accountability systems differ from previous waves of reform in that they specify consequences for poor school and student performance. For students, consequences may include using test scores to determine grade promotion or retention and award high school diplomas. For districts and schools, states have developed a range of rewards, supports, and sanctions based on student test scores. In academic year 2002, 27 states and the District of Columbia provided assistance to low-performing schools (for example, funds for tutoring and additional teacher professional development) and 17 states financially rewarded schools that meet, or make sufficient progress toward, high achievement goals (Editorial Projects in Education 2003). State officials may impose sanctions on low-performing schools in 22 states and the District of Columbia. These include reconstitution (18 states and the District of Columbia), allowing students to transfer to other schools (11 states and the District of Columbia), and school closure (11 states). However, only three states permit withholding funds from schools. States do not necessarily exercise their authority to apply sanctions against schools and staff; they generally try to raise achievement in a low-performing school by first providing additional support such as targeted professional development, new instructional materials, and tutoring. Of the 30 states that identified low-performing schools in 2002, 27 provided some form of assistance to these schools (Achieve, Inc. 2002a).

Implementation Issues in Assessment

The role of standardized testing in accountability systems is controversial. Proponents of testing say it can improve achievement in at least two ways. First, it can provide information about how well educational systems are functioning and insight into where changes may be warranted. Second, accountability for test results can create incentives for students, teachers, instructional material developers, and school administrators to alter their behaviors in ways that facilitate achievement. Critics worry that, in implementing testing regimes, school systems will rely on tests that are insufficiently aligned with their standards and curricula. Such tests would measure school and student performance poorly, and strong incentives to perform well on these tests would undermine curricular priorities.

One indicator of alignment is whether tests were *customized*, or specifically designed for a state's standards and curricula. Customization provides opportunities for alignment, although it does not guarantee it. In the 2002 academic year, 31 states used only customized tests, 12 used a mix of customized tests and tests purchased from commercial publishers that develop tests for a national market, and 7 used tests that were not customized (GAO 2003). Customization will increase over time because the NCLB Act requires states to either develop tests aligned to their standards or augment commercial tests with aligned questions.

Critics also doubt that assessments, especially multiple choice examinations, will effectively measure higher-order thinking and conceptual understanding, which are key emphases in national mathematics and science standards. In the 2002 academic year, 12 states used tests composed solely of multiple-choice questions, while 36 states used tests that combined multiple-choice items with a limited number of written-response questions (GAO 2003).

Definitive data on the effects of enhanced accountability measures do not exist, but the limited studies available suggest that under some circumstances, these measures may improve student achievement (Carnoy and Loeb 2002; Raymond and Hanushek 2003; Roderick, Jacob, and Bryk 2002).

Curriculum and Instruction

Curriculum and instructional methods influence what students learn and whether they can apply knowledge and skills to new problems or applications (Schmidt et al. 2001). This section summarizes data regarding methods of teaching mathematics and science in the United States. It presents findings about textbooks, curricular content, and aspects of teachers' instructional practices and provides international comparisons when available.

Approaches to Teaching Mathematics and Science

Proponents of different curricular emphases and teaching methods, particularly in mathematics, have argued in recent years over the effectiveness of various approaches. Some emphasize computational skills and number operations, and others stress mathematical understanding and reasoning skills (Reys 2001). NRC and others have concluded that students need to develop these and other skills so that they reinforce and complement one another (Kilpatrick and Swafford 2002 and NCTM 2000). Mathematics proficiency, according to NRC, consists of five essential components, or *strands*, that should be integrated to support effective learning. These strands are:

- **Understanding.** Comprehending mathematics concepts, operations, and relations, including mathematical symbols and diagrams.
- **Computing.** Carrying out mathematical procedures (such as adding, subtracting, multiplying, and dividing numbers) flexibly, accurately, efficiently, and appropriately.

- ♦ **Applying.** Being able to formulate problems mathematically and devise strategies for solving them using concepts and procedures appropriately.
- ♦ **Reasoning.** Using logic to explain and justify a solution to a problem or extend from something known to something not yet known.
- ♦ **Engaging.** Seeing mathematics as sensible, useful, and doable when one works at it, and being willing to do the work.

Few national data exist linking curricular reforms to changes in student achievement, although some state and local studies suggest standards-based curricula that integrate a range of skills with knowledge may lead to overall higher achievement and help reduce gaps between minority and white students (Briars 2001, Mullis et al. 2001, Riordan and Noyce 2001, Schneider et al. 2002, and Schoenfeld 2002). Some research also supports the potential effectiveness of inquiry-based instruction in science, in which students learn primarily by conducting experiments to test ideas and answer questions (Amaral, Garrison, and Klentschy 2002; Stoddart et al. 2002; and Stohr-Hunt 1996).

Textbooks

Textbook content can affect teaching and learning. Systematic expert ratings of how well textbooks address nationally recognized content and curriculum standards for mathematics and science have taken place, although the available research does not include rigorous studies that relate textbook content to student achievement.

Starting in 1999, AAAS Project 2061 assigned teams of mathematics and science professors and K–12 teachers to evaluate textbooks, teachers' guides, and related instructional materials in categories based on subject and grade level. Using selected criteria from *Benchmarks for Science Literacy* (AAAS 1993), reviewers in one Project 2061 evaluation (AAAS 1999b) measured how well middle school mathematics textbooks addressed 6 central mathematics concepts/skills and how well the textbooks incorporated 24 instructional criteria consistent with NCTM standards (NCTM 1989 and 2000). Project 2061 rated 4 of the 12 textbooks it evaluated as excellent but judged the remaining 8 to be inadequate overall and merely satisfactory in teaching number and geometry skills. At the time, those eight were among the most widely used middle school mathematics texts in the United States.

Project 2061 also conducted evaluations of algebra textbooks (AAAS 2000a), middle school science materials (AAAS 1999a), and high school biology textbooks (AAAS 2000b). Overall, reviewers judged most to have deficits in teaching students many thinking skills identified by standards documents; they also lacked some content identified in subject standards. Commonly found weaknesses included emphasizing detail and terminology at the expense of core concepts (a problem more prevalent in science materials), insufficiently developing students' reasoning abilities, and providing inadequate guidance for students and teachers to discover and correct misconceptions. Reviewers also identified several common positive attributes: most materials covered content thoroughly and accurately, provided a range of applications and hands-on activities, and used inviting graphics to illustrate ideas. Project 2061 noted that some newer texts showed improvement over older ones.

The American Institute of Biological Sciences (AIBS) assessed how well 10 high school biology textbooks and related materials (Morse 2001) adhered to standards embodied in NSES. Overall ratings ranged from just below adequate to slightly below excellent. In general, AIBS concluded that the materials conveyed life science content very well but were not as effective in providing guidance for teachers and in handling certain non-life-science content. Most instructional materials received high marks for accuracy, attractive illustrations and design, and inclusion of recent developments in biology research. However, AIBS found that most were crammed with too much information and detail, placing a great burden on teachers to select priorities and make links between content areas. In addition, AIBS concluded that most materials failed to fully capitalize on current understanding about how students learn and did not provide useful assessments for tracking and advancing learning.

Reviewers rated some recently developed curriculum materials as strong in areas that rarely receive positive ratings. For example, AIBS concluded that three recently developed instructional packages incorporated the pedagogical recommendations in NSES quite well. An earlier National Science Foundation evaluation of middle school science instructional materials (NSF 1997) also identified several packages that embodied useful standards-based reforms such as organizing content around conceptual themes, emphasizing important concepts in science, balancing breadth and depth of content coverage, and providing assessments tied to instructional goals.

International data indicate that U.S. textbooks tend to address more topics than those used in other countries and to devote less attention to the five most prominent topics. They fail to build more challenging material on simpler content introduced earlier and to make clear connections among content areas (Schmidt, McKnight, and Raizen 1997). As a result, reviewers have criticized U.S. texts as typically less focused and less coherent than those used in many other countries. The data indicate striking differences in textbook length: fourth grade mathematics textbooks in the United States in 1995 averaged 530 pages, more than three times as long as the international average in TIMSS (Valverde and Schmidt 1997). Similar differences in length were found in science textbooks. This greater length results from covering more topics rather than from covering individual topics more thoroughly.

Curriculum

In addition to testing students' learning, the 1995 TIMSS study collected information at the three age and grade levels about the curriculum intended by policymakers, the curriculum that teachers taught, methods of teaching, instructional materials, students' school experiences, and demographic characteristics. TIMSS also examined eighth grade mathematics class practices in the United States, Germany, and Japan through a classroom videotape study and teacher interviews. In TIMSS-R, conducted 4 years later, the videotape component was expanded to include seven countries and to cover science as well as mathematics.[8] Analyses show differences among countries in two important aspects of the mathematics and science curriculum: breadth of coverage and lesson difficulty.

Breadth of Coverage

Consistent with findings about textbooks, research indicates that mathematics and science curricula in the United States generally cover more content areas (NCES 2000a). In eighth grade science, TIMSS-R data showed U.S. students as more likely than the international average to study four of six main content areas: earth science, biology, physics, and scientific inquiry and the nature of science (NCES 2000a).[9] For example, about 95 percent of U.S. eighth graders had received instruction on scientific inquiry before the TIMSS-R assessment compared with an 80 percent international average. The rates for studying the other five topics ranged from 70 to 81 percent in the United States compared with international averages of 53 to 72 percent. (The proportions of U.S. students who studied chemistry and environmental resource issues were comparable to the international average.)

Similarly, eighth grade mathematics classes covered many topics. Higher percentages of U.S. students received instruction in four of the five mathematics content areas in 1999: fractions and number sense; algebra; data representation, analysis, and probability; and measurement. The vast majority of U.S. students had studied these topics by the end of grade 8 (ranging from 91 to 99 percent). Only in geometry did no significant difference exist: 58 percent of eighth graders in the United States had studied that topic compared with 65 percent in other countries (NCES 2000b).

Curriculum in the United States, as observed from curriculum frameworks for both mathematics and science, repeats content across more grades than does curriculum in other countries.[10] In eighth grade mathematics, for example, U.S. curricula often continue to cover topics that no longer appear in the curricula of other nations such as number operations, fractions, percentages, and estimation (Schmidt et al. 2001; Schmidt, McKnight, and Raizen 1997; and Stevenson 1998). U.S. curriculum frameworks generally failed to build more complex content on simpler but related content covered earlier.

In addition, U.S. teachers in 1995 spent significantly less time than German or Japanese teachers on the most emphasized topics (Schmidt, McKnight, and Raizen 1997). U.S. eighth grade mathematics teachers covered 16 to 18 topics during the year with only a single topic receiving more than 8 percent of available teaching time. In Japan, teachers focused extensively on only four topics, allocating two-thirds of total classroom time to these topics (Wilson and Blank 1999). These patterns found in TIMSS reflect findings from the Second International Mathematics and Science Study in the early 1980s (McKnight et al. 1987) and suggest a structural feature of some durability in U.S. elementary and secondary education.

Lesson Difficulty

For the 1999 TIMSS-R mathematics video study, researchers developed a measure of lesson difficulty, *procedural complexity,* based on the number of steps needed to solve a problem using common methods. The measure is thus independent of a student's prior knowledge and skill (NCES 2003b). Japan stood apart from other participating nations in lesson complexity. In the United States and the other five countries, only 6 to 12 percent of problems had high complexity compared with 39 percent of problems used in Japanese lessons (figure 1-11).[11] Only 17 percent of problems in Japanese lessons addressed low-complexity problems compared with 63 to 77 percent in the other six nations. U.S. mathematics lessons did not differ significantly from those in the other five nations in the proportion of problems that had high or low complexity.

Using other measures, the 1995 TIMSS classroom video study also revealed differences in lessons' degree of challenge. Mathematics professors were asked to assign a grade level to videotaped eighth grade mathematics classes: they rated U.S. lessons on average at the seventh grade level, German lessons at the end of eighth grade, and Japanese lessons at the beginning of ninth grade (NCES 1997b). In addition, professors evaluated lesson quality based on the percentage of lessons requiring deductive reasoning by students: 0 percent of lessons in the United States, 21 percent in Germany, and 62 percent in Japan required use of deductive reasoning (Schmidt, McKnight, and Raizen 1997). Deductive reasoning, such as that used to prove a theorem, is a higher order skill that experts recommend students practice and an important component of learning in mathematics, science, and other disciplines.

TIMSS data thus portrayed U.S. eighth grade mathematics classes as rarely emphasizing logic or involving students in logical reasoning. In 1995, in U.S. mathematics lessons, teachers stated the rule students should follow to solve problems for nearly 80 percent of topics rather than explaining the rule or having students work on the reasoning. In contrast, students and teachers developed solutions using logic

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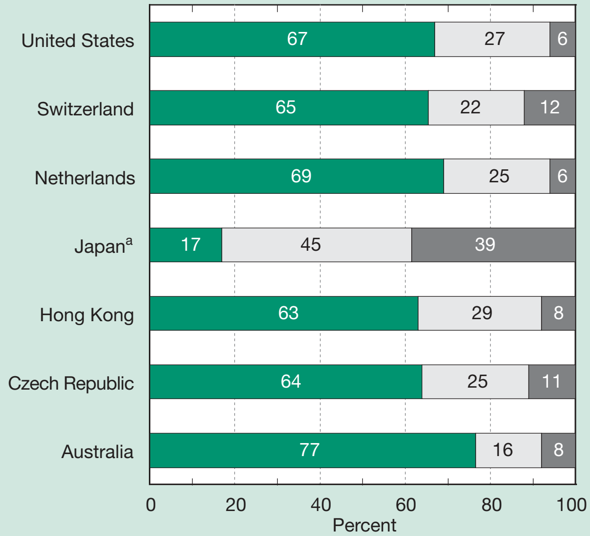
[8]TIMSS–R, limited to eighth grade, collected data from teacher and student surveys on many topics mentioned for TIMSS, although many items were new or different.

[9]A topic counted as being taught if teachers reported that they spent more than five class periods on it during the current year or that students had studied it in a previous grade.

[10]Based on a sample of state and local curriculum frameworks because the United States lacks a national curriculum.

[11]Japan did not participate in the mathematics video study in 1999. Data reported here for Japan come from the 1995 video study. TIMSS collected data from the other six nations in 1999.

Figure 1-11
Average percentage of eighth grade mathematics problems per lesson at each level of procedural complexity, by country/economy: 1999



[a]Data collected in 1995.

NOTES: Percents may not sum to 100 because of rounding. For each country/economy, average percent was calculated as the sum of percents within each lesson divided by the number of lessons. The margin of error varies considerably across locations so that differences of the same magnitude may be significant in some cases but not in others. Low complexity: Australia, Czech Republic, Hong Kong, Netherlands, Switzerland, United States > Japan. Moderate complexity: Hong Kong > Australia; Japan > Australia, Switzerland. High complexity: Japan > Australia, Czech Republic, Hong Kong, Netherlands, Switzerland, United States.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Highlights From the TIMSS 1999 Video Study of Eighth-Grade Mathematics Teaching,* NCES 2003-011 (Washington, DC: U.S. Department of Education, 2003).

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(for example, proving or deriving the answer step by step) for more than 80 percent of topics covered in Japan and nearly 80 percent of topics covered in Germany (Stevenson 1998). German teachers usually proved rules for the class and Japanese teachers tended to give students the assignment of figuring out the solution's proof (NCES 1997b).

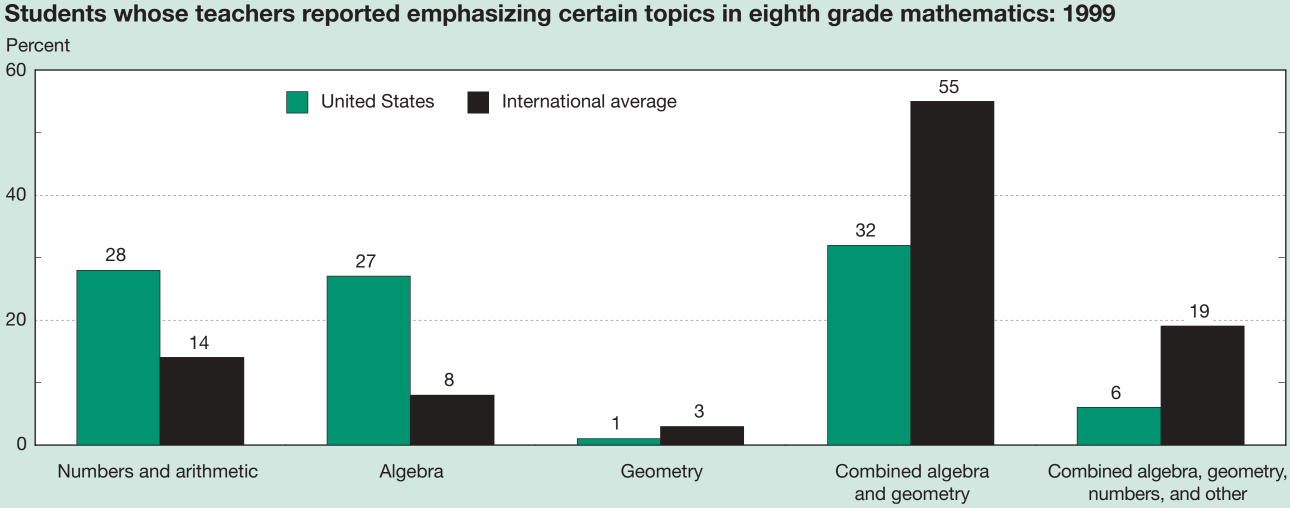
Analyzing the topics teachers prioritize provides another way to examine differences in difficulty. As figure 1-12 shows, U.S. eighth grade mathematics students in 1999 were twice as likely as the international average to be in classes where teachers placed the most emphasis on numbers and arithmetic (28 versus 14 percent), and they were three times as likely to be in classes where algebra received the most emphasis (27 versus 8 percent) (Mullis et al. 2001). In contrast, far higher percentages of other nations' eighth graders experienced a combined emphasis on algebra and geometry or on algebra, geometry, numbers, and other topics.

