Chapter 1
Elementary and Secondary Education

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Highlights

Student Learning in Mathematics and Science

All student groups made gains in mathematics and science during elementary and high school, but performance disparities were evident, and some gaps widened as students progressed through school.

- ♦ Studies that follow the same groups of students as they progress through school reveal performance disparities among demographic subgroups starting when they enter kindergarten. Students from financially poorer families or whose mother had less formal education entered kindergarten with lower levels of mathematics skills and knowledge than their more advantaged peers. Substantial racial/ethnic gaps in mathematics performance were also observed. Although all subgroups made gains in mathematics and science during elementary school, the rates of growth varied and some of the achievement gaps widened.
- ♦ Mathematics performance gaps among demographic subgroups were evident in 10th grade and some continued to widen through 12th grade.

In 2005, U.S. fourth and eighth grade students outperformed those tested in the 1990s in mathematics, and fourth grade students improved in science.

- ♦ Increases in fourth and eighth grade mathematics scores from 1990 to 2005 were widespread, occurring among males and females, all racial/ethnic groups, students from financially disadvantaged and advantaged families, and students performing at all levels of achievement. Some mathematics achievement gaps did decrease over the same period.
- ♦ Widespread increases in mathematics from the 1990s to 2005 were not matched in science. Since 1996, the first year the current national science assessment was given, average science scores increased for 4th graders, held steady for 8th graders, and declined for 12th graders.

Standards and Student Coursetaking

In 2006, slightly more than half the states required 3 or more years of both mathematics and science courses for high school graduation.

- ♦ Students in more than 40 states were required to complete at least 2 years of both mathematics and science in high school; 3 years was the most common requirement for both subjects, in effect in just over half the states. Very few states required 4 years in either subject, and only one state required 4 years in both.

State development of course content standards has progressed in recent years and standards continue to be reviewed and revised.

- ♦ All states had issued content standards in mathematics and science by 2006–07, and 35 states had schedules for reviewing and revising those standards.

Trends from 1990 to 2005 show increases in advanced coursetaking; growth was especially strong in mathematics.

- ♦ Class of 2005 graduates completed mathematics courses at far higher rates than their 1990 counterparts in all categories except trigonometry/algebra III. The proportion of students completing courses in precalculus/analysis, calculus, and Advanced Placement/International Baccalaureate (AP/IB) calculus at least doubled since 1990. Nonetheless, completion of advanced mathematics courses remained below 20% in 2005 except for precalculus/analysis.
- ♦ Student course completion rates have increased since 1990 in advanced biology, chemistry, and physics, although they leveled off between 2000 and 2005.
- ♦ For AP/IB courses, coursetaking rates have not changed significantly for chemistry or physics, but increased slightly for biology and doubled for calculus and environmental science. Despite this growth, just less than 10% of graduates completed an AP/IB calculus course, the highest rate for any AP/IB course.

Course completion rates differed in the graduating class of 2005 by several demographic and school characteristics.

- ♦ Males and females completed advanced mathematics courses at about equal rates, except for precalculus/analysis, where females had a slight advantage. Females studied biology and chemistry at higher rates, whereas males studied physics, engineering, and engineering/science technologies at higher rates.
- ♦ Asian/Pacific Islanders were the most likely of all racial/ethnic groups to earn credits in many mathematics and science subjects, especially in AP/IB classes in calculus, biology, chemistry, and physics.

Mathematics and Science Teacher Quality

Most mathematics and science teachers have the basic teaching qualifications of a college degree and full state certification.

- ♦ Virtually all public school mathematics and science teachers had at least a bachelor's degree and half had an advanced degree such as a master's or doctorate.
- ♦ A large majority of mathematics and science teachers (84% in 2003) held standard or advanced certification issued by their state.

- At least 75% of 2003 mathematics and science teachers with less than 5 years of teaching experience participated in practice teaching before their first teaching job. Although practice teaching contributes to new teachers' confidence in their ability to perform their first jobs, practice teaching declined from 1999 to 2003.

The majority of public high school mathematics and science teachers had a college major or certification in their subject field, that is, they were "in-field" teachers. In-field teaching was less common in middle schools than in high schools.

- In 2003, 78%–92% of mathematics, biology, and physical science teachers in public high schools were teaching in field. Out-of-field teachers (that is, teachers teaching their subject with neither a major nor certification in the subject matter field, a related field, or general education) ranged from 2% of physical science teachers to 8% of mathematics teachers.
- The proportion of in-field mathematics and science teachers in middle schools was lower (33%–55%) than in high schools (78%–92%). About 3%–10% were teaching out of field.

Teachers in schools with low concentrations of minority and low-income students tended to have more education, better preparation and qualifications, and more experience than teachers in schools with high concentrations of such students.

- Mathematics and science teachers in low-minority and low-poverty schools were more likely than their colleagues in high-minority and high-poverty schools to have a master's or higher degree and to hold full certification.
- Mathematics and science teachers in low-minority and low-poverty schools were more likely to teach in field than their colleagues in high-minority and high-poverty schools.
- New mathematics and science teachers (those with 3 or fewer years of teaching experience) were more prevalent in high-minority and high-poverty schools than in low-minority and low-poverty schools.

Professional Development of Mathematics and Science Teachers

Participation in induction and mentoring programs was widespread.

- In 2003, 68%–72% of beginning mathematics and science teachers in public middle and high schools reported that they had participated in a formal teacher induction program or had worked closely with a mentor teacher during their first year of teaching.

Teacher participation in professional development was common. However, various features of professional development identified as being effective in bringing about changes in teaching practices were not widespread.

- In 2003, more than 70% of mathematics and science teachers in public middle and high schools participated in professional development focusing on the content of their subject field. About two-thirds attended professional development in using computers for instruction. Professional development most frequently took the form of workshops, conferences, and training sessions (91% in 2003).
- Recent research has found that intensive participation of at least 60–80 hours may be necessary to bring about meaningful change in teaching practice. In 2003, 4%–28% of mathematics and science teachers in public middle and high schools attended professional development programs for 33 hours or more over the course of a school year.

Teacher Salaries, Working Conditions, and Job Satisfaction

Attrition from teaching was typically lower than from other professions and attrition rates of mathematics and science teachers were no greater than the overall rate. Many were satisfied with being teachers and planned to stay in the profession as long as they could.

- Among all college graduates working in 1994, 34% were working in the same occupational category in 2003 and 54% had made a change in occupation. In contrast, 61% of college graduates entering K–12 teaching in 1994 were still teaching in 2003 and 21% had left teaching for non-teaching jobs.
- Between academic years 2003 and 2004, about 6%–7% of mathematics and science teachers in public schools left teaching, compared with 8% of all teachers.
- In 2003, 90% of mathematics and science teachers said that they were satisfied with being teachers in their schools, 76% planned to remain in teaching as long as they could or until retirement, and more than 66% expressed their willingness to become teachers again if they could start over.

Public secondary schools experienced varying degrees of difficulty in finding teachers in mathematics and science.

- About 80% of public secondary schools reported teaching vacancies (i.e., teaching positions needing to be filled) in one or more fields in academic year 2003. Among these schools, 74% had vacant positions in mathematics and 52%–56% had vacant positions in biology/life sciences and physical sciences.
- About one-third of public secondary schools with vacancies in mathematics or physical sciences reported great difficulty in finding teachers to fill openings in these

fields, whereas 22% of schools reported that this was the case in biology/life sciences.

Science and mathematics teacher salaries continue to lag behind salaries for individuals working in comparable professions and the gaps have widened substantially in recent years.

- In 2003, the median salary for full-time high school mathematics and science teachers was $43,000, lower than the salaries of professionals with comparable educational backgrounds such as computer systems analysts, engineers, accountants or financial specialists, and protective service workers ($50,000–$72,000). From 1993 to 2003, full-time high school mathematics and science teachers had a real salary gain of 8%, compared with increases of 21%–29% for computer systems analysts, accountants or financial specialists, and engineers.
- In 2003, 53% of public middle and high school mathematics and science teachers said that they were not satisfied with their salaries.

Most public school teachers had favorable perceptions of their working conditions.

- In 2003, at least 79% of mathematics and science teachers in public middle and high schools reported strong leadership from the administration in their school, a great amount of collaboration among their colleagues, and sufficient instructional materials.
- Relatively few of them viewed various student problems as “serious” in their schools. The problems that teachers rated most often as serious were students arriving at school unprepared to learn (37%) and student apathy (32%).

Transition to Higher Education

A majority of young people in the United States finished high school with a regular diploma or an equivalent credential.

- In 2005, 88% of 18–24-year-olds not enrolled in high school had received a high school diploma or earned an equivalent credential such as a General Equivalency Diploma (GED) certificate.
- Completion rates showed an upward trend for each racial/ethnic group between 1975 and 2005. The rates increased faster for blacks than for whites, narrowing the gaps between the two groups. The gaps between whites and Hispanics remained wide.
- The on-time graduation rate, which measures the rates at which high school freshmen graduate with a regular diploma 4 years later, ranged from 72%–74% in the early 2000s.

Increasing numbers of students are entering postsecondary education directly after high school.

- Between 1975 and 2005, the percentage of students ages 16–24 enrolling in college immediately following high school graduation rose from 51% to 69%.
- Increases in rates of immediate college enrollment have occurred among all subgroups of students. However, wide gaps among these subgroups have persisted, with black and Hispanic students and those from low-income and poorly educated families trailing behind their white counterparts or those from high-income and well-educated families.

Introduction

This chapter examines recent trends in student achievement and factors influencing the quality of U.S. mathematics and science education at the elementary and secondary levels. Public concern about the achievement of American students in mathematics and science has intensified in recent years. In response, the education community has developed and implemented various approaches to improving K–12 education (NSB forthcoming). Targets of reform include standards and curriculum, knowledge assessments, teacher qualification, professional development, and working conditions.

The chapter begins by summarizing the most recent data on U.S. student learning in mathematics and science. New indicators of achievement include changes during the first 6 years of schooling, focusing on whether gaps between groups grew over that time. Another new topic is learning from 10th to 12th grades. The achievement section also puts U.S. student performance in mathematics and science in an international context.

The chapter next examines high school coursetaking in mathematics and science. This edition includes new data on coursetaking in environmental science, engineering, and engineering/science technologies. It also discusses the latest information on state academic course requirements for high school graduation and the status of statewide assessments.

Turning next to teachers, the chapter examines their qualifications, professional development, salaries, and working conditions, all issues that affect hiring and retaining professionals with backgrounds in mathematics and science. All teacher indicators in this chapter have been updated since *Science and Engineering Indicators 2004* (NSB 2004), using the latest data from the 2003–04 Schools and Staffing Survey (SASS) and parallel data from the 1999–2000 SASS where relevant. New teacher indicators include comparisons between teacher and other professional salaries, teacher job satisfaction and plans for continuing to teach, the link between various aspects of teachers' work environments and their long-term commitment to teaching, school reports of the degree of difficulty filling teaching vacancies in mathematics and science, and comparisons of attrition among teachers and other professionals. In addition, a section on teacher professional development includes new data on content, duration, and format. The chapter closes with indicators of secondary students' transitions into higher education.

The chapter focuses primarily on overall patterns but also reports variations in access to educational resources by minority concentration and school poverty level, and in student performance by sex, race/ethnicity, and family characteristics.

Whenever a difference or change over time is cited in this chapter, it is statistically significant at the 0.05 probability level.[1]

Student Learning in Mathematics and Science

This section presents indicators of student performance in mathematics and science from two types of studies: longitudinal studies and repeating cross-sectional studies. *Longitudinal studies* follow the same group of students over time; for example, from kindergarten through fifth grade. These studies can show achievement gains in a particular subject from grade to grade. *Repeating cross-sectional studies* provide a snapshot of how certain students perform in a particular year and then take another snapshot of a similar group of students in a later year; for example, comparing fourth graders in 1990 to fourth graders in 2005.

Performance as Students Progress Through Elementary School

The Early Childhood Longitudinal Study (ECLS) followed a group of students who entered kindergarten in fall 1998 until spring 2004, when most were in fifth grade.[2] The 2006 volume of *Science and Engineering Indicators* provided data from ECLS through third grade (NSB 2006). Those indicators showed that mathematics achievement differences among subpopulations already existed when students entered kindergarten. Although all groups made gains by third grade, some gaps widened over the 4-year period (Rathbun, West, and Germino Hausken 2004). This volume updates those indicators of early mathematics learning to fifth grade. It also presents the first longitudinal data from ECLS on science learning, from third through fifth grade.

Mathematics: Fifth Grade Performance

The ECLS mathematics assessments provide indicators of student proficiency in nine specific skill areas that represent a progression of skills and knowledge (see sidebar "Mathematics Skills Areas for Elementary Grade Students"). This volume of *Science and Engineering Indicators* focuses on the skill areas assessed in fifth grade, whereas the 2006 volume focused on the lower-order skill areas assessed in kindergarten through third grade.

By the end of fifth grade, almost all students (92%) could solve simple multiplication and division problems, and about three-quarters demonstrated understanding of place value in integers to the hundreds place (figure 1-1; appendix table 1-1) (Princiotta, Flanagan, and Germino Hausken 2006). Other topics proved more challenging, with less than half of fifth graders (43%) able to solve word problems using knowledge of measurement and rate, 13% able to solve problems using fractions, and 2% able to solve problems using area and volume. However, in each of the mathematics skills areas assessed at both time points, the percentages of students demonstrating proficiency increased since the third grade (appendix table 1-1).

Mathematics Skill Areas for Elementary Grade Students

ECLS measures student proficiency at nine specific mathematics skill levels. These skill levels were identified based on frameworks from other national assessments and advice from a panel of education experts and represent a progression of mathematics skills and knowledge. Levels 6, 7, and 8 were first assessed in third grade, and level 9 was first assessed in fifth grade. By the fifth grade, levels 1 through 4 were not assessed. Each level is labeled by the most sophisticated skill in the set.

Level 1 Number and shape: Recognize single-digit numbers and shapes.

Level 2 Relative size: Count beyond 10, recognize the sequence in basic patterns, and compare the relative size and dimensional relationship of objects.

Level 3 Ordinality and sequence: Recognize two-digit numbers, identify the next number in a sequence, identify the ordinal position of an object, and solve simple word problems.

Level 4 Add and subtract: Solve simple addition and subtraction items and identify relationships of numbers in sequence.

Level 5 Multiply and divide: Perform basic multiplication and division and recognize more complex number patterns.

Level 6 Place value: Demonstrate understanding of place value in integers to the hundreds place.

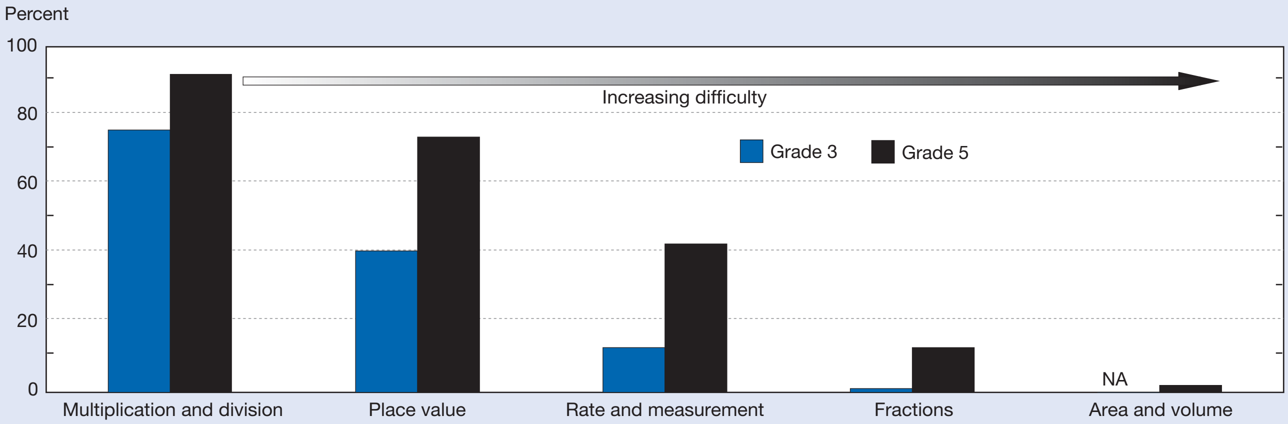
Level 7 Rate and measurement: Use knowledge of measurement and rate to solve word problems.

Level 8 Fractions: Solve problems using fractions.

Level 9 Area and volume: Solve problems using area and volume.

Sources: Princiotta, Flanagan, and Germino Hausken 2006; West, Denton, and Reaney 2000.

Figure 1-1
Proficiency in specific mathematics knowledge and skill areas of students in grades 3 and 5: 2002 and 2004



NA = not available

NOTES: In 2004 followup for Early Childhood Longitudinal Study (ECLS) kindergarten class of fall 1998, 86% of cohort was in grade 5, 14% was in lower grade, and <1% was in higher grade. For simplicity, students in ECLS followups referred to by modal and expected grade, i.e., third graders in spring 2002 assessment and fifth graders in spring 2004 assessment.

SOURCES: National Center for Education Statistics, ECLS, spring 2002 and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-1.

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Mathematics: Achievement Gaps During Elementary School

Fifth grade mathematics performance was related to several student background factors (Princiotta, Flanagan, and Germino Hausken 2006). For each of the mathematics skill levels mentioned above, lower proportions of black and Hispanic students were proficient compared with their white and Asian peers (appendix table 1-1). Students whose mothers had less formal education and students who were living in poverty[3] also generally demonstrated lower proficiency rates than their peers.

Although many of these mathematics achievement differences were evident when these children started kindergarten, the ECLS data suggest that at least some gaps widened as students progressed through elementary school, and that other gaps, such as those between boys and girls, emerged that were not present when students started school (Princiotta, Flanagan, and Germino Hausken 2006; Rathbun, West, and

Germino Hausken 2004). Changes in achievement gaps are most easily summarized by examining average scale scores, which place students on a continuous ability scale based on their overall performance. Results indicate that all demographic groups gain mathematical skills and knowledge during elementary school but the rate of progress varies.