Instructional Practices

The 1999 TIMSS-R video study of mathematics classes in seven nations showed that in the United States teachers spent about half of total lesson time (53 percent) reviewing previously taught material, with the other half nearly equally divided between introducing and practicing new content (NCES 2003b) (figure 1-13). In Japan teachers spent 60 percent of class time introducing new material, more than in any of the other six countries. Although most lessons in each nation included both review and new material, U.S. teachers presented proportionally many more lessons devoted entirely to reviewing old content than did teachers in Hong Kong or Japan, two economies with particularly high scores.

In 1999, U.S. eighth graders watched the teacher demonstrate how to solve mathematics problems more often than their international peers (NCES 2000b). Compared with the international average, U.S. students were more likely to

Figure 1-12
Students whose teachers reported emphasizing certain topics in eighth grade mathematics: 1999



SOURCE: I. V. S. Mullis et al., 2001, *Mathematics Benchmarking Report: TIMSS 1999–Eighth Grade. Achievement for U.S. States and Districts in an International Context* (Chestnut Hill, MA: International Association for the Evaluation of Educational Achievement and Boston College, International Study Center, 2001).

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Figure 1-13
Average percentage of eighth grade mathematics lesson time devoted to various purposes, by country or economy: 1999

[a]Data collected in 1995.

NOTES: For each country, average percent was calculated as the sum of percents within each lesson, divided by number of lessons. Percents may not sum to 100 because of rounding and the possibility of coding portions of lessons as "not able to make a judgment about the purpose." The margin of error varies considerably across locations so that differences of the same magnitude may be significant in some cases but not in others. Reviewing: Czech Republic > Australia, Hong Kong, Japan, Netherlands, Switzerland; United States > Hong Kong, Japan. Introducing new content: Hong Kong, Switzerland > Czech Republic, United States; Japan > Australia, Czech Republic, Hong Kong, Netherlands, Switzerland, United States. Practicing new content: Hong Kong > Czech Republic, Japan, Switzerland.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Highlights From the TIMSS 1999 Video Study of Eighth-Grade Mathematics Teaching*, NCES 2003-011 (Washington, DC: U.S. Department of Education, 2003).

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work alone on mathematics worksheets or textbook problems and to use data from everyday life, but less likely to do projects in their mathematics classes. TIMSS-R also indicated that U.S. eighth grade mathematics students were more likely than the international average (54 versus 43 percent) to write equations to represent mathematical relationships in most, or every, lesson (figure 1-14). However, no significant differences existed for several other learning activities: explaining their reasoning for an answer, representing or analyzing relationships using tables and graphs, working on problems with no obvious method of solution, and practicing computation (Mullis et al. 2001). Students in all countries quite often explained their reasoning (70 percent of all teachers reported this activity in most lessons compared with 72 percent in the United States) and practiced computational skills (73 percent overall compared with 66 percent in the United States).

Teachers' goals can influence how they teach material and the activities they emphasize. In 1995, eighth grade mathematics teachers in the United States were more likely than those in Japan or Germany to prioritize the goal of developing correct answers to problems. German and Japanese teachers made students' understanding of mathematical concepts the priority.

Science class practices in 1999 tended to emphasize student-directed investigations. Higher proportions of science students in the United States than in TIMSS-R countries overall said that they "pretty often or almost always" explained the reasoning behind an idea, worked on science projects, conducted experiments or investigations, and worked from worksheets or textbooks. On average, U.S. students watched teachers show them how to work through a science problem less often than did students in other countries (NCES 2000a). The frequency of other specific learning practices, including explaining observations, representing or analyzing relationships with tables and graphs, and working on problems with no obvious method of solution, did not significantly differ between the United States and the international average (NCES 2000a).

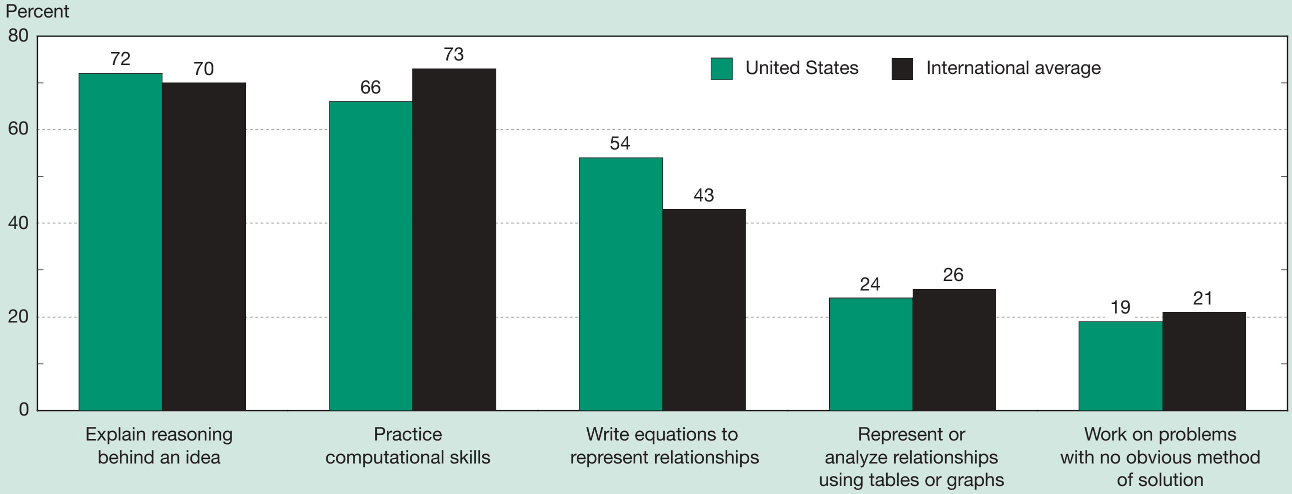
Although U.S. mathematics (and science) teachers report that they are familiar with and are implementing recent content and pedagogical reforms, detailed observation and analysis of mathematics classroom practice in 1995 suggest otherwise. TIMSS data indicate that Japanese eighth grade mathematics teachers were more likely than their U.S. counterparts to be practicing many of the reforms recommended by national organizations like NCTM (NCES 1997b). Teachers who report reforming their methods may be referring to aspects of practice that have little demonstrated effect on students' thinking. In one study, more than two-thirds of reform-oriented teachers identified either real-world applications or students working in groups as examples of reform practices, and only 19 percent identified activities involving problem solving or mathematical thinking (Hiebert and Stigler 2000).

Teacher Quality

Although defining and measuring teacher quality remains difficult, a growing consensus is developing about some of the characteristics of high-quality teachers. Research studies have found that teachers more effectively teach and improve student achievement if they themselves have strong academic skills (Ehrenberg and Brewer 1994, Ferguson and Ladd 1996, and Hanushek 1996), appropriate formal training in the field in which they teach (Ingersoll 1999), and several years of teaching experience (Murnane and Phillips 1981). The body of expert opinions on teacher effectiveness has been summarized in several studies and commission reports (Darling-Hammond 2000; NCTAF 1996 and 1997; and Wayne and Younger 2003).

Some indicators of quality, such as education, certification, and subject-matter knowledge, are components in the

Figure 1-14
Students whose teachers asked them to do various activities in most or every mathematics lesson: 1999



SOURCE: I. V. S. Mullis et al., 2001, *Mathematics Benchmarking Report: TIMSS 1999–Eighth Grade. Achievement for U.S. States and Districts in an International Context* (Chestnut Hill, MA: International Association for the Evaluation of Educational Achievement and Boston College, International Study Center, 2001).

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definition of *highly qualified* teachers in the NCLB Act. For example, starting in fall 2002, the act requires all newly hired elementary and secondary school teachers in Title I schools to hold at least a bachelor's degree and to have full state certification or licensure. In addition, new elementary school teachers must pass tests in subject-matter knowledge and teaching skills in mathematics, reading, writing, and other areas of the basic elementary school curriculum. New middle and high school teachers either must pass a rigorous state test in each academic subject they teach or have the equivalent of an undergraduate major, graduate degree, or advanced certification in their fields (No Child Left Behind Act 2001).

This section discusses these and related indicators of teacher quality, which include the academic abilities of those entering the teaching force, teachers' education and preparation prior to teaching, the match or mismatch between teachers' training and the subject areas they are assigned to teach, and teachers' levels of experience.

Academic Abilities of Teachers

Some evidence suggests that college graduates who enter the teaching profession tend to have lesser academic skills. Using data from the National Longitudinal Study of 1972 high school seniors, Vance and Schlechty (1982) found college graduates with low Scholastic Aptitude Test (SAT) scores more likely than those with high SAT scores to enter and remain in the teaching force. Ballou (1996), using data from the Surveys of Recent College Graduates, found that the less selective the college, the more likely that its students prepared for and entered the teaching profession.

Data from the 2001 Baccalaureate and Beyond Longitudinal Study yielded similar findings. Recent college graduates who taught or prepared to teach were underrepresented among graduates with college entrance examination scores in the top quartile (table 1-1). Results for first-time mathematics and science teachers reflected the overall pattern: 18

Table 1-1
1999–2000 college graduates according to college entrance examination score quartile, by elementary/secondary teaching status: 2001
(Percent distribution)

		Score, quartile		
Teaching status	Total	Bottom	Middle half	Top
Did not teach				
Did not prepare	100	24	49	27
Prepared	100	39	50	11
Taught	100	36	48	16
Math in first teaching job	100	34	49	18
Public school	100	34	51	15
Science in first teaching job	100	27	56	17
Public school	100	26	61	13

NOTES: Substitute teachers and teacher's aides were not considered to have taught. "Prepared" refers to completing a teacher education program or a student teaching assignment but not yet having earned a teaching certificate. Percents may not sum to 100 because of rounding. SAT combined score is derived as either the sum of SAT verbal and mathematics scores or the ACT composite score converted to an estimated SAT combined score.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Baccalaureate and Beyond Longitudinal Study, 2001.

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and 17 percent, respectively, of those who reported teaching science or mathematics in their first job scored in the top quartile on the college entrance examination test compared with 27 percent of those who had neither prepared to teach nor taught. Among those who taught mathematics or science in public schools, an even lower percentage scored in the top quartile: 15 percent for mathematics teachers and 13 percent for science teachers.

However, not all studies have yielded similar results. For example, Latham, Gitomer, and Ziomek (1999) examined the SAT scores of candidates who took and passed the Educational Testing Service (ETS) Praxis II tests between 1994 and 1997 and found that those seeking to teach mathematics and science had higher average mathematics and verbal SAT scores than other college graduates.[12] Using data from the National Education Longitudinal Study of 1988 (NELS:88), Cardina and Roden (1998) found that female high school graduates intending to major in education in college exhibited a range of academic abilities measured by mathematics, science, and reading proficiency levels comparable to that of females intending to major in other fields such as psychology, business, or the health professions.

All of these studies relied heavily on standardized test scores as the sole indicator of the academic competence of teachers or prospective teachers, a major limitation that neglected other traits that may well be associated with teaching effectiveness. For the most part, they also used only a small subsample of teachers (i.e., recent college graduates who entered teaching) or samples of potential teacher candidates (i.e., those seeking to become teachers or intending to major in education), rather than a representative sample of all teachers in the workforce.

Teacher Education and Certification

Although teachers' knowledge of subject matter and pedagogical methods does not guarantee high-quality teaching, this knowledge is a necessary prerequisite. Therefore, teachers' educational attainment and certification status traditionally have been used to gauge teachers' preservice preparation and qualifications (NCES 1999). The conventional route to teaching begins with completion of a bachelor's degree. Although this was once considered adequate preparation for teaching, teachers today often are expected to hold advanced degrees. Indeed, many states and districts, as part of their efforts to raise academic standards, require teachers to attain a master's degree or its equivalent (Hirsch, Koppich, and Knapp 2001).

In academic year 1999, virtually all public school teachers had at least a bachelor's degree and nearly half also had an advanced degree: 42 percent held a master's degree and 5 percent had earned a degree higher than a master's degree, including an educational specialist or professional diploma or a doctoral or first professional degree (table 1-2).[13,14] The degree attainment of mathematics and science teachers was similar to the pattern for all teachers.[15] In comparison, only 26 percent of the overall population age 25 and over had completed 4 or more years of college in 2000 (NCES 2002b).

As of academic year 1999, 47 percent of public secondary school teachers had majored in an academic subject, 39 percent had majored in subject-area education (such as mathematics education), 7 percent had majored in general education, and 7 percent had majored in another education field for their undergraduate or graduate degree (figure 1-15). Thus, although almost all teachers have at least a bachelor's degree, many have an education degree rather than an academic degree.

Having an education degree does not mean that a teacher lacks subject-matter knowledge. As shown in figure 1-15, most secondary teachers with education degrees had subject-matter education majors such as mathematics education or science education. In recent years, many states have upgraded teacher education by requiring subject-area education majors to complete substantial coursework in an academic discipline. At many teacher-training institutions, a degree in mathematics education currently requires as much coursework in the mathematics department as does a mathematics degree (Ingersoll 2002).

Certification is another important measure of teacher qualifications. Teacher certification, or licensure by the state in which one teaches, includes requirements for formal education (usually a bachelor's degree with requirements

Table 1-2
Public school teachers according to highest degree earned: Academic year 1999
(Percent distribution)

Highest degree earned	All teachers	Mathematics and science teachers
All degrees	100	100
Less than bachelor's	1	0
Bachelor's	52	50
Master's	42	44
Higher than master's	5	5

NOTES: Percents may not sum to 100 because of rounding. Academic year refers to the school year beginning in fall 1999.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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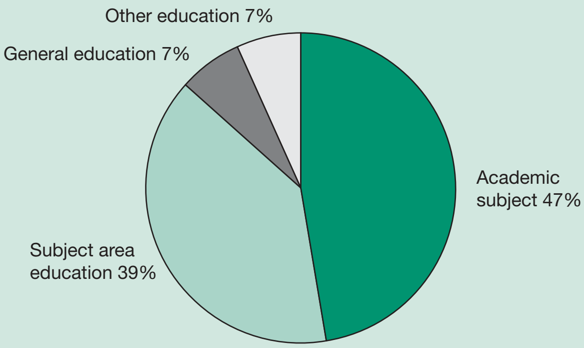
[12]Praxis II tests are designed to measure teachers' content and pedagogical knowledge of the subjects they will teach. States often use them to grant initial teaching licenses.

[13]The level of teachers' educational attainment remained fairly stable during the past decade. In academic year 1987, 99 percent of public school teachers held at least a bachelor's degree, including 47 percent who had a master's degree or higher (Choy et al. 1993).

[14]Data for the analysis on teachers' education, certification, match between preparation and assignment, and experience are based on a nationally representative sample of teachers who participated in the 1999–2000 NCES Schools and Staffing Survey (SASS).

[15]Mathematics and science teachers are identified by their main assignment field, i.e., the subject area they taught most often.

Figure 1-15
Distribution of secondary public school teachers, by undergraduate or graduate major: 1999–2000



NOTES: Subject area education is the study of methods for teaching an academic field, such as mathematics education. General education includes preelementary and early childhood education, elementary education, and secondary education. Examples of other education fields are special education, curriculum and instruction, and educational administration. Secondary school teachers include those who taught at least one of grades 7–12 and whose main assignment field was not prekindergarten, kindergarten, general elementary, or special education; those who taught special education to seventh and eighth grades only but were designated secondary teachers by the school; and those who taught “ungraded” students and were designated secondary teachers by the school. Teachers with more than one major (graduate or undergraduate) or degree were counted only once. Majors/degrees were counted in the following order: academic field, subject area education, other education, and general education.

SOURCE: U.S. Department of Education, National Center for Education Statistics (NCES), *The Condition of Education 2002,* NCES 2002-025, Indicator 32 (Washington, DC: U.S. Department of Education, 2002).

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for special courses related to teaching), clinical experience (student teaching), and often, some type of formal testing (Mitchell et al. 2001). Types of certification and requirements for each type vary considerably across states. Although most states have increased their standards since the 1980s, more than 30 states still allow hiring of teachers who have not met state licensing standards. This practice actually has increased in some states because the demand for teachers has grown due to increased enrollment and reduced class size (Darling-Hammond 2000 and Jepsen and Rivkin 2002). Some states allow the hiring of teachers who do not have a license, and others fill short-term vacancies by issuing emergency, temporary, or provisional licenses to candidates who may or may not have met various requirements. More than 40 states have developed various alternative certification procedures allowing individuals interested in teaching (i.e., former Peace Corps volunteers, liberal arts college graduates, and military retirees) to become teachers without first completing a formal teacher education program (Feistritzer 1998 and Shen 1997).