Gender Gaps. Boys and girls started kindergarten at the same overall mathematics performance level (appendix table 1-2), but by the end of fifth grade, boys had made larger mathematics gains than girls, resulting in a small but observable gender gap of four points.

Race/Ethnicity Gaps. Gaps between white and black students and between white and Hispanic students existed when students started kindergarten and they widened over time. In mathematics, from kindergarten to fifth grade, white students posted a gain of 93 points; Hispanics, a gain of 89 points; and blacks, a gain of 80 points (table 1-1; appendix table 1-2). By fifth grade, the gap between white and black students in average mathematics scores was 19 points, and the average score of black fifth grade students was equivalent to the average third grade score of white students.

Mother's Education and Family Income Gaps. Students whose mothers had higher levels of education entered kindergarten with higher average mathematics scores than their peers whose mothers attained less formal education and these gaps increased as students progressed through elementary school (appendix table 1-2). By grade 5, the gaps in mathematics scores were substantial, with students whose mothers had dropped out of high school posting a lower average mathematics score than students whose mothers had graduated from college had posted at grade 3. Students living in families with incomes below the poverty threshold also entered school with lower mathematics skills than their peers from higher income families, and those discrepancies in scores grew by fifth grade.

Other research suggests that widening achievement gaps as students progress through school are, at least in part, a result of differential learning growth and loss during the summer (Alexander, Entwisle, and Olson 2001; Borman and Boulay 2004; Cooper et al. 1996). For example, although lower- and upper-income primary grade students made similar gains in mathematics during the school year, lower-income students experienced declines in mathematics skills during summer breaks, whereas higher-income students experienced gains (Alexander, Entwisle, and Olson 2001). These findings have been attributed to greater ability among higher-income parents to provide their children with mathematically stimulating materials and activities during the summer.

Science: Performance Gains and Gaps From Third to Fifth Grade

ECLS began assessing students in science in the third grade and tested those students' science knowledge again in fifth grade (Princiotta, Flanagan, and Germino Hausken 2006; Rathbun, West, and Germino Hausken 2004). The science assessments placed equal emphasis on life science, earth and space science, and physical science, asking students to demonstrate understanding of the physical and natural world, make inferences, and understand relationships. Assessments also required students to interpret scientific data, form hypotheses, and develop plans to investigate scientific questions. ECLS science assessments were not designed to measure proficiency in specific skill areas and therefore do not lend themselves to proficiency levels; results are instead summarized by average scale scores.

Gains in science skills and knowledge between third and fifth grade were seen across each demographic group, but performance gaps persisted (appendix table 1-3). Gaps were evident the first time students were assessed in science, in third grade. Boys had slightly higher average science scores

Table 1-1
Average mathematics scores of students from beginning kindergarten to grade 5, by race/ethnicity: 1998, 2000, 2002, and 2004

Race/ethnicity	Fall 1998 kindergarten	Spring 2000 grade 1	Spring 2002 grade 3	Spring 2004 grade 5	Gain from kindergarten to grade 5
All students	22	39	91	112	89
White, non-Hispanic	25	43	97	118	93
Black, non-Hispanic	19	33	79	99	80
Hispanic	19	36	85	108	89
Asian	25	39	94	118	93
Other[a]	20	38	86	107	86

[a]Includes non-Hispanic Native Hawaiians, Pacific Islanders, American Indians, Alaska Natives, and children of more than one race.

NOTES: Early Childhood Longitudinal Survey (ECLS) mathematics scale ranged from 0 to 153. In 2004 followup for ECLS kindergarten class of fall 1998, 86% of cohort was in grade 5, 14% was in a lower grade, and <1% was in a higher grade. For simplicity, students in ECLS followups referred to by modal and expected grade, i.e., first graders in spring 2000 assessment, third graders in spring 2002 assessment, and fifth graders in spring 2004 assessment.

SOURCES: National Center for Education Statistics, ECLS, fall 1998 and spring 2000, 2002, and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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than girls and they maintained this small difference in performance in fifth grade. In third grade, white and Asian students had higher average science scores than did blacks and Hispanics, and Hispanics outperformed their black peers. By fifth grade, none of these gaps had narrowed and the black-Hispanic gap had increased. The average score for black fifth graders was lower than the average score for white third graders.

Third graders whose mothers had more formal education performed better in science than did their peers with mothers who were less educated, and students who lived above the poverty threshold did better in science than those who lived below it (appendix table 1-3). By fifth grade these gaps in science performance by mothers' education and poverty status either remained constant or grew wider. Students from families below the poverty threshold had average fifth grade science scores equivalent to the third grade scores of students above the poverty threshold.

Mathematics Performance as Students Progress Through High School

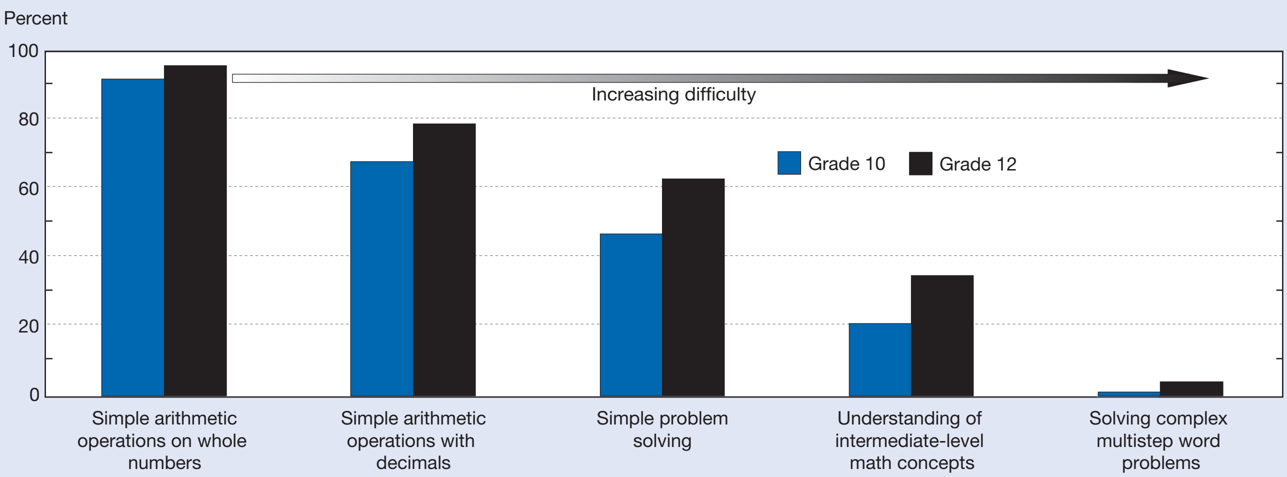
Another longitudinal study, the Education Longitudinal Study (ELS), provides indicators of student learning during high school by following a nationally representative sample of students who were in 10th grade in 2002 (NCES 2007a). These students were assessed again in 2004 in 12th grade. ELS includes an assessment of student performance in mathematics, which provides information both on specific skills and on overall mathematics performance. The specific skills are divided into levels representing a progression of mathematics skills: (1) simple arithmetical operations with whole numbers; (2) simple operations with decimals, fractions, powers, and roots; (3) simple problem solving requiring the understanding of low-level mathematical concepts; (4) understanding of intermediate-level mathematical concepts and multistep solutions to word problems; and (5) complex multistep word problems and advanced mathematics material (NCES 2007a).

In 2004, almost all 12th grade students (96%) were proficient in simple arithmetical operations with whole numbers and 79% were also proficient in simple operations with decimals, fractions, roots, and powers (figure 1-2; appendix table 1-4). However, the proportions demonstrating proficiency in more advanced mathematics skills were lower and decreased as more advanced skills were tested. Only 4% of 12th grade students reached proficiency at the highest level (solving complex multistep word problems). Nevertheless, at each level, the percentages of students demonstrating proficiency increased from the 10th to the 12th grade.

Each demographic subgroup examined improved in mathematics skills from 10th to 12th grade, but achievement disparities were evident. The ECLS data reviewed in the previous section found that boys and girls entered kindergarten with similar overall mathematics performance, but by the fifth grade, boys demonstrated slightly higher performance. This small gender gap favoring boys was also observed in the 10th and 12th grades in ELS, with the gap holding steady between those 2 years (appendix table 1-4).

Substantial differences among racial/ethnic groups were found in mathematics achievement at grade 10, with white and Asian/Pacific Islander students posting higher average scores than black and Hispanic students, and Hispanic students scoring slightly higher than black students (appendix table 1-4). After 2 additional years of schooling, white-Hispanic and Hispanic-black gaps held steady, and the white-black, Asian-black, and Asian-Hispanic gaps increased. By 12th grade, the average performance of black students was slightly lower than the average 10th grade performance of white and Asian students.

Figure 1-2
Proficiency in specific mathematics knowledge and skill areas of students in grades 10 and 12: 2002 and 2004



SOURCES: National Center for Education Statistics, Education Longitudinal Study, spring 2002 and 2004; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 1-1 and 1-4.