In academic year 1999, a vast majority of public school teachers (87 percent overall and 81 percent of mathematics and science teachers) had advanced or regular certification in their main teaching assignment field (appendix table 1-12). Some teachers (8 percent overall and 9 percent of mathematics and science teachers) held other types of certification, including probationary, provisional or alternative, temporary, or emergency certifications. About 6 percent of teachers in public schools held no certification in their main assignment field. These teachers might be certified in another field that may or may not be related to their main teaching field. Mathematics and science teachers more often lacked certification in their main assignment field, and this phenomenon occurred more frequently in academic year 1999 than in academic year 1993. In academic year 1993, about 7 percent of mathematics and science teachers in public schools lacked certification (Henke et al. 1997) compared with 10 percent in academic year 1999.

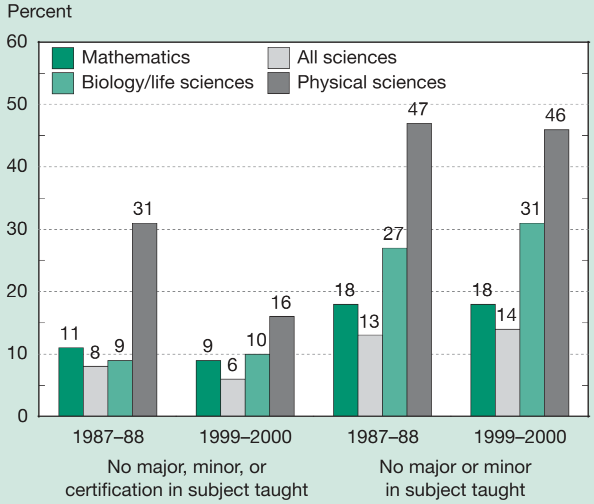
Match Between Teacher Preparation and Assignment

A growing body of research suggests that teachers’ subject-matter knowledge is one of the most important elements of teacher quality and that students, particularly in the higher grades, benefit most from teachers with strong subject-matter background (Goldhaber and Brewer 1997 and 2000; Monk and King 1994; and Rowan, Chiang, and Miller 1997). However, studies show that teaching “out of field” (teachers teaching subjects outside their areas of subject-matter training and certification) is not an uncommon phenomenon (Bobbitt and McMillen 1995 and Seastrom et al. 2002). In academic year 1999, 9 percent of public high school students enrolled in mathematics classes, 10 percent of students enrolled in biology/life science classes, and 16 percent of students enrolled in physical science classes received instruction from teachers who had neither certification nor a major or minor in the subject they taught (figure 1-16).

If the definition of a “qualified teacher” is limited to those who hold at least a college minor in the subject taught, the amount of out-of-field teaching substantially increases: 18 percent of public high school students in mathematics classes received instruction from teachers without at least a minor in mathematics, statistics, mathematics education, or a related field, such as engineering and physics. About 31 percent of students in biology/life science classes and 46 percent of students in physical science classes received instruction from teachers who did not have a major or minor in these subjects (figure 1-16). These percentages changed little between academic years 1987 and 1999. (See sidebar, “International Comparisons of Teacher Preparation in Eighth Grade Mathematics and Science,” and figure 1-17.)

The amount of out-of-field teaching varies in different types of schools. In general, students in high-poverty schools more often received instruction from out-of-field teachers than students enrolled in more affluent schools (Ingersoll 1999 and 2002). The following discussion examines the mismatch between those teaching mathematics and science and their academic backgrounds in those fields and how this mismatch varies by poverty level and minority concentration.

Figure 1-16
Public high school students taught by mathematics and science teachers without various qualifications, by subject field: 1987–88 and 1999–2000



NOTES: Biology/life and physical sciences are included in all sciences. Fields of study considered a mathematics major or minor include mathematics education, mathematics, statistics, physics, and engineering. Fields of study considered a science major or minor include science education, biology/life sciences, chemistry, geology/earth sciences, physics, other natural sciences, and engineering. Fields of study considered a biology/life science major or minor include biology/life sciences, and those considered a physical science major or minor included chemistry, geology/earth sciences, physics, and engineering.

SOURCE: M. M. Seastrom et al., *Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987–88 to 1999–2000,* NCES 2002-603 (Washington, DC: U.S. Department of Education, 2002).

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Mathematics

The amount of out-of-field teaching depends on how strictly one defines a match between teacher preparation and teaching assignment. In academic year 1999, 40 percent of public school students in high grades (hereafter referred to as *high school* students) studied mathematics with a teacher who majored in mathematics or statistics (figure 1-18). Another 32 percent studied with a teacher who majored in mathematics education. Broadening the definition to include teachers who minored in mathematics or statistics raised the match by 5 percentage points. Adding those who majored or minored in a natural science, computer science, or engineering increased the total by another 5 percentage points, for a total match of approximately 82 percent. In other words, about 18 percent of public high school students studied mathematics with a teacher who did not major or minor in mathematics or a related field. Middle grade students were less likely than their peers in high grades to be taught mathematics by a teacher with a degree in mathematics or statistics and more likely to study mathematics with a teacher without any formal training in mathematics or a related field (figure 1-18).

Biology/Life Sciences

Sixty-three percent of public high school students received instruction in biology or life sciences from a teacher with a major in that subject in academic year 1999. An additional 6 percent studied with a teacher who minored in biology/life sciences, another 6 percent studied with a teacher who majored or minored in another natural science (i.e., chemistry, geology/earth sciences, or physics), and 9 percent studied with a teacher with an undergraduate or graduate degree in science education (figure 1-18). Thus, about 15 percent of public high school students received instruction in biology/life sciences from a teacher without a degree in biology, life sciences, or a related field. Middle grade students studied with a teacher who taught out of field even more often.

Physical Sciences

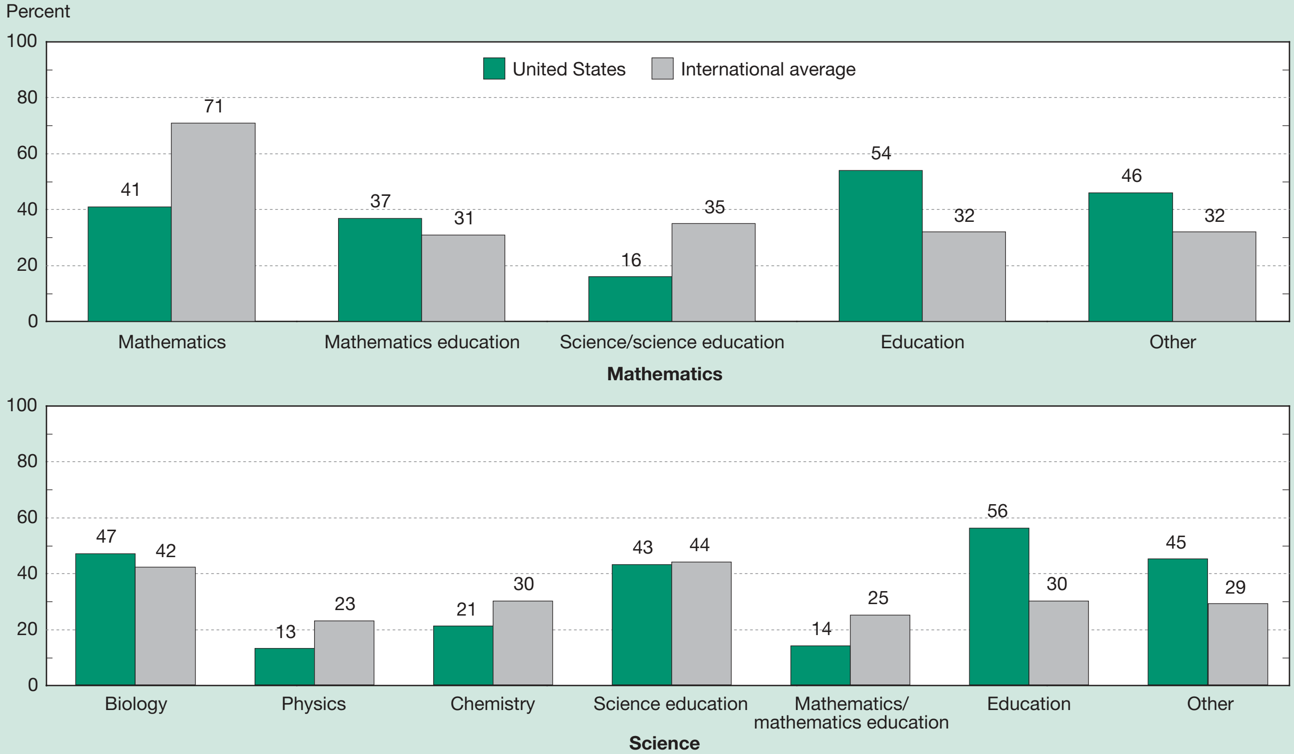
The match between teaching assignment and teacher preparation in physical sciences follows a similar pattern to that for biological sciences, although, at 41 percent, high school students less often received instruction in physical sciences from a teacher who majored in a physical science (including chemistry, geology/earth sciences, physics, or other natural sciences), or who majored in engineering, and more often received instruction from a teacher who minored in physical sciences or engineering (14 percent). (Figure 1-18.) It also was not

International Comparisons of Teacher Preparation in Eighth Grade Mathematics and Science

In the Third International Mathematics and Science Study-Repeat (TIMSS-R) conducted in 1999 (4 years after the original TIMSS), mathematics and science teachers of eighth graders were asked about their main areas of study (i.e., their majors or the international equivalent) at the bachelor's and master's degree levels. In 1999, 41 percent of eighth grade students in the United States received instruction from a mathematics teacher who specialized in mathematics (i.e., majored in it at the undergraduate or graduate level or studied mathematics for certification), considerably lower than the international average of 71 percent (figure 1-17). In science, U.S. eighth graders were about as likely as their international peers to receive instruction from a teacher with a bachelor's or master's degree major in biology, chemistry, or science education. However, they were less likely than their international peers to receive instruction from a teacher who majored in physics (13 percent of U.S. students compared with 23 percent of international students) and more likely to receive science instruction from a teacher who majored in education (56 percent of U.S. students compared with 30 percent of international students).

SOURCE: NCES 2001b, Indicator 43.

Figure 1-17
Eighth graders taught mathematics and science by teachers who reported various main areas of study for bachelor's and master's degrees: 1999



NOTES: More than one category could be selected when teachers chose their major/main area of study. International average includes the following countries: Australia, Belgium-Flemish, Bulgaria, Canada, Chile, Chinese Taipei, Cyprus, Czech Republic, England, Finland, Hong Kong, Hungary, Indonesia, Islamic Republic of Iran, Israel, Italy, Japan, Jordan, Latvia, Lithuania, Malaysia, Moldova, Morocco, Netherlands, New Zealand, Philippines, Republic of Macedonia, Romania, Russian Federation, Singapore, Slovak Republic, Slovenia, South Africa, South Korea, Thailand, Tunisia, Turkey, and United States.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2001,* NCES 2001-072, Indicator 43 (Washington, DC: U.S. Department of Education, 2001).

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uncommon for high school physical science students to receive instruction from teachers who majored or minored in biology/life sciences (16 percent) or who majored in science education (13 percent). Sixteen percent of high school students received instruction in physical sciences from an out-of-field teacher (i.e., no major or minor in a physical science, engineering, or a related field). As with mathematics and biology/life sciences, middle grade students more often received instruction in physical sciences from an out-of-field teacher.

Variations Across Schools

Students in high-poverty public high schools were as likely as students in low-poverty schools to receive mathematics instruction from teachers who majored in mathematics or statistics, or to receive instruction in biology/life sciences from teachers with a major in biology/life sciences (appendix table 1-13).[16] However, students in high-poverty public high schools received instruction in physical sciences from a teacher who majored in physical sciences less often. About 31 percent of students in high-poverty public high schools studied physical sciences with a teacher who majored in that field compared with approximately 42 percent of students in low-poverty schools. In addition, students in high-poverty and high-minority schools less often received mathematics or science instruction from a teacher who majored in mathematics or science education.

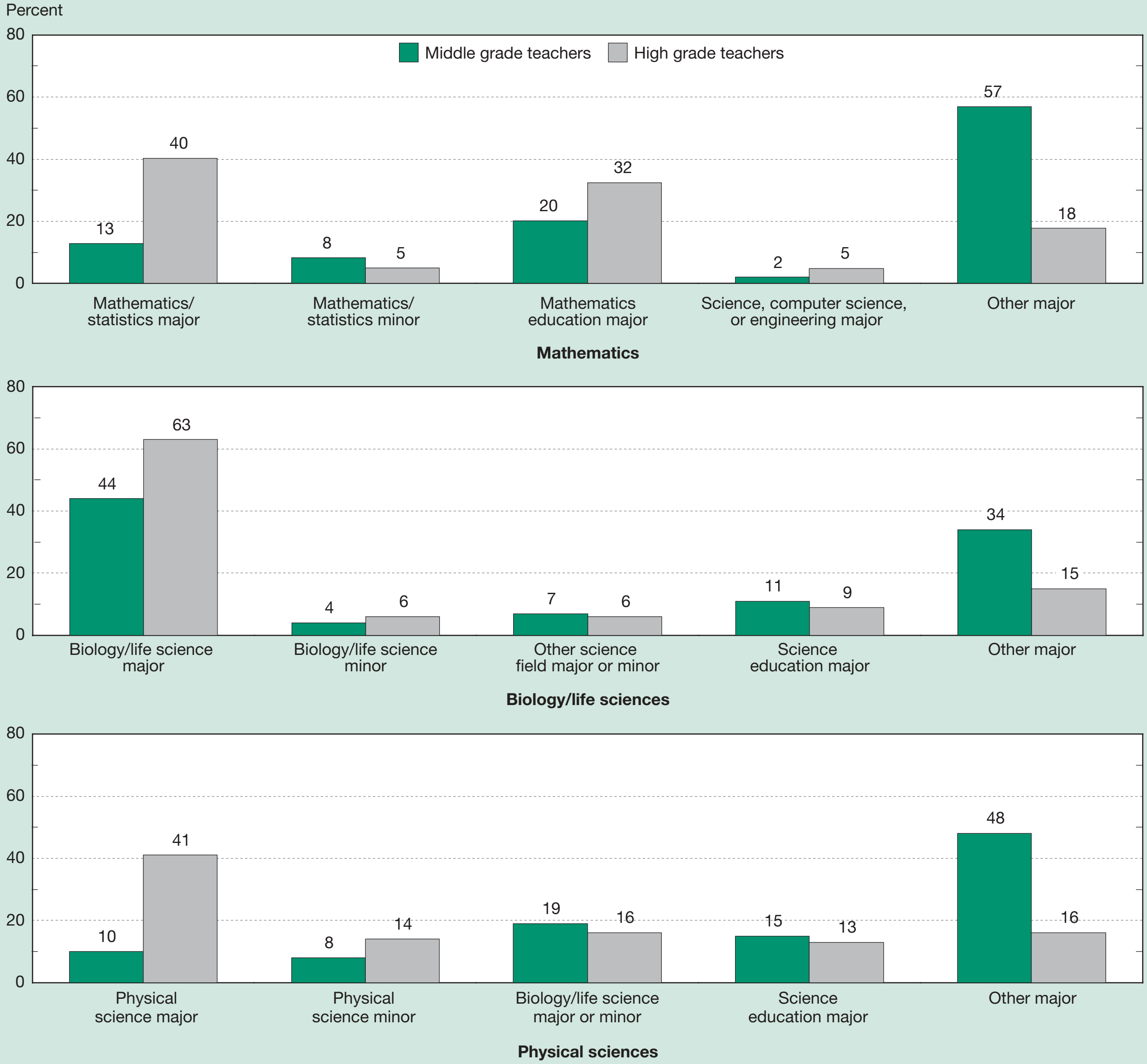
No statistically significant differences existed in the percentage of students who had an out-of-field mathematics, biology/life science, or physical science teacher by either school poverty level or minority concentration (appendix table 1-13).

Teacher Experience

Research examining the effects of teacher experience on student learning has found a relationship between teachers' effectiveness and their years of experience (Murnane and Phillips 1981; and Rowan, Correnti, and Miller 2002).

[16]High-poverty high schools are those schools in which 50 percent or more of students are approved to receive free or reduced-price lunches. Low-poverty high schools are those with 10 percent or less of students approved to receive free or reduced-price lunches.

Figure 1-18
Public school students whose mathematics and science teachers majored or minored in various subject fields, by teacher grade level: 1999–2000



NOTES: Middle grade teachers include teachers who taught students in grades 5–9 and did not teach any students in grades 10–12; teachers who taught in grades 5–9 who identified themselves as elementary or special education teachers were excluded. High grade teachers include all teachers who taught any of grades 10–12 and teachers who taught grade 9 and no other grades. Physical sciences include chemistry, geology/earth sciences, physics, other natural sciences, and engineering, except biology/life sciences.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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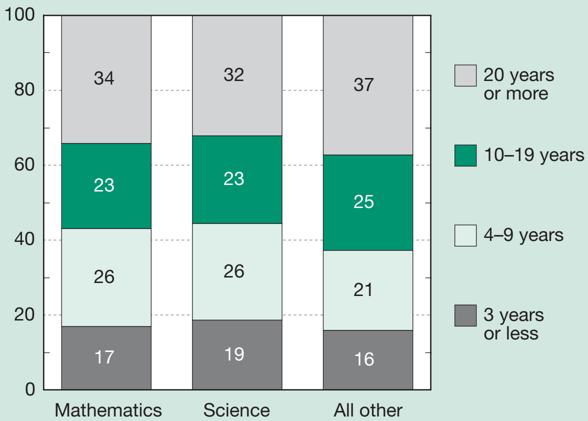
Many studies have established that inexperienced teachers typically are less effective than more senior teachers, but the measurable benefits of experience appear to level off after 5 years (Rosenholtz and Simpson 1990).