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The mathematics skill gaps observed in kindergarten (and found to be greater in fifth grade) between students whose mothers had lower levels of education compared with students whose mothers were more educated were evident among ELS 10th graders (appendix table 1-4). These differences generally increased through the 12th grade. Students from low socioeconomic families[4] had lower average 10th grade mathematics scores than their peers in middle socioeconomic families, who in turn had lower scores than students in high socioeconomic families. By 12th grade these gaps had grown.

Performance of 4th, 8th, and 12th Grade Students Since the 1990s

The two longitudinal studies described above showed that students start school with different levels of knowledge and skills and that some of those differences grow as the same students move through the educational system. Notably, none of the achievement gaps reviewed above between historically privileged and underprivileged groups narrowed during elementary or high school.

Another type of assessment, a well-known repeating cross-sectional study, provided indicators that showed a somewhat more positive trend. As will be detailed below, fourth and eighth grade students in 2005 (including most subgroups) performed better on mathematics tests on average than fourth and eighth graders a decade and a half earlier. However, fewer gains were observed in science and substantial achievement gaps among subgroups of students in these grades persisted in both mathematics and science.

The National Assessment of Educational Progress (NAEP), also known as the "Nation's Report Card," has charted the academic performance of U.S. students in the upper elementary and secondary grades since 1969. Previous *Science and Engineering Indicators* reports described trends in mathematics and science results dating back to the first NAEP assessments.[5] This volume focuses on more recent trends, from 1990 to 2005 for mathematics (grades 4 and 8) and from 1996 to 2005 for science (grades 4, 8, and 12) (NCES 2006a, b). Twelfth graders were assessed in mathematics in 2005 but the assessment was not comparable with previous NAEP assessments, and therefore trend data are not available for grade 12 mathematics.[6]

The NAEP assessments are based on frameworks developed through a national consensus process that involves educators, policymakers, assessment and curriculum experts, and the public. The frameworks are then approved by the National Assessment Governing Board (NAGB) (NCES 2006a, 2007b). The mathematics grades 4 and 8 assessments contain five broad content strands (number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics and probability; and algebra and functions). The mathematics grade 12 assessment contains four content strands that are similar to the grade 4 and 8 strands, but with measurement and geometry collapsed together. The science framework includes a content dimension divided into three major fields of science: earth, life, and physical.

Student performance on the NAEP is measured with scale scores as well as achievement levels. Scale scores place students on a continuous ability scale based on their overall performance. For grades 4 and 8, the mathematics scales range from 0 to 500 across the two grades. For grade 12, the mathematics scale ranges from 0 to 300. For science, the scales range from 0 to 300 for each of the three grades.

Achievement levels are set by NAGB based on recommendations from panels of educators and members of the public, and describe what students should know and be able to do at the basic, proficient, and advanced levels for each grade (NCES 2006b and 2007b). The *basic* level represents partial mastery, *proficient* represents solid academic performance, and *advanced* represents superior performance on assessments measuring mastery of knowledge and skills for each grade level. This review of NAEP results focuses on the percentage of students deemed proficient (for more detailed definitions of the proficient levels, see *Science and Engineering Indicators 2006*, pp. 1–13 and 1–14 [NSB 2006 and NCES 2007b]).

Disagreement exists about whether NAEP has appropriately defined these levels. 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 setting achievement levels (Bourque and Byrd 2000). However, both the National Center for Education Statistics (NCES) and NAGB believe the levels are useful for understanding trends in achievement. They warn readers to use and interpret the levels with caution (NCES 2006b).

In this section, NAEP results are examined in various ways, including changes in average scale scores and in the proportion of students reaching the *proficient* level both overall and among various subgroups of students. In addition, achievement gaps between demographic subpopulations and changes in those gaps are reviewed.

Examining a set of measures reveals more about student performance than does examining just one measure (Barton 2004). For example, without examining changes in achievement for high-, middle-, and low-achieving students, it would be impossible to know whether a rise in average scores resulted from increased scores among one or a few groups of students, or whether it reflected broader improvements.

Mathematics Performance From 1990 to 2005

The average mathematics scores of fourth and eighth grade students have steadily increased since 1990 (the first year in which the current assessment was given), including small improvements during the more recent period 2003–05 (NCES 2006a) (figure 1-3; table 1-2; appendix table 1-5). The pattern of higher average mathematics scores among fourth and eighth grade students was widespread (table 1-2; appendix table 1-5). At grades 4 and 8, average mathemat-

Table 1-2
Changes in mathematics performance of students in grades 4 and 8, by student characteristics and other factors: 1990–2005 and 2003–05

	Grade 4		Grade 8	
Student characteristic	1990–2005	2003–05	1990–2005	2003–05
Average score				
Total	▲	▲	▲	▲
Sex				
Male	▲	▲	▲	▲
Female	▲	▲	▲	▲
Race/ethnicity				
White, non-Hispanic	▲	▲	▲	▲
Black, non-Hispanic	▲	▲	▲	▲
Hispanic	▲	▲	▲	▲
Asian/Pacific Islander[a]	NA	▲	NA	▲
American Indian/Alaska Native[b]	NA	▲	NA	•
Free/reduced-price lunch[c]				
Eligible	▲	▲	▲	▲
Not eligible	▲	▲	▲	▲
Percentile scores[d]				
10th	▲	▲	▲	▲
25th	▲	▲	▲	▲
50th	▲	▲	▲	▲
75th	▲	▲	▲	▲
90th	▲	▲	▲	▲
Changes in achievement gaps in average scores				
Gender gap	•	•	•	•
White-black gap	▼	▼	•	▼
White-Hispanic gap	•	•	•	▼
Eligible and not eligible for free/reduced-price lunch gap[c]	▼	•	•	•

▲ = increase; • = no change; ▼ = decrease (based on *t*-tests using unrounded numbers); NA = not available

[a]Insufficient sample size in 1990 for Asian/Pacific Islanders precluded calculation of reliable estimates.
[b]Insufficient sample size in 1990 for American Indians/Alaska Natives precluded calculation of reliable estimates.
[c]Information on student eligibility for free/reduced-price lunch first collected in 1996: comparisons in 1990s columns from 1996 to 2005.
[d]Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

NOTES: 2005 grade 12 assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-5.

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ics scores were higher for both male and female students in 2005 compared with both 1990 and 2003. This was also true for students regardless of eligibility for free or reduced-price lunch (a commonly used measure of poverty).[7] Generally, improvements were observed for white, black, Hispanic, and Asian/Pacific Islander populations.[8]

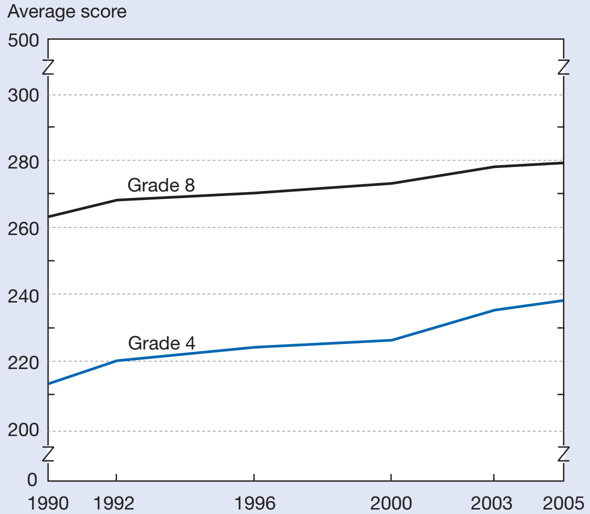
Examining trends for students at the lower, middle, and higher ranges of performance can uncover whether overall trends are driven by changes in only one or two of these groups. However, NAEP mathematics results indicate that the overall increase in mathematics performance was not driven by students at any one performance level (table 1-2; appendix table 1-5). Average scores for students in the 10th, 25th, 50th, 75th, and 90th percentiles in 2005 were all higher than those recorded in 1990 and 2003, providing evidence that gains in mathematics were widespread. (*Percentiles* are scores below which a specified percentage of the population falls. For example, among eighth graders in 2005, the 75th percentile score for mathematics was 304. This means that 75% of eighth graders had mathematics scores at or below 304, and 25% scored above 304).

The percentage of students reaching the proficient level for their grade also rose (figure 1-4; appendix table 1-6). In 1990, 13% of fourth graders were deemed proficient in mathematics compared with 36% in 2005. Among eighth graders the percentage increased from 15% to 30%.

Mathematics Performance From 2005 to 2007

The NAEP 2007 fourth and eighth grade mathematics assessment results were released too late to incorporate more than a brief summary in this volume. Both fourth and eighth grade students registered continued improvements in mathe-

Figure 1-3
Average mathematics score of students in grades 4 and 8: Selected years, 1990–2005



NOTES: Scores on 0–500 scale across grades 4 and 8. 2005 grade 12 mathematics assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); and National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments. See appendix table 1-5.