In academic year 1999, new teachers (i.e., those with 3 years of experience or fewer) made up 17 and 19 percent, respectively, of mathematics and science teachers in public middle and high schools compared with 16 percent of teachers in all other areas (figure 1-19).

Among public high schools, high-poverty schools and high-minority schools both had a higher proportion of new science teachers than low-poverty schools and low-minority schools[17] (figure 1-20). High-poverty schools had a lower share of the most experienced mathematics and science

[17]High-minority high schools are those with minority enrollment of 45 percent or more, and low-minority high schools are those with enrollment of 5 percent or less.

Figure 1-19
Public middle and high school teachers with various years of teaching experience, by subject field: 1999–2000



NOTE: Percents may not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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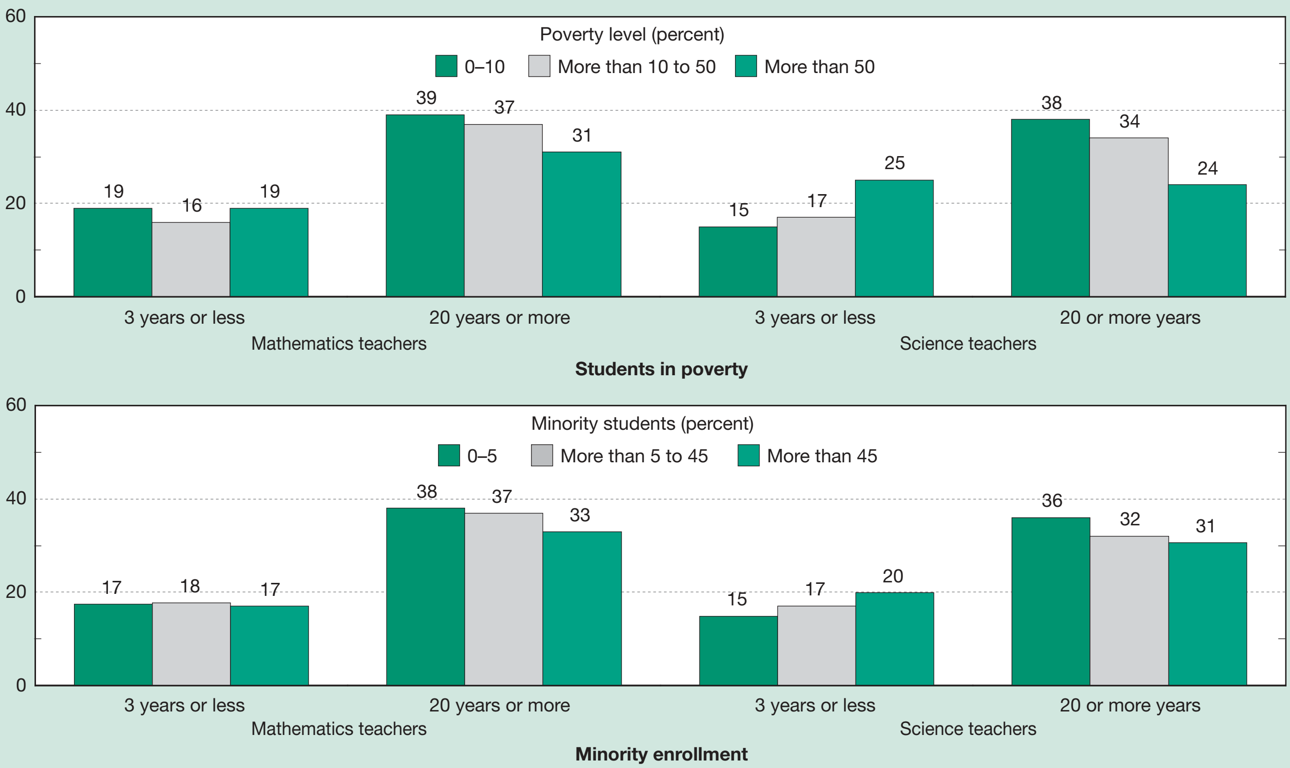
teachers (those with 20 or more years of experience) compared with low-poverty schools; high-minority schools also had a lower share of the most experienced science teachers compared with low-minority schools.

Teacher Induction, Professional Development, and Working Conditions

Recent school reform initiatives have drawn increased attention to the role of professional development and working conditions in enhancing teacher quality and guaranteeing an adequate supply of well-qualified teachers (NCTAF 1996, 1997, and 2003; National Education Goals Panel 1995; National Foundation for the Improvement of Education 1996; and No Child Left Behind Act 2001). The need for professional development has become more urgent as the nation's schools prepare for increased teacher retirements over the next decade (NCTAF 2003).

Research shows that teachers cite working conditions as among the top reasons for leaving their teaching jobs (NCTAF 2003). Inadequate support from administrators, student discipline problems, little faculty input into school decision making, inadequate facilities and supplies, and low salaries

Figure 1-20
Experience of public high school mathematics and science teachers, by poverty level and minority enrollment in schools: 1999–2000



NOTE: Students in poverty are those who are approved to receive free or reduced-priced lunches.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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all contribute to teacher turnover (Ingersoll 2001, NCTAF 2003, and NCES 1997a). This section examines teachers' professional development and working conditions, based on the responses of a nationally representative sample of teachers in the 1999–2000 Schools and Staffing Survey (SASS), and has a special focus on public middle and high school mathematics and science teachers.

New Teacher Induction

Induction programs typically have two goals: to improve the skills of beginning teachers and to reduce attrition. The National Commission on Teaching and America's Future (1996) contended that school districts usually assign new teachers to classes (often those with the most difficult students), and leave them to cope on their own. These initial experiences can contribute to high turnover rates among new teachers (NCES 1997a, and NCTAF 2003). To ease new teachers' entry into the profession, many school districts increasingly use formal induction and mentoring programs to help them adjust to their new responsibilities (AFT 2001).

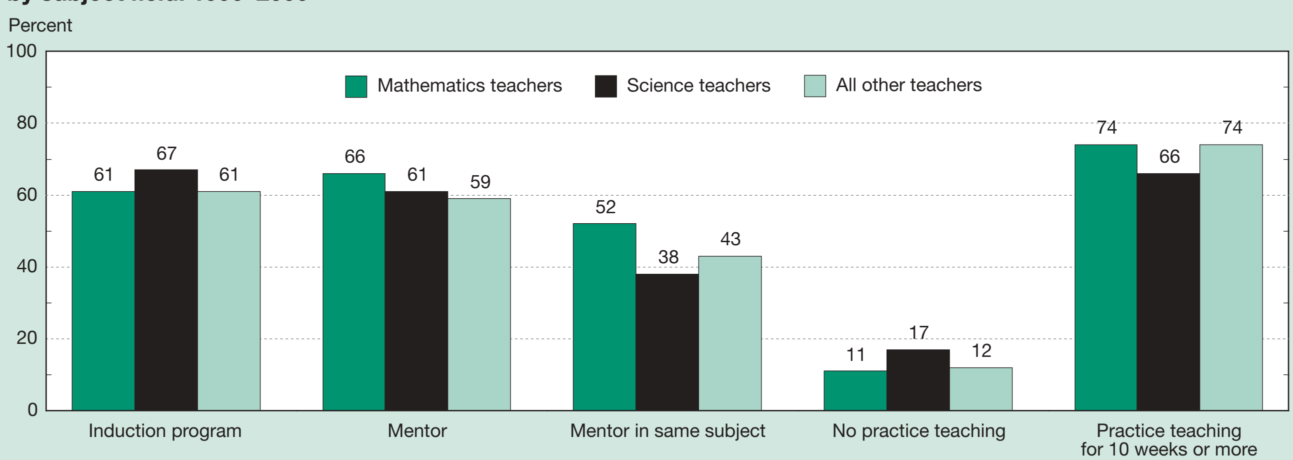
Among public middle and high school mathematics teachers who entered the profession between 1995 and 1999 (hereafter referred to as *recently hired teachers* or *new teachers*), 61 percent participated in an induction program in their first year of teaching (figure 1-21). A similar proportion (66 percent) reported that they worked with a master or mentor teacher, although fewer (52 percent) reported working with another mathematics teacher as their mentor. Recently hired science teachers had similar participation rates in induction programs and mentorship activities, although even fewer new science teachers (38 percent) reported being mentored by someone who teaches in the same subject area.

Induction participation rates did not significantly differ between new mathematics teachers in high- and low-poverty public high schools (61 versus 56 percent), but were significantly lower for new science teachers in high-poverty schools compared with their counterparts in low-poverty schools (51 versus 70 percent) (appendix table 1-14). Participation in mentoring activities did not significantly differ for new mathematics and science teachers in high- and low-poverty schools.

In addition to induction and mentoring, new teachers also can benefit from practice teaching before they enter the classroom. In academic year 1999, a majority of new mathematics and science teachers in public middle and high schools (89 and 83 percent, respectively) performed practice teaching before entering teaching (figure 1-21). For most of them (74 and 66 percent, respectively), practice teaching lasted for 10 or more weeks (figure 1-21). Participation in practice teaching was significantly related to schools' poverty level and minority enrollment. In public high schools, new mathematics and science teachers in high-poverty schools were less likely than their counterparts in low-poverty schools to have performed practice teaching for 10 weeks or more; in fact, they were more likely to have not performed practice teaching at all (appendix table 1-14). Similar gaps in practice teaching experience also existed between high- and low-minority schools.

A vast majority of new mathematics and science teachers in public middle and high schools reported they felt well prepared to teach mathematics or science in their first year of teaching (figure 1-22). At least two-thirds felt well prepared to perform various teaching activities such as planning lessons, assessing students, and using a variety of teaching methods in their classes. At least half felt well prepared in

Figure 1-21
Public middle and high school teachers who entered profession between 1995–96 and 1999–2000 and participated in induction and mentoring activities in first year and those with either no or 10 weeks or more of practice teaching, by subject field: 1999–2000



SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000. See appendix table 1-14.

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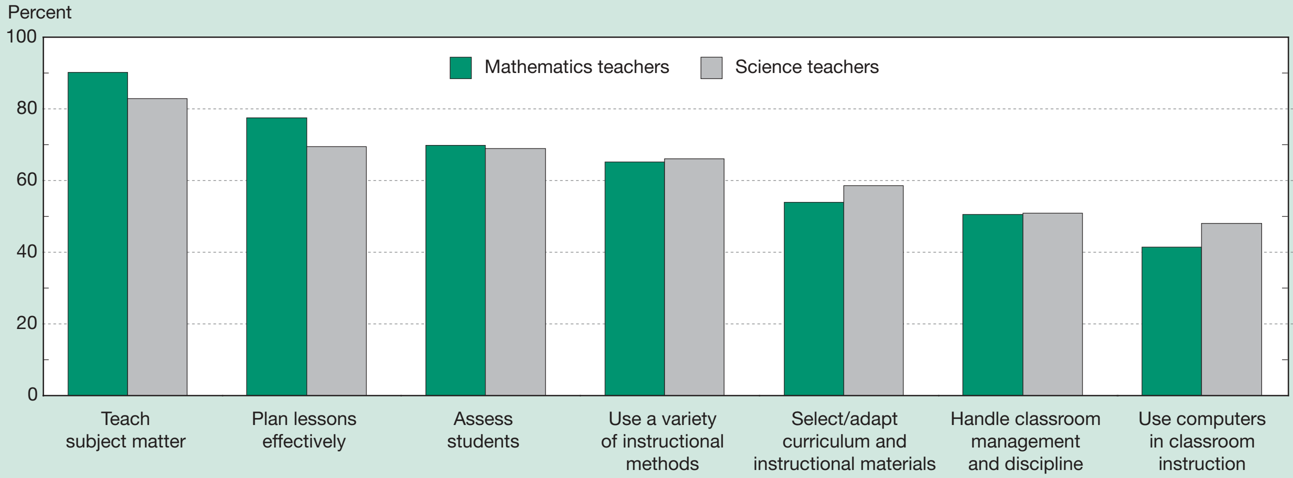
Figure 1-22
Public middle and high school mathematics and science teachers who entered profession between 1995–96 and 1999–2000 and reported feeling well prepared in various aspects of teaching in first year: 1999–2000



SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000. See appendix table 1-15.

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selecting or adapting curriculum and instructional materials and in handling a range of classroom management and discipline situations. About 41 percent of new mathematics teachers and 48 percent of new science teachers felt well prepared to use computers for classroom instruction.

A positive relationship existed between participation in induction and mentoring programs and new teachers' feelings of preparedness. For example, new mathematics teachers who participated in an induction program more often felt well prepared to use computers for classroom instruction, and those who worked with a mentor teacher more often felt well prepared to use a variety of instructional methods in the classroom (appendix table 1-15). Participation in induction programs and mentoring activities had an even more positive relationship to feelings of preparedness among new science teachers than among new mathematics teachers. New science teachers who had induction or mentoring experiences more often reported feeling well prepared in planning lessons effectively, assessing students, selecting or adapting curriculum and instructional materials, and using a variety of teaching methods compared with their counterparts who did not have such experiences.

Teacher Professional Development

The following analysis reviews the content of professional development programs in which public middle and high school mathematics and science teachers participated during the 12 months before the SASS survey took place in academic year 1999.

Teacher Professional Development Program Content

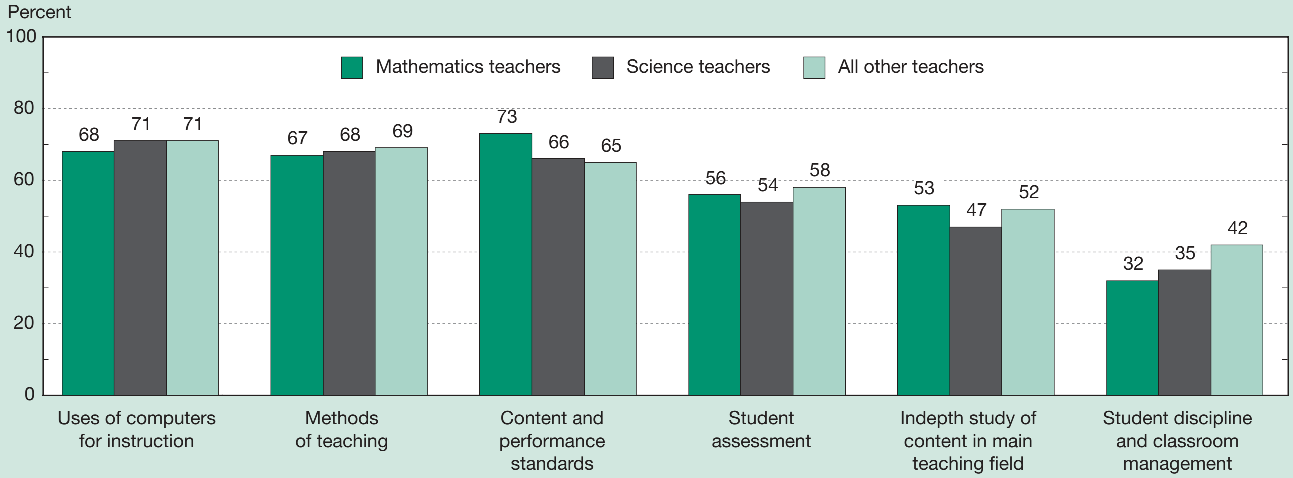
Mathematics and science teachers exhibited a pattern of participation in professional development programs similar to the pattern exhibited by all other teachers. Teachers reported the use of computers for instruction, methods of teaching, and content and performance standards as the three top subjects for professional development in academic year 1999. Between 66 and 73 percent of public middle and high school mathematics and science teachers reported participating in professional development programs on one of these three topics (figure 1-23). Slightly more than half of mathematics and science teachers (56 and 54 percent, respectively) reported participating in programs on student assessment. Participation in indepth study of content in a teacher's main field ranked comparatively lower, reported by 53 percent of mathematics teachers and 47 percent of science teachers. Teachers were least likely to have participated in programs on student discipline and classroom management.

Both mathematics and science teachers rated use of technology for instruction as one of their top interests for future professional development (figure 1-24). They also gave high ratings to study in their main subject field. Methods of teaching, teaching students with special needs, and student assessment received the lowest ratings.