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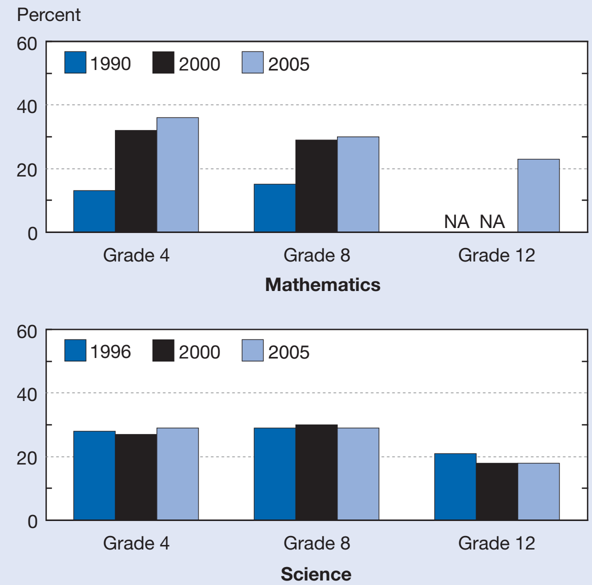
Figure 1-4
Proficiency in mathematics and science, grades 4, 8, and 12: Selected years, 1990–2005



NA = not available

NOTE: 2005 grade 12 mathematics assessment not comparable with previous assessments; therefore mathematics trend information for grade 12 not available.

SOURCES: National Center for Education Statistics (NCES), The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); The Nation's Report Card: Science 2005, NCES 2006-466 (2006); and National Assessment of Educational Progress, 1990, 1996, 2003, and 2005 mathematics assessments and 1996, 2000, and 2005 science assessments. See appendix tables 1-6 and 1-8.

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matics achievement between 2005 and 2007 (Lee, Grigg, and Dion 2007). Improvements occurred across all performance percentiles and income levels in both grades. Among fourth graders, scores increased for whites, blacks, Hispanics, and Asians/Pacific Islanders but no significant increase could be reported for American Indians/Alaska Natives because of insufficient sample size. Among eighth graders, whites, blacks, and Hispanic students improved their scores but Asians/Pacific Islanders and American Indians/Alaska Natives registered no gain. The percentage of students scoring at or above *proficient* in both grades increased from 36% to 39% among fourth graders and 30% to 32% among eighth graders.

Although most groups showed improved performance from 2005 to 2007, performance gaps were resistant to improvement. In the fourth grade, the white-black and white-Hispanic gaps did not change between 2005 and 2007. In the eighth grade, the white-black gap decreased but the white-Hispanic gap remained about the same.

Science Performance From 1996 to 2005

Since 1996, the first year the current NAEP science assessment was given, average scores increased for 4th graders, held steady for 8th graders, and declined for 12th graders (table 1-3, appendix table 1-7) (NCES 2006b). Trends in percentile scores suggest the increase in average scores at grade 4 was driven by lower- and middle-performing students: scores at the 10th, 25th, and 50th percentiles increased in 2005 compared with both 1996 and 2000, while scores at the 75th and 90th percentiles did not change over the same periods (appendix table 1-7).

The proportion of students reaching the *proficient* level for their grade in science did not change for grades 4 and 8, and declined slightly for grade 12 (figure 1-4; appendix table 1-8). In 2005, 29% of fourth and eighth grade students reached the proficient level. Rates were lower among 12th graders (18% scored at or above the proficient level).

Changes in Achievement Gaps Since the 1990s

The longitudinal studies outlined in the beginning of this chapter reveal racial/ethnic gaps in mathematics and science performance as students start kindergarten, some of which grow as students progress through elementary and high school. NAEP, with snapshots of three grades over time, paints a slightly different picture. Since 1990, the white-black gap in mathematics achievement decreased among fourth graders and held steady for eighth graders (table 1-2; appendix table 1-5). The white-Hispanic mathematic gaps held steady over this time for students in grades 4 and 8. In science, fourth grade black students narrowed the achievement gap with white students from 1996 to 2005 (table 1-3; appendix table 1-7). Despite some narrowing, substantial racial/ethnic gaps

Table 1-3
Changes in science performance of students in grades 4, 8, and 12, by student characteristics and other factors: 1996–2005 and 2000–05

Student characteristic	Grade 4		Grade 8		Grade 12	
	1996–2005	2000–05	1996–2005	2000–05	1996–2005	2000–05
Average score						
Total	▲	▲	•	•	▼	•
Sex						
Male	▲	▲	•	•	▼	•
Female	•	▲	•	•	▼	•
Race/ethnicity						
White, non-Hispanic	▲	▲	•	•	•	•
Black, non-Hispanic	▲	▲	▲	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	NA	•	•	•	•
American Indian/Alaska Native	•	•	▼	▼	•	•
Free/reduced-price lunch						
Eligible	▲	▲	•	▲	NA	NA
Not eligible	▲	▲	▲	•	NA	NA
Percentile scores[b]						
10th	▲	▲	•	•	▼	•
25th	▲	▲	•	•	▼	•
50th	▲	▲	•	•	•	•
75th	•	•	•	•	▼	•
90th	•	•	•	•	▼	•
Changes in achievement gaps in average scores						
Gender gap	•	•	•	•	•	•
White-black gap	▼	▼	•	•	•	▲
White-Hispanic gap	•	▼	•	•	•	•
Eligible and not eligible for free/reduced-price lunch gap	•	▼	•	▼	NA	NA

▲ = increase; • = no change; ▼ = decrease (based on *t*-tests using unrounded numbers); NA = not available

[a]National Center for Education Statistics (NCES) did not publish 2000 science scores for grade 4 Asians/Pacific Islanders because of accuracy and precision concerns.

[b]Percentage of students whose scores fell below a particular score, e.g., 75% of students had scores <75th percentile.

SOURCES: NCES, The Nation's Report Card: Mathematics 2005, NCES 2006-453 (2006); National Assessment of Educational Progress,1996, 2000, and 2005 science assessments; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-7.

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in mathematics and science remained. For example, among 12th grade students in 2005, 24% of white students and 23% of Asian/Pacific Islander students were *proficient* in science compared with 13% of American Indian/Alaska Native students, 5% of Hispanic students, and 2% of black students (appendix table 1-8). Although grade 12 trends are not available for mathematics, the 2005 data reveal substantial racial/ethnic gaps in this subject as well: 36% of Asian/Pacific Islander 12th graders, 29% of white 12th graders, 8% of Hispanic 12th graders, and 6% each of black and American Indian/Alaska Native 12th graders reached the proficient level in mathematics (appendix table 1-6).

In 2005, boys in grades 4, 8, and 12 performed slightly better than girls in both mathematics and science (appendix tables 1-5, 1-6, 1-7, and 1-8). These small gender gaps have remained stable since 1990 in mathematics (for grades 4 and 8) and 1996 in science (for grades 4, 8, and 12). In 2005, students in grades 4 and 8 who were eligible for the federal subsidized lunch program had lower average mathematics scores than their peers who were not eligible (appendix table 1-5). However, the grade 4 gap with regard to subsidized lunch was slightly less in 2005 than it had been in 1996 (table 1-2; appendix table 1-5). Achievement differences with regard to subsidized lunch eligibility were also found in science, with fourth and eighth grade students eligible for the lunch program performing below their ineligible peers (appendix table 1-7). Between 2000 and 2005, these science gaps by subsidized lunch eligibility in grades 4 and 8 decreased somewhat (table 1-3; appendix table 1-7).

International Comparisons of Mathematics and Science Performance

Two assessments help compare mathematics and science performance in the United States to other countries: the Trends in International Mathematics and Sciences Study (TIMSS) and the Program for International Student Assessment (PISA). Results from the most recent administration of these assessments are included in more detail in *Science and Engineering Indicators 2006* and are only summarized here.

In 2003, U.S. students scored above international averages on the TIMSS assessment and below international averages on the PISA assessment, differences that may be explained, in part, by each test's focus and the set of countries participating in each assessment (Neidorf et al. forthcoming). TIMSS tests primary and middle grade students on curriculum-based knowledge and skills. PISA tests 15-year-olds on their ability to apply scientific and mathematical concepts and thinking skills to real-world problems. Although TIMSS includes results from 46 industrialized and developing countries, PISA results reported here include 30 countries, all of which are industrialized.

According to TIMSS data, U.S. fourth and eighth graders performed above the international average in mathematics and science in 2003 (Gonzales et al. 2004). However, because TIMSS includes many developing countries in its international average, it also can be helpful to compare U.S. performance to two similarly industrialized countries, the United Kingdom and Japan. Japan outperformed U.S. fourth and eighth graders in both mathematics and science. The United Kingdom outperformed U.S. fourth graders in both subjects, but had insufficient numbers participating in eighth grade to make a comparison. According to PISA results, U.S. 15-year-olds performed below the average for industrialized countries in both mathematics and science (Lemke et al. 2004). Of 30 participating industrialized nations, 20 outperformed the United States in mathematics and 15 outperformed it in science (see sidebar "Achievement Negatively Correlated With Confidence in Learning Across Countries/Economies").

Summary

Two national longitudinal studies found that students enter kindergarten with varied mathematics knowledge and skills, and all groups made gains during elementary and high school but at different rates. The result is that most mathematics achievement gaps remain, or have grown, by the time students graduate from high school. The national longitudinal data for science report achievement gaps in third grade (the first time students are assessed) and gains among all groups from third to fifth grade, but also no narrowing

Achievement Negatively Correlated With Confidence in Learning Across Countries/Economies

TIMSS measured a concept less frequently reported with standardized test results: whether students are self-confident in learning. Correlating achievement with self-confidence reveals surprising results. When comparing mathematics score averages across countries/economies, those with higher percentages of students reporting higher confidence in learning mathematics scored *lower* than countries/economies with lower percentages of students reporting such confidence (Loveless 2006; Mullis et al. 2004).