Teacher Professional Development Program Duration

One of the most important concerns about teacher professional development is the duration of training. Richardson (1990) notes that providing adequate time for professional development programs is crucial to allow teachers to learn and absorb the information supplied during their training. A recent study that used a nationally representative sample of

Figure 1-23
Public middle and high school teachers who participated in professional development programs that focused on various topics in past 12 months, by subject field: 1999–2000



SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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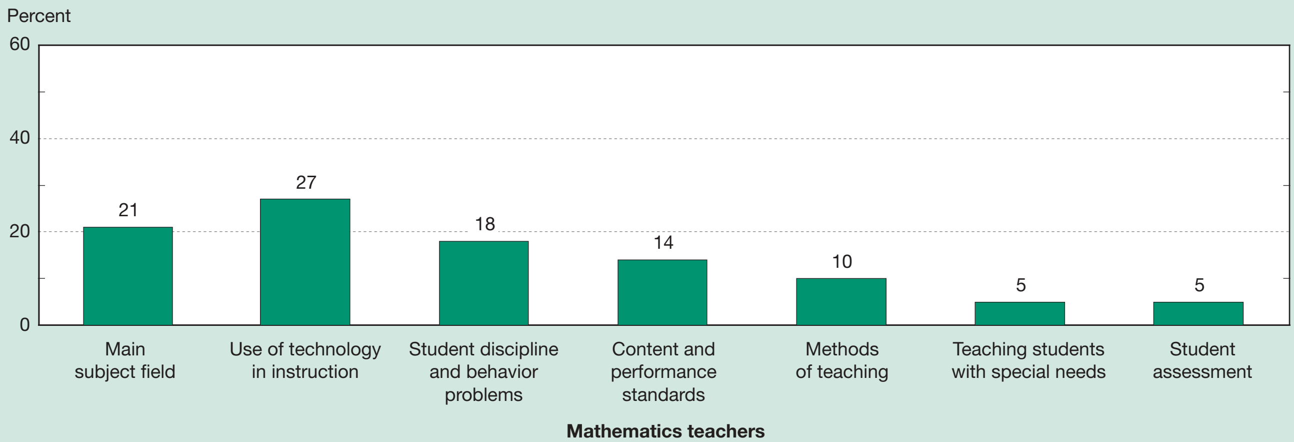
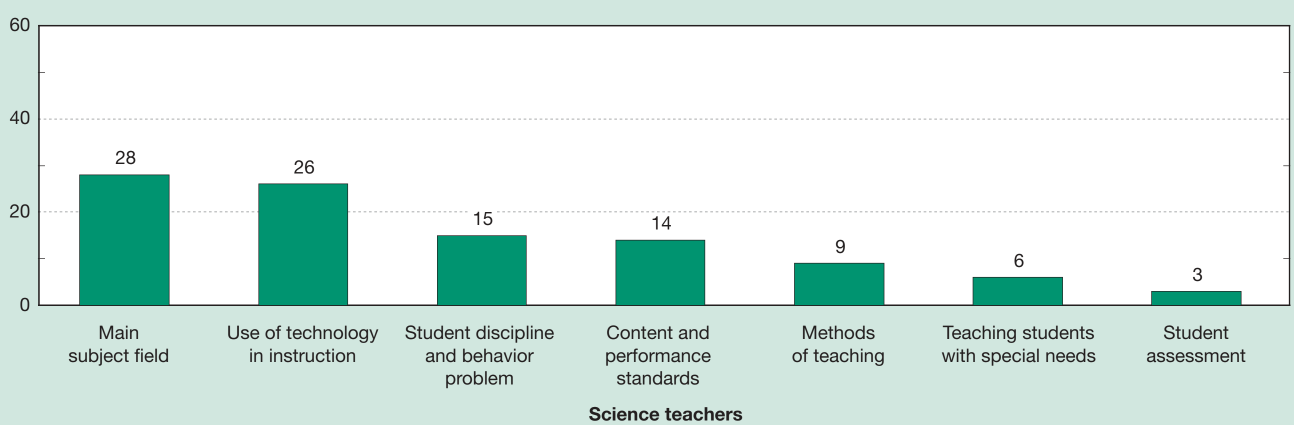
Figure 1-24
Public middle and high school mathematics and science teachers who rated various topics as first priority for additional professional development: 1999–2000





SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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mathematics and science teachers to identify characteristics of effective professional development supported this statement (Garet et al. 2001). Researchers generally agree that short-term professional development activities are not as conducive to meaningful change in teaching performance as more intensive activities (Little 1993).

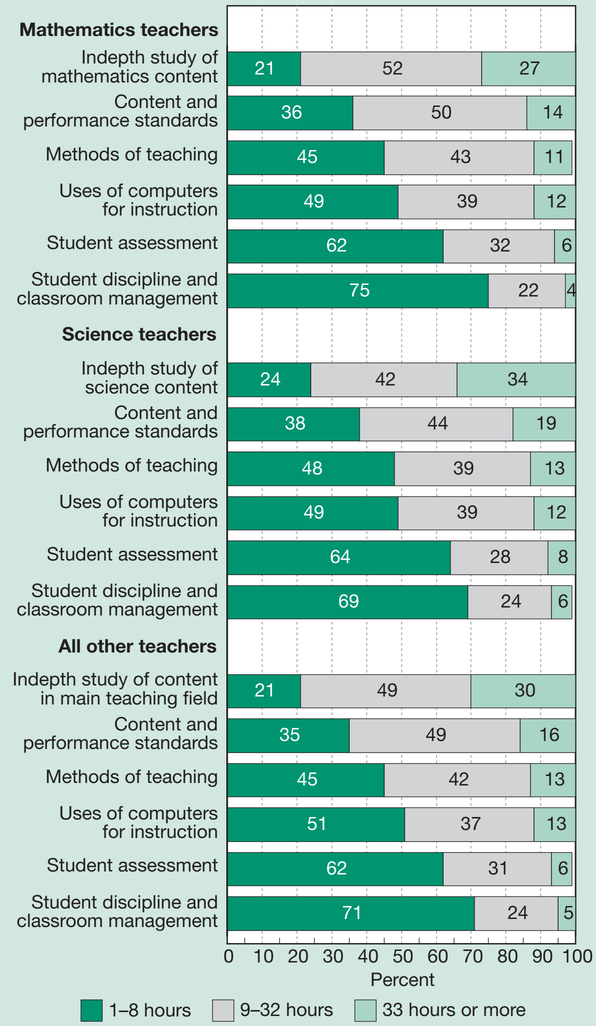
Although the majority of mathematics and science teachers (68 and 71 percent, respectively) reported participation in professional development programs on the use of computers for instruction (figure 1-23), only about half of those participants reported attending such programs for more than 8 hours, or the equivalent of 1 or more days (figure 1-25). Mathematics and science teachers were most likely to spend more than 1 day of professional training on the indepth study of their main subject field or on content and performance standards. Between 42 and 52 percent of mathematics and science participants reported spending more than 1 day of training on these two topics and an additional 14 to 34 percent reported participating for about a week or more. The topics on which teachers spent the least amount of time in training were student assessment and discipline and classroom management.

Perceived Usefulness of Professional Development

Available national surveys provide information about the prevalence of professional development, topic coverage, and duration, but reveal little about the structure and quality of these programs (Mayer, Mullens, and Moore 2000). Using the 1993–94 SASS, Choy and Chen (1998) found that most teachers had positive views about the impact of their professional development programs. For example, 85 percent of teachers who participated in professional development programs thought these programs provided them with new information, 65 percent agreed that these programs made them change their teaching practices, and 62 percent agreed that the programs motivated them to seek further information or training. Parsad, Lewis, and Farris (2001) also found that most teachers (at least 89 percent) who participated in professional development programs in various areas believed that these programs somewhat improved their teaching. Teachers who participated in longer programs reported this more often than those who participated only in shorter programs.

In academic year 1999, mathematics and science teachers who participated in professional development programs on various topics for more than 8 hours generally found them useful. In public middle and high schools, approximately three-fourths of teachers who participated in longer programs covering indepth study of their main subject field or the use of computers for instruction found these programs useful or very useful (appendix table 1-16). Approximately two-thirds of participants found programs on content and performance standards, student assessment, student discipline and classroom management, and methods of teaching useful. Teachers' perceptions of the usefulness of various professional development programs were related to their duration: teachers who participated in training for 8 hours or more were more likely than those who participated for from 1 to 8 hours to report that the training was useful or very useful.

Figure 1-25
Public middle and high school teachers who participated in professional development programs on various topics, by time spent on topic and subject field: 1999–2000



NOTE: Percents may not sum to 100 because of rounding.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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Teacher Salaries and Working Conditions

Although good working conditions can help attract and retain teachers, salary also matters. In an effort to attract and retain high-quality teachers, many states and school districts are attempting to raise teacher salaries and improve working conditions (NCTAF 2003). The following analysis examines trends in teacher salaries over recent decades, compares salaries of U.S. teachers to those of their counterparts in other nations, and looks at conditions in which teachers work.

Trends in Teacher Salaries

Average salaries (in constant 2001 dollars) of all public K–12 teachers decreased between 1970 and 1980 by about $700 annually (Nelson, Drown, and Gould 2002) (figure 1-26). Teacher salaries rose in the 1980s and continued to grow, albeit slowly, during the 1990s. In academic year 2000, the average salary for all public K–12 teachers was $43,250. After adjusting for inflation, this was about $1,000 more than the average salary of teachers in academic year 1990.

The overall trend of salaries for beginning teachers resembled the trend for all teachers. However, during recent years, beginning teacher salaries have risen faster than the salaries of all teachers, increasing more than 4 percent in academic years 1999 and 2000 compared with 3.3 to 3.4 percent for all teachers (Nelson, Drown, and Gould 2002). However, beginning teachers receive substantially lower salaries than the average salary for new college graduates in other occupations. In academic year 2000, the average starting salary offer to college graduates in other occupations was $42,712, whereas the average salary for beginning teachers was just under $29,000 (Nelson, Drown, and Gould 2002). Teacher salaries typically are 9-month based.

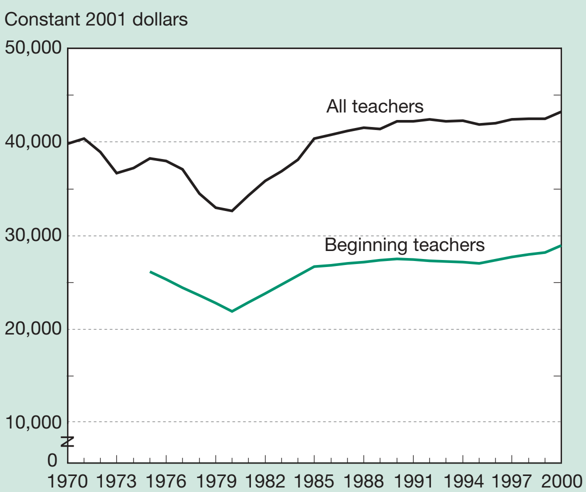
International Comparisons of Teacher Salaries

Compared with teachers in many other countries, U.S. teachers are paid relatively well. In 2000, the annual statutory salaries of lower and upper secondary teachers with 15 years of experience in the United States were about $40,072 and $40,181, respectively, compared with respective averages of $31,221 and $33,582 for teachers in OECD countries (figure 1-27).[18]

Nevertheless, teacher pay scales in the United States tend to be lower than those in a number of other countries. For example, the annual statutory salary of U.S. lower secondary teachers with 15 years of experience ($40,072) lagged behind those of Switzerland (U.S. dollars $54,763), South Korea (U.S. dollars $43,800), and Japan (U.S. dollars $42,820). Gaps were particularly wide at the upper secondary (high school) level because some countries require higher educational qualifications and thus pay teachers significantly more at this level. For example, in 2000, the statutory salaries for upper secondary teachers with 15 years of experience exceeded $42,000 in Germany, the Netherlands, Belgium, South Korea, and Japan, and exceeded $65,000 in Switzerland (OECD 2002). The comparable salary for the United States was about $40,000.

Comparing statutory salaries relative to per capita gross domestic product (GDP) is another way to assess the relative value of teacher salaries across countries. A high salary relative to per capita GDP suggests that a country invests more of its financial resources in its teachers. Relative to per capita GDP, teacher salaries rank lowest in the Czech Republic, Hungary, and Norway, and highest in South Korea, Switzerland, and Spain (figure 1-27). The United States had a below-average ratio of teacher salaries relative to per capita GDP (1.12 compared with 1.35 for lower secondary teachers, and 1.12 compared with 1.45 for upper secondary teachers). These data indicate that the United States spent a below-average share of its wealth on teacher salaries.

Figure 1-26
Salary trends for public K–12 and beginning teachers: Academic years 1970–2000



NOTE: Salary data for beginning teachers before 1975 were not available.

SOURCE: F. H. Nelson, R. Drown, and J. C. Gould, *Survey & Analysis of Teacher Salary Trends 2001* (Washington, DC: American Federation of Teachers, 2002).

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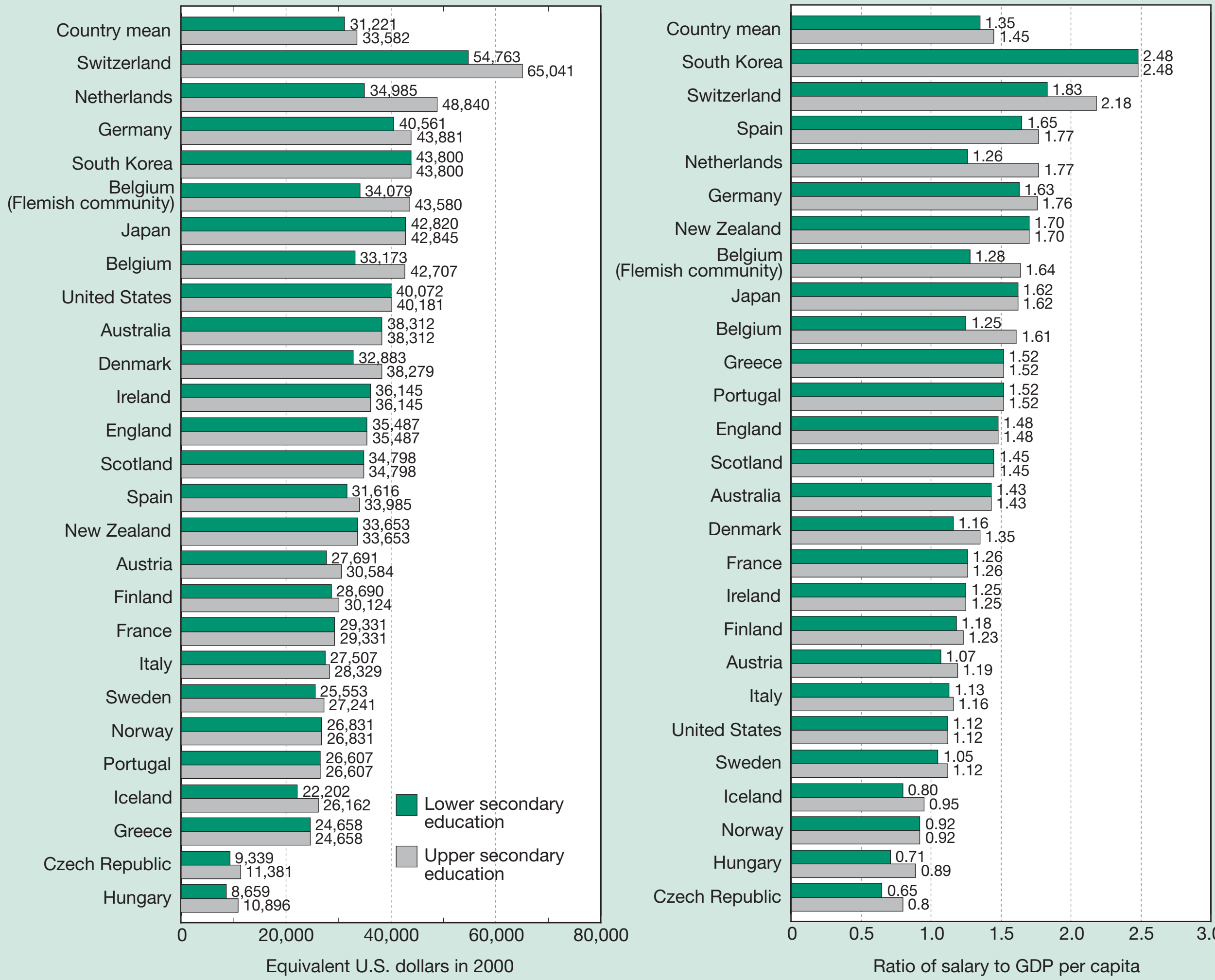
Variation in Average Salaries of U.S. Mathematics and Science Teachers

The 1999–2000 SASS data indicate that the base salaries of public middle and high school mathematics and science teachers averaged between $39,000 and $40,000 in academic year 1999, a range similar to that for all other teachers (figure 1-28). Their average earnings, which included additional school-year compensation (e.g., from coaching, sponsoring a student activity, or teaching evening classes), summer school salaries, and any nonschool earnings, totaled between $42,000 and $45,000 for mathematics and science teachers, not significantly different from the average earnings of between $43,000 and $45,000 for all other teachers.

Mathematics and science teachers in high-poverty public high schools tended to earn less than their counterparts in low-poverty public high schools, but the pattern differed in schools with high- and low-minority enrollment (figure 1-29). Mathematics teachers in high-minority schools earned more than their counterparts in low-minority schools ($46,000 compared with $42,000), and science teachers in

[18]Statutory salaries refer to official pay scales and are different from actual salaries, which are also influenced by other factors such as the age structure of the teaching force or the prevalence of part-time work (OECD 2002). Salaries are expressed in equivalent U.S. dollars converted using OECD purchasing power parities (see discussion in chapter 4).

Figure 1-27
Annual statutory salary of public school teachers with 15 years experience and ratio of statutory salaries to GDP per capita, by level of schooling and OECD country: 2000



GDP gross domestic product
OECD Organisation for Economic Co-operation and Development

NOTES: Salaries refer to scheduled annual salary of full-time teacher with minimum training necessary to be fully qualified. OECD countries are Australia, Austria, Belgium, Belgium (Flemish community), Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Turkey and Mexico were omitted from this figure because of missing data.

SOURCE: OECD, *Education at a Glance: OECD Indicators 2002* (Paris, 2002).

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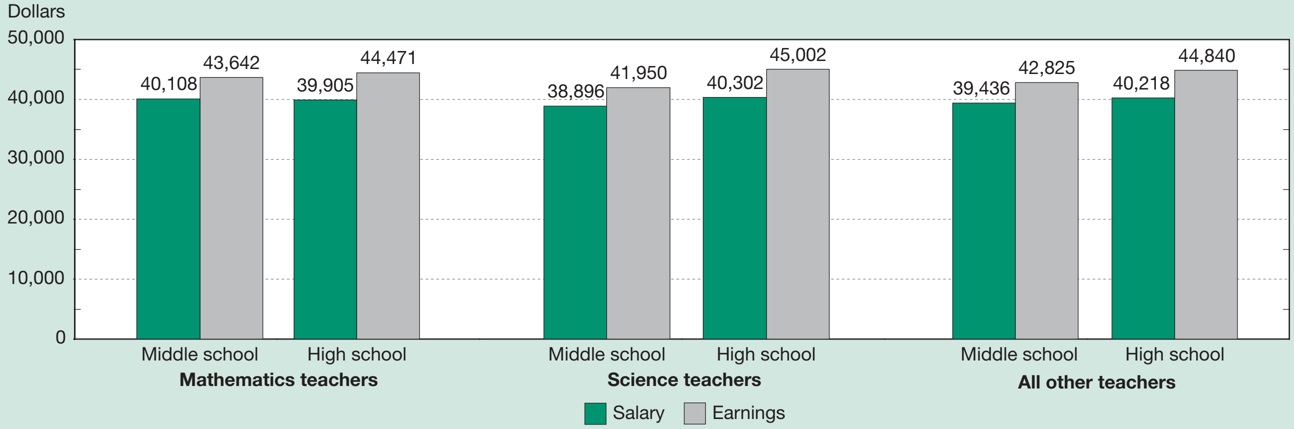
high-minority schools earned about the same as their counterparts in low-minority schools ($45,000 compared with $43,000). These differences may partially reflect different experience levels.

Mathematics and science teachers in high-poverty public high schools were less likely than their counterparts in low-poverty schools to feel satisfied with their salaries (figure 1-29). Although teachers in high-minority schools earned more than (mathematics teachers) or as much as (science teachers) their counterparts in low-minority schools, they were less satisfied with their salaries. Differences in cost of living and working conditions may help explain this finding.

Other Aspects of Working Conditions

Other aspects of teachers' working conditions can affect teacher recruitment and retention (Ingersoll 2001, NCES 1997a, and NCTAF 2003). The 1999–2000 SASS data indicate that, in many respects, teachers found their working environments to be supportive. A majority of public high school teachers agreed that their principal made staff members aware of expectations (86 percent) and enforced school rules (79 percent), they received support and encouragement from their school administration (77 percent), their school district made necessary materials available (75 percent), and staff members worked together cooperatively (73 percent) (figure 1-30). However, teachers in high-poverty and high-

Figure 1-28
Average base salary and total earnings of public school teachers, by subject field: 1999–2000



NOTE: Total earnings include base salary, additional school year compensation (e.g., from coaching, sponsoring a student activity, or teaching evening classes), summer school salaries, and any nonschool earnings.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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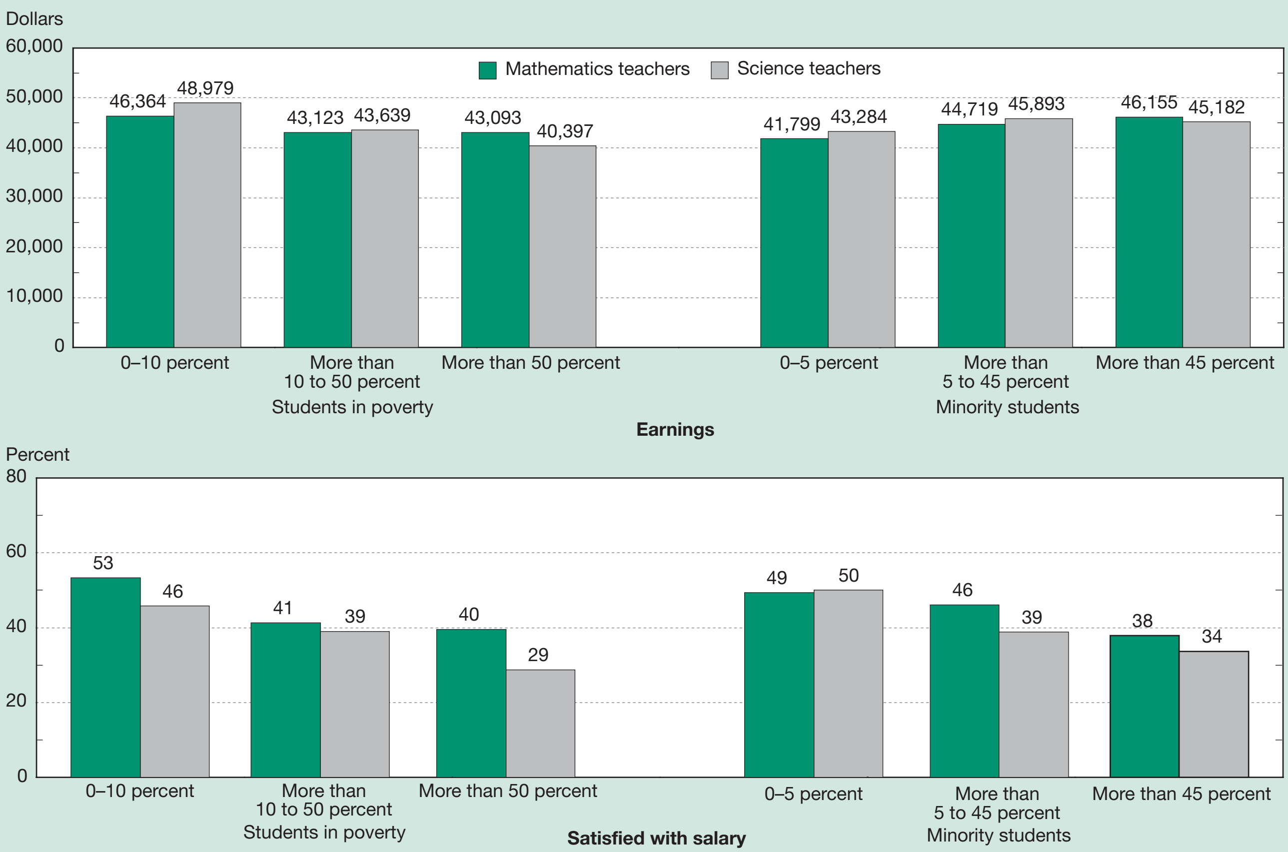
Figure 1-29
Total earnings of public high school mathematics and science teachers and percentage of teachers satisfied with salary, by poverty level and minority enrollment in school: 1999–2000



NOTE: Students in poverty are those who are approved for free or reduced-priced lunches.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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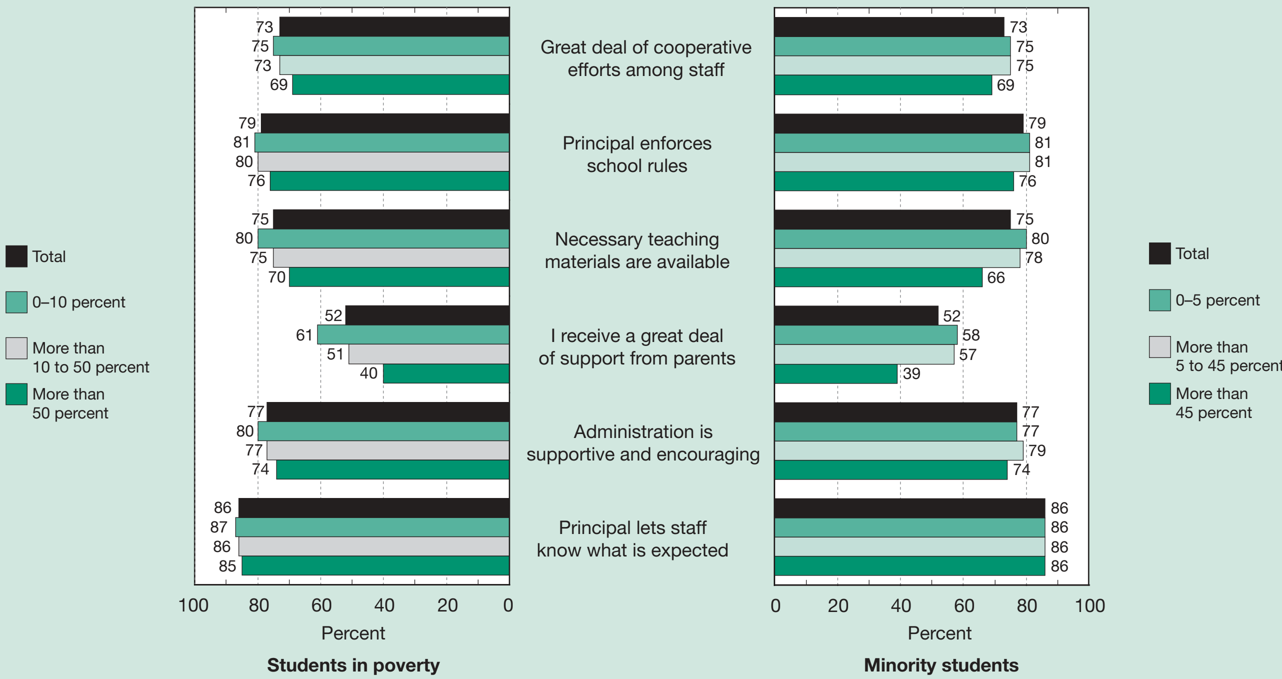
Figure 1-30
Public high school teachers who agreed or strongly agreed with various statements about support they received in school, by poverty level and minority enrollment in school: 1999–2000



NOTE: Students in poverty are those who are approved to receive free or reduced-priced lunches.

SOURCE: U.S. Department of Education, National Center for Education Statistics, Schools and Staffing Survey, 1999–2000.

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minority schools had less favorable perceptions of their working conditions. They were less likely to report that they received a great deal of parent support, administrators provided support and enforced school rules, colleagues worked together cooperatively, and school districts made necessary teaching materials available (figure 1-30).

A majority of public high school teachers experienced some problems in their schools that they identified as moderate or serious. These problems included students coming to school unprepared to learn (72 percent), student apathy (69 percent), absenteeism (65 percent), tardiness (56 percent), disrespect for teachers (55 percent), and truancy (39 percent) (appendix table 1-17). These problems were more likely to be reported in high-poverty and high-minority schools.

Information Technology in Schools

As IT becomes more pervasive in U.S. society, unfamiliarity with IT will increasingly limit students' economic and educational opportunities. Data on student access to IT at home and at school provide indications of the degree to which Americans become acquainted with IT and the Internet during their school years, including the degree to which exposure varies with demographic characteristics.

Schools have sought to take advantage of IT to improve education. Much remains to be learned about how IT can be used to help students learn mathematics and science, and much experimentation is under way. The NCLB Act authorizes funds for states and districts to increase IT use, and it places particular emphasis on equalizing access for students in all schools.

This section describes data on student access to IT in school, ways in which schools currently use IT for instruction in mathematics and science, and teacher preparation for its use. It also looks at student access to IT at home.

IT Access at School

A vast majority of students now study in schools and classrooms with computers and at least some form of Internet access. Where differences in school access persist, they concern student-computer ratios, teacher preparation for using IT, and ways in which teachers use IT. These issues go beyond sheer access to encompass quality and effectiveness in IT use.

Access to computers and the Internet has increased rapidly during the past decade. Virtually all schools have Internet access in at least one location; in fact, most classrooms have access. By fall 2001, an estimated 99 percent of public schools and 87 percent of instructional rooms had Internet connections. (Instructional rooms include classrooms, computer and other labs, library/media centers, and any other rooms used for instructional purposes.) This represents a dramatic increase over 1994, when only 35 percent of public schools and 3 percent of instructional rooms had Internet connections (Kleiner and Farris 2002).

Schools with high concentrations of students eligible for the Free/Reduced-Price Lunch Program or with high minority enrollment tend to have somewhat less access. Classrooms in these schools were less likely to have computers and the number of students per Internet-accessible instructional computer was higher. In schools with 75 percent or more students eligible for the Free/Reduced-Price Lunch Program, the ratio of students to Internet-accessible computers reached 6.8:1, compared with 4.9:1 in schools with fewer than 35 percent eligible students. The figures for minority enrollments show a similar difference: a 6.4:1 ratio for schools with 50 percent or more minority enrollment versus a 4.7:1 ratio in schools with 5 percent or less minority enrollment. However, access in low-income and minority schools increased between 2000 and 2001. The proportion of instructional rooms with Internet access rose from 60 to 79 percent in schools with the highest concentration of poverty, and from 64 to 81 percent in schools with the highest minority enrollment (Kleiner and Farris 2002).

IT in Math and Science Instruction

As early as kindergarten, a majority of students have access to IT at school. According to the Early Childhood Longitudinal Study (ECLS), in spring 1999, most kindergartners used computers in the classroom at least weekly to learn mathematics (61 percent), and some used them to learn science (20 percent) (Rathburn and West 2003).

At the high school level, large majorities of public school teachers in all fields report using computers for instructional purposes (appendix table 1-18). Teachers who had used computers in classes during the previous 2 weeks were asked to select one of their classes and indicate how often they used computers for various purposes in that class. Teachers reported using computers for practicing skills, solving problems, learning course materials, and working collaboratively more often than they reported using them to produce multimedia projects or correspond with experts or others outside the school. In this respect, mathematics and science teachers did not differ greatly from their colleagues who teach other subjects.

NAEP data show substantially increased use of computers in mathematics and science classes between 1996 and 2000. In 2000, the percentage of mathematics teachers in grades 4, 8, and 12 who reported that their students had access to computers in their classrooms at all times increased at least 20 percentage points above the 1996 level. Computer use in fourth and eighth grade science classes also increased during this period. NAEP did not collect data on 12th grade science classes (NCES 2001c and 2003b).

In 2000, more than half of 12th grade science students used computers in each of the following ways: collecting data, analyzing data, downloading data and related information from the Internet, and using lab equipment that interfaces with computers. Almost half reported using the Internet to exchange information with other students or scientists about experiments (NCES 2003c). Educators are currently exploring a variety of new uses of IT (see sidebar "New IT Forms and Uses").

High school mathematics and science teachers in schools with a high percentage of minority students who had used computers within the previous 2 weeks reported somewhat different use patterns than their counterparts in other high schools. These teachers were more likely to use computers to practice skills, solve problems, and teach course material in more class periods than teachers in schools with a lower percentage of minority students.

Teacher Preparation and Training in Using IT

Advocates for IT in schools stress that teachers need both targeted and meaningful professional development and timely, accessible, and ongoing technical support to help them use IT effectively in their teaching (Bray 1999, CEO Forum on Education and Technology 1999, and Hruskocy et al. 1997). The NCLB Act requires each local education agency receiving formula funds from state technology grants (Title II, Part D, Subpart 1) to allocate 25 percent of its funds for high-quality professional development toward integrating technology into instruction.

Recent large-scale studies indicate that teachers want more support in integrating IT into everyday classroom practice. In 1999, two-thirds of teachers listed inadequate teacher training as a barrier to effective IT use. However, new teachers (those with 3 or fewer years of teaching experience) were less likely to report that they were not at all prepared to use computers and the Internet for classroom instruction (10 percent) than teachers with 10 to 19 years of teaching experience (14 percent), or with 20 or more years (16 percent). In addition, teachers in this survey identified other barriers to using IT effectively as being as important as lack of training: lack of release time (82 percent), lack of scheduled time for students to use computers (80 percent), insufficient computers (78 percent), lack of good instructional software (71 percent), outdated computers with slow processors (66 percent), and difficulty accessing the Internet connection (58 percent) (NCES 2000c).

States are addressing the need for computer literacy among teachers. As of 2002, 26 states and the District of Columbia required IT training or coursework before initial teacher licensure. In seven states, teachers must demonstrate their technological skill in order to receive a license. Thirteen states offer various incentives, such as free laptop computers or continuing education credits, to encourage teachers to use IT in their classrooms. In 2002, 22 states offered incentives for principals and administrators to use IT in schools, up from 11 states in 2000 (Editorial Projects in Education 2002).