On eighth grade mathematics assessments, 39% of U.S. students reported that they usually do well in mathematics, compared with 4% in Japan (table 1-4). However, the average national test score for the United States was 66 points lower than Japan's. Within a given country, however, students who were more self-confident in learning did score *higher* than other students in their country (Loveless 2006).

Table 1-4
Eighth-grader's confidence in mathematics, by mathematics achievement score and country/economy: 2003

Country/economy	Students who "agree a lot" (%)	Average score	Score above international average
Jordan	48	424	
Egypt	46	406	
Israel	43	496	x
Ghana	41	276	
Bahrain	40	401	
Tunisia	39	410	
Cyprus	39	459	
Palestinian Authority	39	390	
United States	39	504	x
South Africa	38	264	
International average	27	467	
Romania	18	475	x
Singapore	18	605	x
Latvia	17	508	x
Moldova	17	460	
Netherlands	16	536	x
Malaysia	13	508	x
Chinese Taipei	11	585	x
Hong Kong	10	586	x
Korea	5	589	x
Japan	4	570	x

NOTE: Countries/economies ranked by percentage of students who "agree a lot" that *I usually do well in mathematics*.

SOURCES: Loveless T, How Well are American Students Learning? The Brown Center on Education Policy, Brookings Institution (2006), figure 2-1; and International Association for the Evaluation of Educational Achievement Trends in International Mathematics and Science Study (2003).

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and even some widening of the achievement gaps over this 2-year period.

Repeating cross-sectional studies of mathematics and science performance provide different types of indicators. In 2005, students in grades 4 and 8 posted higher mathematics scores than students in those same grades in 1990. The pattern of higher scores was widespread, occurring among males and females, across racial/ethnic groups, for students from financially advantaged and disadvantaged families, and for students in the lower, middle, and higher ranges of performance. Additionally, some achievement gaps narrowed. In science, average scores increased for fourth grade students, held steady for eighth graders, and declined for 12th graders between 1996 (the first year the assessments were given) and 2005. Trends in percentile scores suggest the increase in overall science scores of fourth graders were driven by improved scores among lower- and middle-performing students.

Despite the gains made in mathematics (and to a lesser extent, science) from the 1990s to 2005, most 4th, 8th, and 12th graders do not perform at levels considered proficient for their grade. Just more than one-third of fourth graders reached the proficient level in mathematics in 2005, and the rates were lower for mathematics at grades 8 and 12, and at all three grades for science. International comparisons of student mathematics and science performance indicate U.S. students perform below average in mathematics and science for industrialized countries.

Standards and Student Coursetaking

Standards provide a foundation of support for other key components of any educational accountability system, for example, courses and curriculum, teacher skills and professional development, and assessments. In the face of generally flat performance trends in the upper high school grades even after curricular standards were raised over the past two decades,[9] policymakers and educators are seeking new ways to revise standards and courses to help effectively educate young people (Achieve, Inc. 2004; Achieve, Inc., and National Governors Association 2005; Hurst et al. 2003). Currently, revisions focus on adding specific college-preparatory requirements and on making high school standards congruent with the expectations of colleges and employers by involving their representatives in the revision process.

The courses that students take, along with the curricula and teaching methods used, strongly influence what they learn and how well they are able to apply that learning. Research has linked completing more challenging courses with stronger academic performance, and coursework may play a direct role in increasing student achievement (Bozick, Ingels, and Daniel 2007; Chaney, Burgdorf, and Atash 1997; Lee, Croninger, and Smith 1997; and Schmidt et al. 2001). In their 1990 study, Bryk, Lee, and Smith concluded that coursetaking was the “principal determinant of achievement.”

Links Between Coursetaking and Learning

Researchers have uncovered an association between courses completed and achievement scores, but not all have controlled for student ability. Students with strong academic skills are likely to take more challenging courses, but if they learn more than other students over time, researchers would like to know how much of the additional gain is attributable to skill and how much to coursework.

Two recent studies that applied controls for ability are described here. Using data from students who took its college entrance exams in 2004, an ACT study found that students who completed a recommended core curriculum scored higher on the ACT tests, regardless of sex, race/ethnicity, family income, or ability (ACT 2006). ACT defined that core curriculum as 3 years each of mathematics, science, and social studies and 4 years of English. Taking advanced courses beyond the core requirements, including additional courses in mathematics and science, was linked to larger score gains, even after controlling for students’ prior achievement. Completing the core curriculum also led to higher rates of college enrollment and success in first-year courses like college algebra. Core curriculum graduates were also more likely to be prepared for further workforce training, according to tests of applied learning.

In another study, Bozick, Ingels, and Daniel (2007) used student 10th-grade mathematics proficiency scores as one control measure in examining associations between the mathematics courses taken in 11th and 12th grades and test score gains from 10th to 12th grades. The analysis found that mathematics achievement test scores in 12th grade and achievement gains from 10th to 12th grades were positively related to student mathematics course sequences during the last 2 years of high school. The largest overall gains, and the greatest gains in advanced skills such as derivations and making inferences from algebraic expressions, were made by students who took precalculus in 11th grade plus an additional mathematics course in 12th grade (in most cases, calculus). The largest gains in intermediate skills (such as simple operations and problem solving) were made by those who followed the geometry/algebra II sequence. The smallest gains were made by students who took one mathematics course or no mathematics courses during their last 2 years of secondary school. The analyses controlled for students’ prior skill levels and demographic characteristics, including socioeconomic status, educational aspirations, family composition, and school sector.

This section presents several indicators of standards and coursetaking, including increases in state academic course requirements for high school graduation and revisions of content standards. In addition, high school course completion trends are shown from 1990 through 2005 for advanced mathematics, science, and engineering, as well as for engineering/science technologies, which are generally not considered advanced courses. The section concludes by examining course completion rates for 2005 graduates with various characteristics.

State Coursetaking and Curriculum Standards

Completing advanced courses in high school, particularly in mathematics, not only contributes to increased learning, but also predicts college enrollment and degree completion (Adelman 1999, 2006; Rose and Betts 2001). Students who complete such courses increase their college acceptance chances, are better prepared for college study, and have a higher likelihood of earning a bachelor's degree (see sidebar "Links Between Coursetaking and Learning"). However, a recent American College Test (ACT) report (2006) found that close to half of students who planned to attend college had not completed the academic courses necessary to enroll in credit-bearing college courses. Raising course requirements for graduation provides one method of bridging such gaps in preparation; if preparation is strengthened, not only would college completion rates increase, but many students also would earn degrees more quickly and college remediation costs would decline.

Furthermore, studying high-level mathematics in secondary school, particularly calculus, may increase the likelihood of choosing a mathematics or science major in college (Federman 2007). After adjusting for ability and course preferences, Federman found that the number of high school mathematics courses completed was positively related to propensity to major in a technical field, including all science, technology, engineering, and mathematics (STEM) and some high-level medical fields. Mathematics coursetaking as a stepping stone into such fields may be especially applicable to young women (Trusty 2002). Completing a range of advanced mathematics courses in high school was associated with women's majoring in mathematics and science subjects at higher rates. However, for men, high school physics was the only predictor for majoring in mathematics or science in college.[10] Increasing course completions in advanced mathematics and science may therefore help enlarge the college graduate pool and the workforce in these fields as well as increase women's participation in occupations in which they have been traditionally underrepresented.

Core Subject Requirements

In 2006, 3 years was the most common state requirement for both mathematics (26 states) and science (27 states) courses for high school graduation. In 12 states, the mathematics requirement was two or fewer years and 16 states required 2 or fewer years or science. The shift from a predominant requirement of 2 years in each subject in the mid-1980s is notable (table 1-5). Few states (six for mathematics and one for science) required 4 years of study in these subjects, and one state required 4 years in both.

Six states left course requirements up to local districts, whose standards apply to all high school students in the district. In practice, districts generally require the courses that students need for admission to the state's public universities. Therefore, these states may not differ substantially from those with published statewide requirements. (Districts may also add requirements above state minimums.)

Table 1-5
States requiring various years of mathematics and science study for high school graduation: 1987, 1996, and 2006

State/local standard	Mathematics 1987	Mathematics 1996	Mathematics 2006	Science 1987	Science 1996	Science 2006
Local decision	6	7	6	6	7	6
1–2 years[a]	33	26	12	40	33	16
3 years	10	15	26	3	8	27
4 years	0	2	6	0	2	1

[a]In 2006, all states with statewide requirements required ≥2 years of mathematics courses, and only one state required 1 year of science.

NOTES: Data included for all states for 2006 and for all states plus District of Columbia for years before 2006, with two exceptions: in 1987, Arkansas and Vermont required total of 5 mathematics and science credits (2 or 3 credits in each) so not assigned to a category; in 1996, Vermont alone not counted for this reason. Some states had separate requirements for different kinds of diplomas. For these, states categorized by requirements for "standard" diploma or for type most students likely receive, if more than one type and none called standard. In some states and some years, a new requirement enacted by year in column head but did not necessarily apply to graduating class of that year.