Teachers who participate in IT-oriented professional development activities appear likely to increase their use

New IT Forms and Uses

Some studies have found that although most teachers now use computers in their classrooms, they often use them for drill-and-practice exercises rather than for more sophisticated tasks and projects such as multimedia projects and teaching from Internet-based curricula (NCES 2000c). However, new forms of IT are introduced into the classroom each year. Distance education (in which time, location, or both separate the instructor and students) and online learning (also known as electronically delivered learning or *e-learning*) have begun to change the landscape of education, especially at the secondary level. Distance education courses are delivered to remote locations via synchronous (real time) or asynchronous means of instruction, and include written correspondence, text, graphics, audio- and videotape, CD-ROM, online learning, audio- and videoconferencing, interactive TV, and facsimile (Kaplan-Leiserson 2000).

E-learning covers a broad set of applications and processes, including Web-based learning, computer-based learning, virtual classrooms, virtual high schools, and digital collaboration.* It includes the delivery of content via the Internet, an intranet, audio- and videotape, satellite broadcast, interactive TV, or CD-ROM. Twelve states have established fully operational online or virtual high school programs for academic year 2001, and five other states have programs in development. Well-established virtual high schools in Florida and Utah have student enrollments in the thousands (Clark 2001). Twenty-five states allow for the creation of virtual, or cyber, charter schools, and 32 states have various e-learning initiatives underway, according to a new survey of state IT coordinators (Editorial Projects in Education 2002). These programs and policy changes make online education available to many more students. For example, e-learning may give students in small, rural, or less affluent high schools access to specialized courses such as AP courses. A recent report estimates that 40,000 to 50,000 K–12 students enrolled in an online course during academic year 2001 (Clark 2001). Currently, most of these students are high school students, but momentum to serve elementary and middle school pupils is building.

Popular innovative technologies that use a range of multimedia applications include digital white boards, videodisk, CD-ROM, and Web-based digital imaging. These technologies facilitate visualization and simulations in mathematics and science. In some cases, these technologies supplement other forms of instruction, whereas in others, they provide the basis for distance learning applications that do not include live instruction (Clark 2001; and Thompson, Ganzglass, and Simon 2001). Potential uses span the spectrum from embellishments within a traditional lecture to instruction that is completely Internet-based.

* A virtual high school is a state-approved and/or regionally accredited school offering secondary courses through distance learning methods that include Internet-based delivery (Clark 2000).

of IT (Becker 1999, Fatemi 1999, and Wenglinsky 1998). Teachers who spent 9 or more hours per year on professional development in this area felt substantially better prepared to use computers and the Internet in class than those who had spent less time (NCES 2000c).

In addition to classroom applications, the Internet also provides teachers with the opportunity to expand their professional learning communities and to share curricula and instructional strategies with other teachers. Databases of curriculum materials and electronic discussion lists provide teachers with access to a broad range of resources and colleagues. Telementoring has become a popular way of providing effective coaching and training for teachers, especially in technology integration (Harris 1999). The Internet also facilitates schools' partnerships and communications with external organizations, parents, and the community. Industry partners sometimes help train teachers in how to use IT effectively or provide schools with financial resources and equipment (CEO Forum on Education and Technology 1999; Means 1998; and Rocap, Cassidy, and Connor 1998).

IT Access at Home

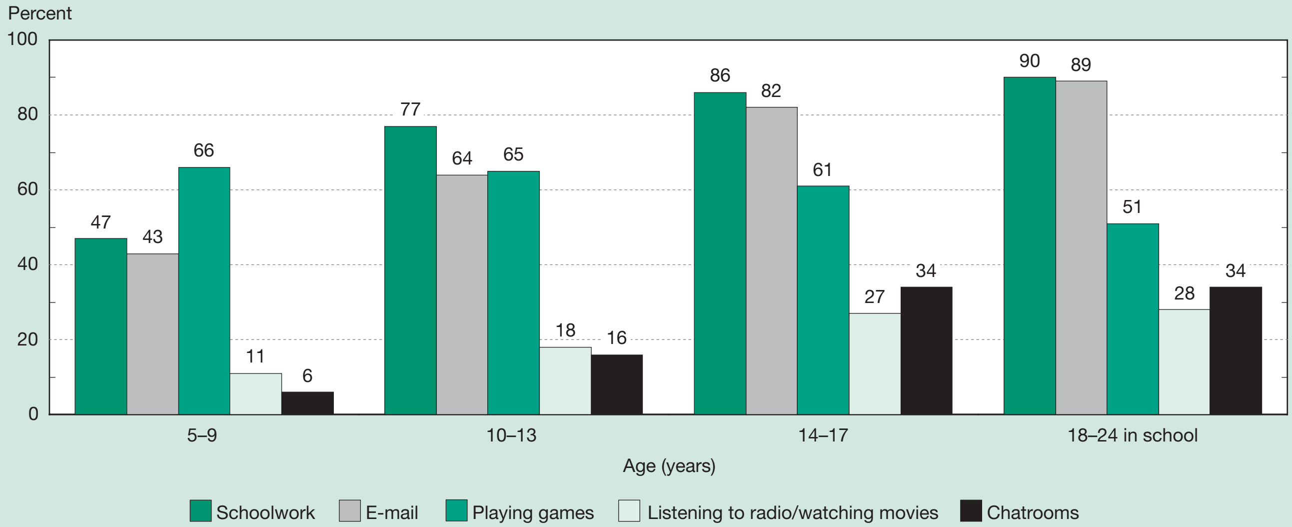
Because Internet access provides educational and social opportunities that can be increasingly important for school-aged children, it is important to look at access to this relatively recent technology outside the classroom. Approximately 77 percent of preteens (ages 10–13) and 86 percent of teens (ages 14–17) use the Internet when doing their schoolwork (figure 1-31).

Families with children more often have computers and Internet connections than do other households. According to a National Telecommunications and Information Administration report (NTIA 2002) based on September 2001 Current Population Survey (CPS) data, 70 percent of such families had computers compared with 59 percent of families with no children and 39 percent of nonfamily households.[19] Similar differences existed in Internet access, at 62 percent access for family households with children under the age of 18, 53 percent for family households with no children, and 35 percent for nonfamily households. Home access is much more unequally distributed than school access. Low-income (figure 1-32) and minority (NTIA 2002) children are much less likely than their peers to have Internet access at home.

Approximately one-third of children ages 10–17 in the lowest income category have home access to computers, but access in the highest income group is nearly universal. Overall computer use at school is much more equal, at 80 percent for children in the lowest income category and 89 percent for those in the highest income category. As a result, reliance on school for access is common for children in the lowest income category, where 52 percent use computers at school but not at home. However, it is rare in the highest income category,

[19]Conducted by the U.S. Department of Commerce's Census Bureau, CPS provides a very reliable measure of computer and Internet access because it surveyed approximately 57,000 households containing more than 137,000 individuals in all 50 states and the District of Columbia.

Figure 1-31
Major uses of Internet among U.S. children and young adults, by selected age groups: 2001



SOURCES: U.S. Department of Commerce, National Telecommunications and Information Administration (NTIA) and Economics and Statistics Administration, using U.S. Bureau of the Census Current Population Survey Supplements, September 2001; and U.S. Department of Commerce, NTIA, *A Nation Online: How Americans Are Expanding Their Use of the Internet* (Washington, DC, 2002), http://www.esa.doc.gov/nationonline.cfm. Accessed 10 March 2003.

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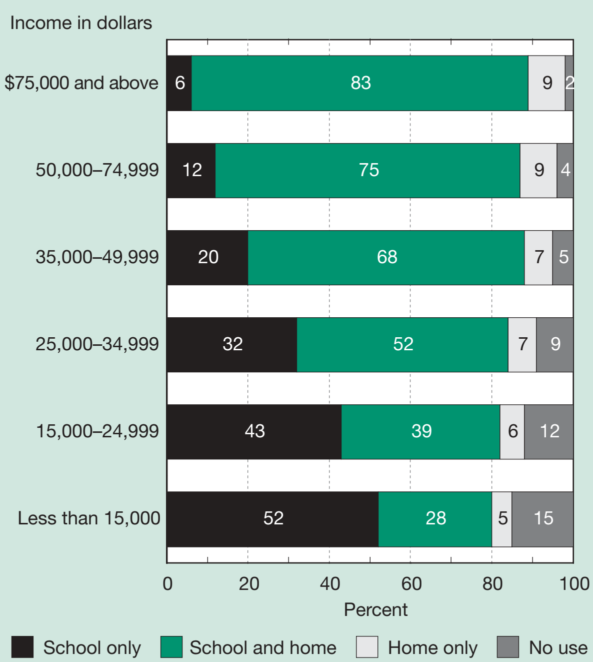
Figure 1-32
Computer use among 10–17-year-olds, by household income and location: 2001



NOTE: Percents may not sum to 100 because of rounding.

SOURCES: U.S. Department of Commerce, National Telecommunications and Information Administration (NTIA) and Economics and Statistics Administration, using U.S. Bureau of the Census Current Population Survey Supplements, September 2001; and U.S. Department of Commerce, NTIA, *A Nation Online: How Americans Are Expanding Their Use of the Internet* (Washington, DC, 2002), http://www.esa.doc.gov/nationonline.cfm. Accessed 10 March 2003.

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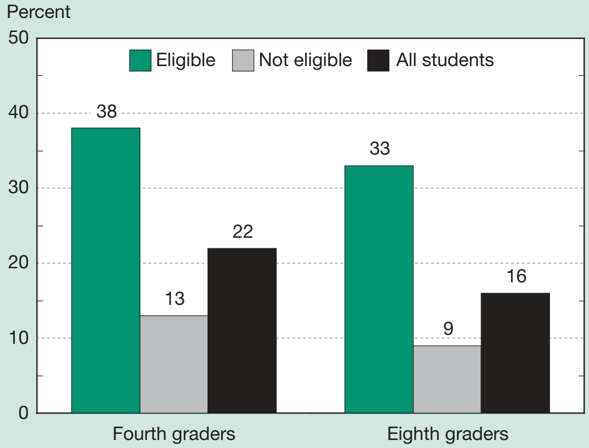
where the corresponding figure is 6 percent. Although schools do play a role in equalizing access, figure 1-32 also shows that the lower a family's income, the more likely it is that the children do not use computers at all.

NAEP data present similar findings about the relationship between income and home computer access. Overall, 78 percent of fourth graders and 84 percent of eighth graders reported having a computer available at home. Among students eligible for the Free/Reduced-Price Lunch Program, however, only 62 percent of fourth graders and 67 percent of eighth graders had computers at home (Editorial Projects in Education 2002) (figure 1-33).

Home access to the Internet is likewise strongly associated with family income. Figure 1-34 shows that 22 percent of children in the lowest income category use the Internet at home compared with 83 percent in the highest income category. A substantially larger disparity related to income exists in children's access to the Internet at school (35 percent of children in the lowest income households versus 63 percent of children from the highest income households) compared with the disparity for school computer access overall. As a result, a much greater difference exists in Internet use between children in the highest and lowest income groups (42 percentage points) than exists for computer use overall (13 percentage points) (figures 1-32 and 1-34). Thus, although schools have helped reduce the disparities associated with family income in children's overall access to computers, they appear to do much less to reduce income-related disparities in children's access to the Internet.

Racial and ethnic differences are also big. Black and Hispanic students lag far behind their white and Asian/Pacific

Figure 1-33
Fourth and eighth graders without computers at home, by eligibility for national free or reduced-price lunch programs: 2001



SOURCE: U.S. Department of Education, National Center for Education Statistics, NAEP Data Tool Online, 2000, http://nces.ed.gov/nationsreportcard/naepdata. Accessed 10 March 2003.

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Islander counterparts when it comes to home computer access, with 45 percent of black children and 39 percent of Hispanic children having access to a home computer compared with 79 percent of whites and 74 percent of Asian/Pacific Islanders (U.S. Bureau of the Census 2001).

At almost every income level, fewer households in rural areas own computers compared with those in urban or central city areas (NTIA 1999).

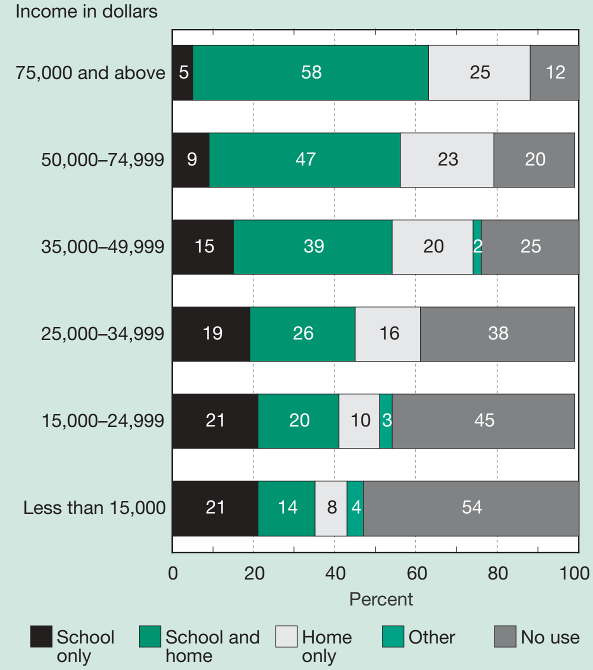
Transition to Higher Education

Adequate preparation of high school graduates for their transition to postsecondary education remains a concern. This section examines data on the college enrollment rates of high school graduates, compares postsecondary participation at the international level, and describes remedial coursetaking by U.S. college students.

Immediate Transition From High School to Postsecondary Education

The percentage of high school graduates who enrolled in postsecondary education immediately after graduation has increased over the past 3 decades, rising from 47 percent in 1973 to 62 percent in 2001 (figure 1-35 and appendix table 1-19) (NCES 2003a). The enrollment rate of any particular cohort or subgroup depends on several factors, including academic preparedness, access to financial resources (e.g., personal resources and financial aid), the value placed on postsecondary education relative to alternatives such as working, and the job market for high school graduates.

Figure 1-34
Internet use among 10–17-year-olds, by household income and location: 2001



NOTE: Percents may not sum to 100 because of rounding.

SOURCES: U.S. Department of Commerce, National Telecommunications and Information Administration (NTIA) and Economics and Statistics Administration, using U.S. Bureau of the Census Current Population Survey Supplements, September 2001; and U.S. Department of Commerce, NTIA, *A Nation Online: How Americans Are Expanding Their Use of the Internet* (Washington, DC, 2002), http://www.esa.doc.gov/nationonline.cfm. Accessed 10 March 2003.

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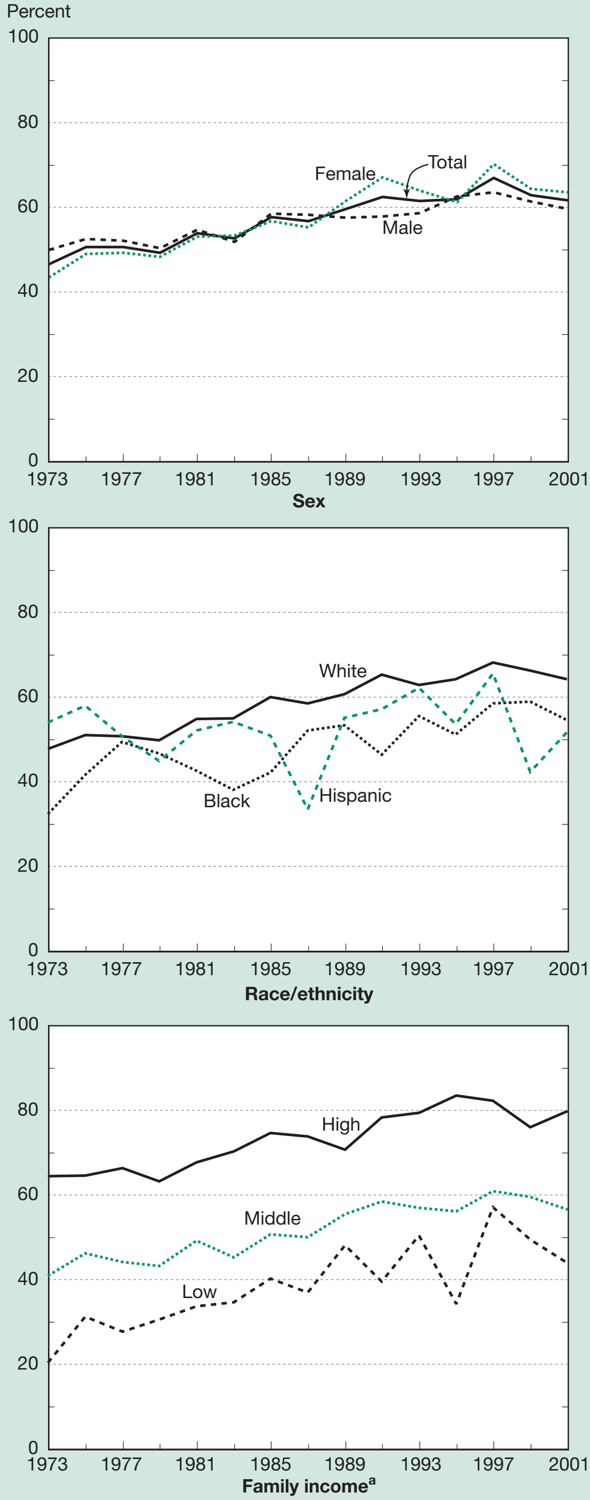
Sex, Race/Ethnicity, and Family Income

The immediate enrollment rate of high school graduates in 2- and 4-year colleges has increased more for females than males (figure 1-35 and appendix table 1-19). Between 1973 and 2001, the rate at which females enrolled in postsecondary institutions increased from 43 to 64 percent, whereas the rate for males increased from 50 to 60 percent.

The immediate enrollment rate for white high school graduates increased from 48 percent in 1973 to 64 percent in 2001 (figure 1-35 and appendix table 1-19). For black graduates, the immediate enrollment rate increased from 32 percent in 1973 to 55 percent in 2001. Although enrollment rates for blacks were generally lower than those for whites, the gap between the two groups has diminished since 1983. Among Hispanics, immediate enrollment rates remained relatively constant between 1973 and 2001; thus, the gap between Hispanic students and white students has increased.

The gap in immediate postsecondary enrollment rates between high school graduates from high- and low-income families persisted from 1973 to 2001 (figure 1-35 and appendix table 1-19). This gap reflects both differences in

Figure 1-35
High school graduates enrolled in college the October after completing high school, by sex, race/ethnicity, and family income: 1973–2001



[a]Low income is the bottom 20 percent of all family incomes, high income is the top 20 percent, and middle income is the 60 percent in between.

NOTE: Includes students ages 16–24 completing high school in a given year.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2003*, Indicator 18, 2003. See appendix table 1-19.

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academic preparation and in financial resources available to pay college costs. It also reflects differences in the degree to which students take preparatory steps that lead to college enrollment such as aspiring to a bachelor's degree, taking a college admissions test, and applying for admission (NCES 2002a).

Access to Postsecondary Education: An International Comparison

Many countries have high rates of participation in education beyond secondary school. In 2000, OECD countries had an average 45 percent first-time entry rate into tertiary type A education programs leading to the equivalent of a bachelor's or higher degree, and an average 15 percent first-time entry rate into tertiary type B programs that focus on practical, technical, or occupational skills for direct entry into the workforce (figure 1-36).[20]

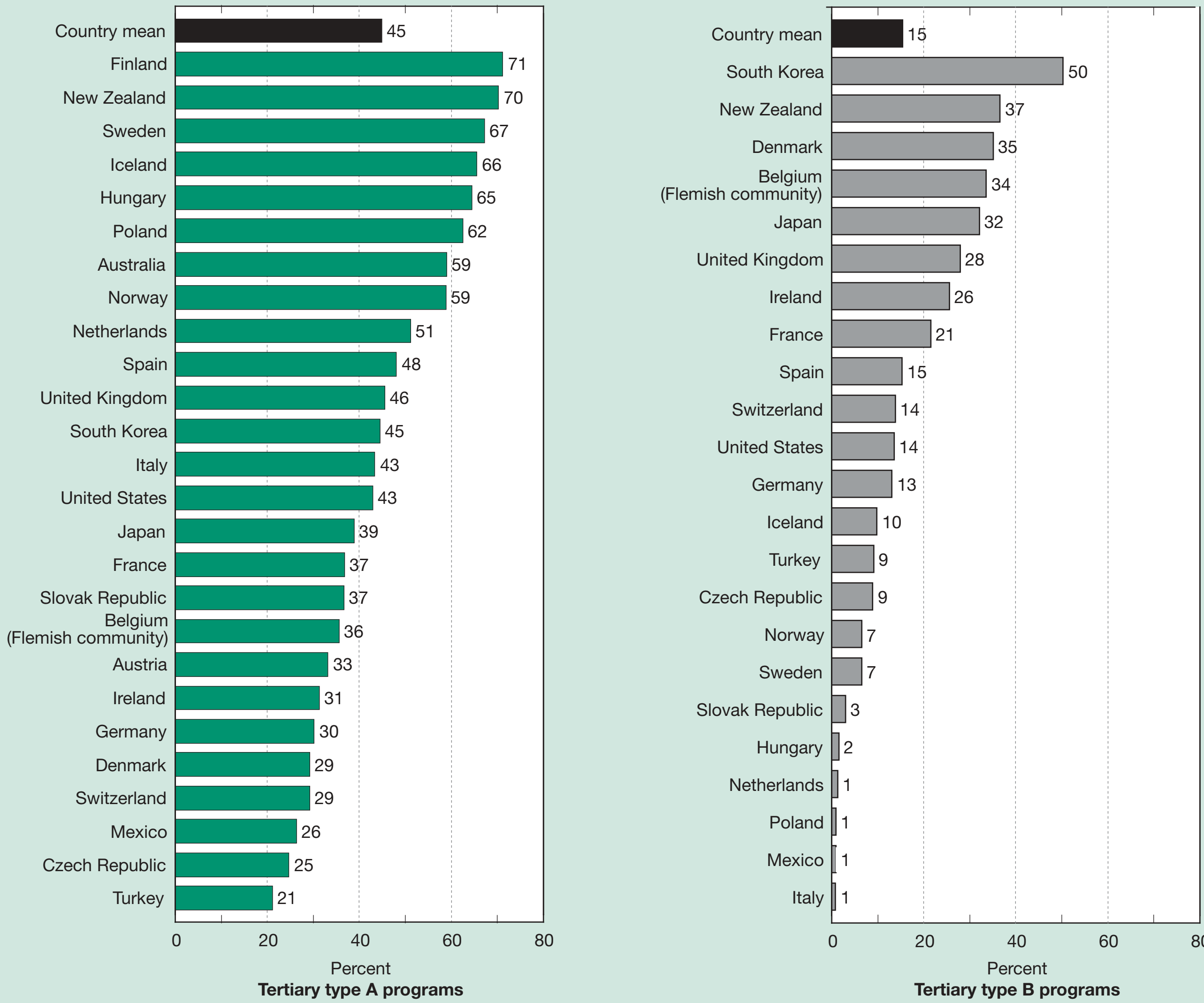
In 2000, U.S. students had entry rates of 43 and 14 percent for tertiary type A and B programs, respectively, which are comparable to the OECD country averages. Finland, New Zealand, Sweden, Iceland, Hungary, and Poland had entry rates for tertiary type A education of more than 60 percent, all significantly higher than the U.S. entry rate. At one time, the United States had a higher entry rate compared with most OECD countries (OECD 1992). However, many OECD countries have adopted policies to expand postsecondary education during recent years, leading to substantially increased participation. In OECD countries, the average 17-year-old in 2000 could be expected to go on to complete approximately 2.5 years of tertiary education, of which 2 years would be full-time study (OECD 2002).

Remedial Education in College

Despite the increasing number of graduates who enter college immediately after high school, many college freshmen apparently lack adequate preparation for higher education. Many postsecondary institutions (78 percent in 1995, for example) offer remedial courses to those needing assistance in doing college-level work (Lewis, Farris, and Greene 1996). Participation in college-level remedial education is widespread (Adelman, Daniel, and Berkovitz forthcoming). About 4 out of 10 students in the NELS:88 cohort who attended postsecondary institutions between 1992 and 2000 took at least one remedial course during their college years: 16 percent took one remedial course, 15 percent took two to

[20]Tertiary type A programs are theoretically based and are designed to provide sufficient qualifications for entry into advanced research programs or professions with high skill requirements. Tertiary type B programs focus on occupationally specific skills so that students can directly enter the labor market. Entry rates are obtained by dividing the number of first-time entrants of a specific age to each type of tertiary education by the total population in the corresponding age group and adding the entry rates for each single age group (OECD 2002). Entry rates do not refer to a specific population group. The U.S. entry rates reported by OECD cannot be directly compared with the immediate enrollment rates in figure 1-35 due to different definitions of postsecondary education and calculations of rates used in the OECD 2002 indicator report.

Figure 1-36
First-time entry rates to tertiary education, by program type and OECD country: 2000



OECD Organisation for Economic Co-operation and Development

NOTES: Tertiary type A programs are designed to provide sufficient qualifications for entry into advanced research programs and professions with high-skill requirements, such as medicine, dentistry, or architecture. Programs have a minimum cumulative duration of 3 years full-time equivalent, although they typically last 4 or more years. Tertiary type B programs focus on practical, technical, or occupational skills for direct entry into the labor market. They have a minimum duration of 2 years full-time equivalent at the tertiary level. OECD countries are Australia, Austria, Belgium, Belgium (Flemish community), Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, South Korea, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. Because of missing data, Belgium, Canada, Greece, Luxembourg, and Portugal were not included in the figure for tertiary type A programs, and Australia, Austria, Belgium, Canada, Finland, Greece, Luxembourg, and Portugal were not included in the figure for tertiary type B programs.

SOURCE: OECD, *Education at a Glance: OECD Indicators 2002* (Paris, 2002).

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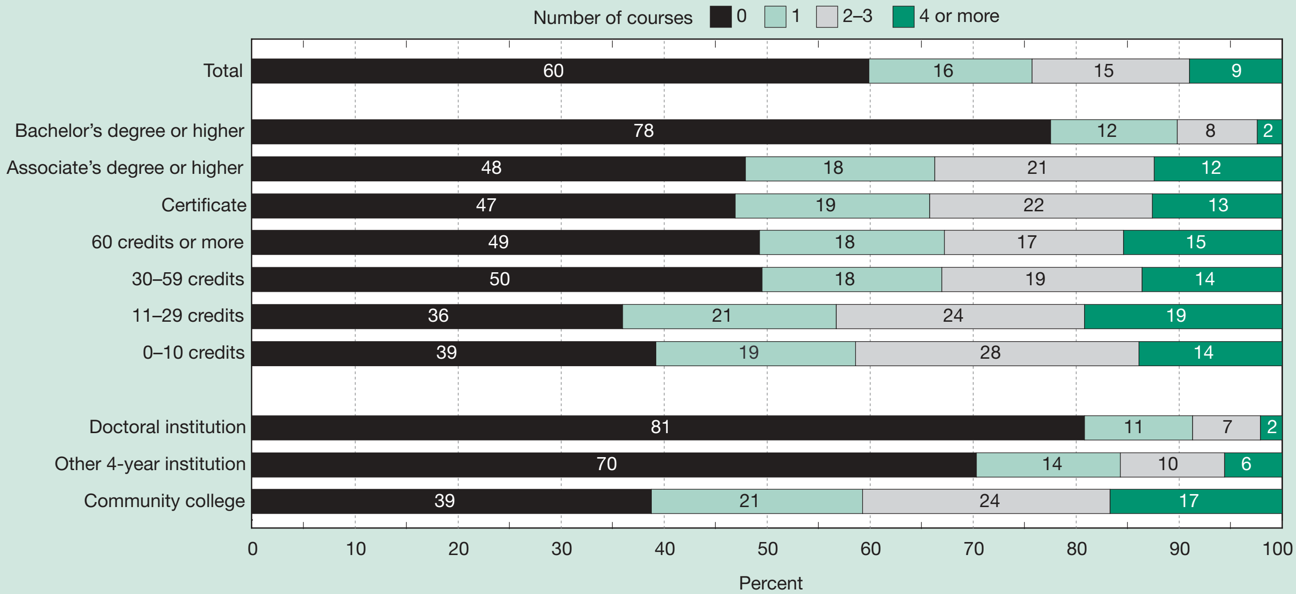
three remedial courses, and 9 percent took four or more such courses (figure 1-37).

Remedial coursetaking was related to students' postsecondary attainment level and the type of institution they first attended. Students who had earned at least a bachelor's degree by 2000 took fewer remedial courses than those who did not. Among those who did not earn any degree but who did accumulate undergraduate credits, at least half took a minimum of one remedial course. Remedial coursetaking occurred more often at community colleges than at 4-year institutions. About 62 percent of students who first attended community colleges took at least one remedial course compared with 20 percent of those who first attended doctoral degree-granting institutions and 30 percent of those who first attended other types of 4-year institutions (figure 1-37). These participation rates may reflect the remedial course offerings of different types of institutions, because 2-year community colleges typically serve as important providers

Figure 1-37
Students taking remedial courses after entering postsecondary education, by number of courses, attainment level, and type of first institution: 1992–2000



NOTES: Percents may not sum to 100 because of rounding. Included in total but not shown separately are students from other subbaccalaureate institutions.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *Postsecondary Attainment, Attendance, Curriculum, and Performance: Some Results From the NELS:88/2000 Postsecondary Education Transcript Study* (PETS:2000) (Washington, DC, forthcoming).

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of remediation. In 1995, almost all public 2-year institutions offered remedial reading, writing, and mathematics courses; in contrast, 81 percent of public 4-year institutions and 63 percent of private 4-year institutions offered remedial courses in these subjects (Lewis, Farris, and Greene 1996). In 2000, enrollment in remedial mathematics courses accounted for 14 percent of total mathematics enrollment in 4-year institutions and 60 percent in 2-year institutions (Lutzer, Maxwell, and Rodi 2002). Although undergraduate enrollment in remedial mathematics courses in 4-year institutions declined by 16 percent from 1990 to 2000, enrollment in remedial mathematics courses in 2-year institutions increased by 5 percent during the same period (Lutzer, Maxwell, and Rodi 2002). Enrollments in remedial S&E courses are not known.

Conclusion

The United States has recorded some improvement in student mathematics and science achievement since the 1970s. But gains have been modest and were mostly achieved before the 1990s. Students are taking more advanced coursework than in the past, and more students are going on to higher education than in earlier decades.

However, compared with students in other countries, U.S. students are not achieving at high levels, and U.S. students fare worse in international comparisons at higher grade levels than at lower grade levels. Several other developed countries appear to be producing better qualified cohorts of high school graduates and sending as many or more of them on to higher education.

Achievement differences between male and female students have largely disappeared, especially in mathematics. However, substantial gaps persist among different racial/ethnic and income groups. Blacks and Hispanics are achieving at lower levels than whites and Asian/Pacific Islanders, and students in high-poverty schools are doing worse than their peers in low-poverty schools. Coursetaking patterns parallel these achievement patterns, although with greater disparities in some fields (e.g., physical sciences) and smaller ones in others (e.g., advanced biology). Higher proportions of blacks are going on to college than in the past, and the difference between blacks and whites in this respect has narrowed somewhat. But the same is not true for Hispanics.

Schools that serve students from different racial, ethnic, and income groups provide students with differing access to educational resources. Access to challenging courses, qualified and experienced teachers, good learning environments, and learning opportunities that make use of computers and the Internet is unequally distributed, but more so in some respects than in others:

- ♦ **Course availability.** Differences in access to some mathematics and science courses are modest. High schools with high proportions of low-income students are comparable to other schools in the percentages offering courses in advanced biology, chemistry, and trigonometry/algebra III. Wider gaps exist for physics, but all of these courses are almost universally accessible in U.S. public high schools. However, AP courses are more widely available in high schools with very low proportions of low-income students, and the availability of certain specialized mathematics courses is negatively associated with the percentage of low-income students.

- **Out-of-field teachers.** The extent of inequalities in exposure to out-of-field teachers depends on how out of field is defined and measured. Using a broad definition of out of field (lacking a college major or minor in either the field taught or one of several closely related fields) yields marginal but consistent differences between schools with high and low percentages of low-income or minority students: students in high poverty or high minority schools are slightly more likely to have out-of-field teachers. Using a narrow concept of out of field (lacking a major in the subject taught) yields no substantial difference between schools with different percentages of minority students. Likewise, students taking mathematics and biology/ life science courses have similar chances of encountering teachers who did not major in these subjects regardless of their school's poverty level. The same is not true for physical science students, however, where school poverty is associated with out-of-field teaching. One of the most striking differences in teacher qualifications is that fewer students in heavily minority or low-income schools had mathematics or science teachers who majored in mathematics or science education; although critics have questioned the value of these types of credentials, they appear to be more common in schools with more advantaged students.
- **New teachers.** The percentage of inexperienced mathematics teachers does not vary with school poverty or minority enrollment, but the percentage of inexperienced science teachers does. New mathematics and science teachers in schools with large percentages of students from low-income or minority families had substantially less practice teaching experience before taking on their assignments. Science teachers in these schools were also substantially less likely to participate in an induction program, but only relatively modest differences existed for mathematics teachers. In both subjects, the proportion of teachers who had worked with a mentor did not vary substantially with a school's minority or low-income enrollment.
- **Learning environment.** Teachers had more favorable perceptions of the learning environment in high schools with fewer low-income and minority students. Differences in perceptions varied in size: they were small for questions about administrative practices, larger for questions about available teaching materials and student apathy and disrespect, and largest for questions about parental involvement and student attendance.
- **IT access.** In recent years, IT has rapidly become more available in public schools. Disparities by race/ethnicity and income are much smaller for computer access than for Internet access. Access at home is much more unequally distributed than access at school.

As a result of reform efforts begun in the 1980s and continuing most recently with the NCLB Act, changes are occurring in mathematics and science education. Increasing numbers of states are developing and implementing standards, states and school districts are increasing graduation requirements, and students are being offered (and are taking) more advanced courses. In addition, educators and policymakers are paying increasing attention to teacher professional development and to taking advantage of computers and the Internet in instruction. The NCLB Act has introduced new levels of accountability, requiring schools to demonstrate improvement for all students or face sanctions, thus raising the stakes for all involved.

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