SOURCES: Council of Chief State School Officers, Key State Education Policies on PK-12 Education: 2006 (2007); and National Center for Education Statistics, *Digest of Education Statistics*, 1988 and 1998 editions (1988 and 1999).

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Rising standards have increased the number of required academic courses since the mid-1980s. In the past decade or so, the policy focus has expanded to include listing specific courses that must be completed and improving course content. A primary goal of adding requirements for more mathematics and science study is to direct students into more challenging courses, particularly those intended to prepare them for success in college. To that end, in 2006, 21 states required completion of specific mathematics courses (with algebra the most common) and 22 states required specific science courses (most often biology) (CCSSO 2007). Nearly all states that required specific courses in mathematics also required them in science. Another five states required students to complete a science course with laboratory work but required no specific course.

Course Content Standards and Testing

In addition to specifying key courses that must be completed, states have developed and applied new standards for course content. All states had adopted content standards in mathematics and science by 2006–07, and 35 states had schedules for reviewing and revising those standards (Editorial Projects in Education 2007).

In light of continuing dissatisfaction on the part of employers and college professors with high school graduates' skill levels (see sidebar "Attitudes of Parents, Students, and School Staff Toward Standards") and the overall lack of substantial achievement gains for 12th graders on national and international tests, some policymakers want additional standards revisions and are seeking input from stakeholders outside of K–12 education. Reforms are intended to address the primary problems that critics lodge against standards: they are vague and lack focus, they cover too much and thus cause teachers

Attitudes of Parents, Students, and School Staff Toward Standards

Prominent business and education organizations have continued to underscore the need for high schools to raise standards so that students will gain the skills and knowledge base required by employers and postsecondary institutions. Among these organizations are the Gates Foundation and the American Diploma Project (ADP), a consortium that includes Achieve, Inc., many state leaders, the Education Trust, and the Thomas B. Fordham Foundation. In addition, majorities of employers and professors surveyed in 1998–2002 reported that many or most high school graduates (depending on the specific question) lacked skills needed for successful job performance and course completion. For example, in 2001 nearly two-thirds of both groups thought that graduates' basic mathematics skills were fair or poor, and 73%–75% rated student writing ability fair or poor (Public Agenda 2002).

However, these views contrast with those of parents and students. A 2006 survey of parents and students in public school grades 6–12 showed that most do not believe that their local schools need much improvement or that more mathematics and science instruction is necessary. For example, 32% of parents thought their child's school should be teaching more mathematics and science, whereas 57% thought the current amounts were fine (Public Agenda 2006). At 70%, parents of high school students were the most likely (compared with parents of younger students) to think that no increases were needed. Concern about this issue has decreased since 1994, when 52% of parents identified not learning enough mathematics and science as a serious problem, compared with 32% in 2006. This change may partly reflect increases over time in student coursetaking in these subjects.

On academic standards, students in grades 6–12 also expressed some complacency. Only 35% thought it was a problem at their school that "academic standards are too low and kids are not expected to learn enough," and it was not a high priority among 13 problems rated by students. More were concerned about fellow students lacking respect and using bad language, cheating, skipping school/classes, and "too much pressure to make good grades." Even fewer parents (15%) identified "low academic standards and outdated curricula" as a source of the most pressing problems in schools (in a question with different wording).

Active support from school leaders and teachers is also necessary for reforms to be effective. However, many educators (particularly leaders) do not agree that schools need to raise standards or enact other fundamental reforms. Nearly 80% of both principals and superintendents called it "not a serious problem" that academic standards were too low and students were not expected to learn enough. On a related question, 93% of superintendents and 80% of principals evaluated current educational quality as better than the education they received.

Most parents rated their children's public schools highly in 2006. The majority believed that when their children graduate from high school they will have the skills needed for employment or success in college (61% and 69%, respectively). Nearly two-thirds (65%) of parents said that their children were learning more difficult material in school than they had in their school days, and 61% thought their children's schooling was better than their own at that age. Despite their satisfaction with schools overall, parents of different income levels tended to have divergent opinions. For example, over half of low-income parents in a 2002 survey (56%) worried a lot about the low quality of public schools, compared with just 38% of high-income parents (Public Agenda 2002).

to rush through material, and they differ widely across states (Peterson and Hess 2006; Ravitch 2006; Smith 2006).

Disagreement also exists about whether a single set of standards should apply to all students regardless of their intention to attend college after high school. Whereas standards defining college readiness generally include specific courses, standards for work readiness instead tend to focus on skills, including those specific to a career or industry and broader skills required for any job (Lloyd 2007).

In 2006 the National Council of Teachers of Mathematics (NCTM) called for greater classroom focus on fewer high-priority “focal points” and provided a limited number of specific skill goals for each grade level (NCTM 2006). Similarly, a committee of the National Research Council (NRC) recently urged educators to place continued emphasis on a few fundamental concepts over a span of many grades, and to introduce more complex material related to these concepts as students mature (NRC 2007). Such strategies enable students to develop a deeper understanding of the concepts over time. These recommendations build on curriculum standards documents published earlier by NCTM (2000), the American Association for the Advancement of Science (1993), and NRC (1996).

Despite years of work on standards, a substantial gap still exists in most states between the skills and knowledge required for high school graduation and those needed for college study and work (Achieve, Inc. 2007; Cohen et al. 2006). Efforts to bridge these gaps state by state include the High School Honor States program, which is sponsored by the National Governors Association (NGA), and the American Diploma Project (ADP).

The Honor States program awards grants to states to improve high schools by revamping standards and taking other related actions under NGA leadership (NGA 2007). Funds support developing exemplary practices using NGA’s guidelines, and NGA disseminates findings to policymakers in other states. One primary goal is to align state standards at all school levels, including postsecondary, so that students are prepared to succeed in college courses and the workplace after they graduate from high school. Among promising practices noted so far in the Honor States program is providing financial incentives to support coordination between secondary and postsecondary educators. A practical example of collaboration between these sectors is administering college placement tests in high school to make college academic expectations clear to students. Also, some states have implemented broad media campaigns to raise students’ and others’ awareness of the need to prepare adequately for college and work.

The ADP initiative, sharing the Honor States program goals, provides technical assistance to help educators raise standards and increase consistency across districts. Tracking progress toward aligned standards requires developing and using data systems that follow students from kindergarten or pre-K through their college years. State education agency staff were working in 29 states in 2006 with leaders from elementary, secondary, and postsecondary education (including representatives of the American Council on Education, the National Association of System Heads, and State Higher Education Executive Officers) and business leaders to upgrade curriculum standards. Once in place, such “real-world standards” would help students choose courses and guide them to expend sufficient effort in high school, reducing the need for remedial courses in college (Achieve, Inc. 2007) (see sidebar “The State of State Assessments”).

In 2006, 12 states surveyed by Achieve had curriculum standards in place that met ADP’s college- and work-readiness benchmarks for both mathematics and English curricula (Achieve, Inc. 2007; Cohen et al. 2006). In addition, 27 more states were working to align graduation requirements with these benchmarks and another 5 states had plans to do so. Another element of the program covers requiring all students to complete specific courses for graduation. The ADP minimum levels for course requirements include 4 years of mathematics (including 1 year of algebra II) and 4 years of college-preparatory or equivalent English courses. On this measure, 13 states had adopted such requirements by 2006 and another 16 states had plans to do so within a few years (Achieve, Inc. 2007).

Course Completions by High School Students

Indicators of advanced coursetaking are based on data from the NAEP High School Transcript Study for the graduating class of 2005 and for earlier cohorts when examining trends. The transcript studies gather coursetaking data for a subset of the overall NAEP sample of 12th graders. (See sidebar “Advanced Mathematics and Science Courses” for an explanation of which courses are included as advanced.)

Trends in Course Completions

On average, high school students have completed more mathematics and science courses since 1990 (appendix tables 1-9 and 1-10), including more advanced courses in these subjects. In mathematics in particular, class of 2005 graduates completed courses at higher rates than their 1990 counterparts in all advanced mathematics categories except trigonometry/algebra III[11] (figure 1-5). For example, the proportion of students completing courses in statistics/probability increased eightfold (to about 8%), and for precalculus/analysis, any calculus, and AP/IB calculus, it doubled over the 15-year period. (These jumps were from small initial bases in 1990.) Such increases likely result from a combination of higher state requirements, students’ rising postsecondary aspirations, and growing demand for mathematics and logic skills in the workplace. Nevertheless, relatively small proportions of 2005 graduates had studied most of these subjects; at 29%, precalculus/analysis had the highest completion rate of mathematics courses shown.

Students also have registered higher course completion rates since 1990 in advanced biology, chemistry, and physics, although rates leveled off between 2000 and 2005 for these subjects (figure 1-6; appendix table 1-10). Except for environmental science, the rates of increase were not as sharp as for most mathematics categories. Whereas 4%

The State of State Assessments

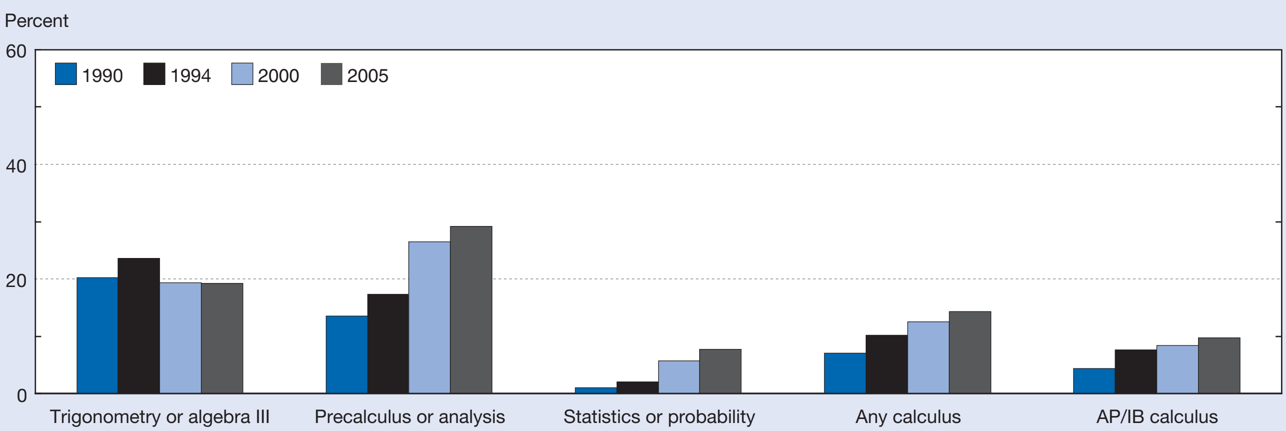
State-administered tests seek to demonstrate whether students are achieving at the level required by state standards; they are also used to track progress in meeting federal requirements for student proficiency. In the 2006 academic year, 47 states and the District of Columbia administered mathematics assessments aligned with state standards at the elementary, middle, and high school levels (Editorial Projects in Education 2007). The No Child Left Behind (NCLB) Act requires assessments in mathematics by academic year 2005 in each grade 3–8 and one in grades 10–12; and in science by 2007 in at least one grade in elementary, middle, and high school. State-approved science assessments were thus commonly given but somewhat less widespread in 2006; for example, 20 states lacked them at the high school level. In addition, to graduate from high school in many states, students must surpass a cutoff score on upper grades tests that include mathematics.

How closely tests are aligned with course standards and curriculums remains a contested issue (Barton 2006). The American Federation of Teachers (AFT) recently reviewed state assessments and concluded that in some states, some tests are not sufficiently aligned with the standards (AFT 2006). Students in these states may therefore be tested on some skills and material that their teachers either did not address or covered inadequately, and their test results would not accurately reflect learning differences among groups or gains over time. Even tests with closely aligned content may have other drawbacks, particularly in science. Although written tests can determine whether students understand elements like scientific concepts, methods of inquiry, and terminology, they cannot test hands-on laboratory skills.

Experts have also questioned the quality of state achievement tests, pointing to both the validity of test items and the scores set for reaching certain achievement levels. For example, critics charge that some states may set the minimum score for *proficient* too low (Petrilli and Finn 2006; Ravitch 2005). The percentage of students reaching *proficient* on many state tests is close to the percentage reaching the *basic* level on NAEP, whereas in other states, percentages for the two tests are similar (Center for Public Education 2006; NCES 2007c). (See chapter 8 for recent NAEP scores by state.) Moreover, in an effort to increase the percentage of students considered proficient (a measure specified in NCLB), and facing pressure to make continuing progress toward the goal of universal proficiency by 2014, some state agencies have lowered the proficient cutoff scores on their tests over time (Petrilli and Finn 2006), thus undermining progress toward higher student achievement.

Discrepancies existed between state and NAEP test results even before NCLB took effect (Fuller et al. 2006). Although setting and reviewing standards and developing aligned tests are widely viewed as effective mechanisms for increasing learning, the details of implementation may still need to be evaluated and improved over time.

Figure 1-5
High school graduates completing advanced mathematics courses, by subject: Selected years, 1990–2005



AP = Advanced Placement; IB = International Baccalaureate.

SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 2000, and 2005 High School Transcript Studies; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-9.

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Advanced Mathematics and Science Courses

Advanced courses referenced in this section are defined as courses that not all students complete and that are not, as a rule, required for graduation. However, whether all courses in certain categories should be categorized as advanced is debatable. For example, any chemistry course, even a standard college preparatory course, is included in the category "any chemistry." This point also applies to the categories any physics, any calculus, and any environmental science.

The "any advanced biology" category is slightly different from the other categories labeled "any" in that it includes second- and third-year biology courses and those designated honors, accelerated, or Advanced Placement/International Baccalaureate (AP/IB), plus a range of specialized courses like anatomy, physiology, and physical science of biotechnology, most of which are college-level courses. *Advanced biology* therefore does not include the standard first-year biology courses required of nearly all students. Similarly, earth science courses are not counted here because they are often (1) required and (2) not advanced, taking the form of basic survey courses that most students take in 9th or 10th grade. On the other hand, certain courses that are clearly advanced are not measured here because they are so rarely studied in high school (for example, space science/astronomy).

AP/IB courses are all advanced; they aim to teach college-level material and develop skills needed for college study. A school's AP/IB courses are included in the broader category for the relevant subject as well as in the separate AP/IB category, which isolates the subset of courses that meet either of these programs' guidelines.

of 1990 graduates studied environmental science, this rate grew to 10% for 2005.

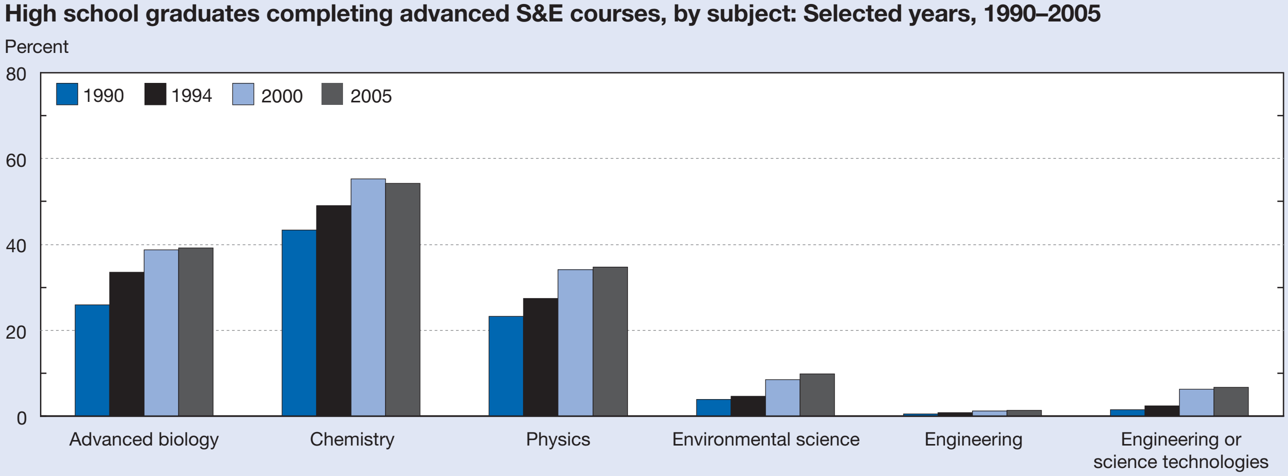
Study of engineering was rare in all years examined, reaching 1.4% in 2005, but it did exhibit a strong growth trend between 1990 and 2005 (appendix table 1-10). The proportion of students taking courses in engineering/science technologies more than quadrupled over this time period, reaching nearly 7% in 2005.

Among the AP/IB courses, coursetaking rates doubled (or more) for calculus and environmental science (since 2000 for the latter) and increased slightly for biology.[12] Overall, just less than 10% of graduates completed an AP/IB calculus course and smaller proportions completed other AP/IB courses.

That course completions were rising while high school student test performance showed a mostly flat trend may appear puzzling. However, the increases in coursetaking may not yet be sufficient, particularly in science, to significantly raise average performance or the overall percentage of students reaching proficiency. (The increases in coursetaking have been less pronounced for science than for mathematics.) Also, the 2005 NAEP mathematics scores cannot fairly be compared with earlier scores because of the new test framework for 2005. Therefore, it is unclear whether mathematics achievement has recently gone up.

Any number of other factors may also contribute to this apparent discrepancy, including changes in student characteristics, teacher skills, course content, and how closely the tests align with curriculum taught. For example, some students who in the past would have been unlikely to take these more advanced courses may have lower cognitive ability, less motivation, weaker study skills, and, for recent immigrants, lesser English skills than the more traditional advanced course takers. All of these factors could impede test performance. In addition, teachers of newly added courses may lack sufficient training to teach those courses effectively or may reduce coverage of material or complexity of

Figure 1-6
High school graduates completing advanced S&E courses, by subject: Selected years, 1990–2005



SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 2000, and 2005 High School Transcript Studies; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-10.

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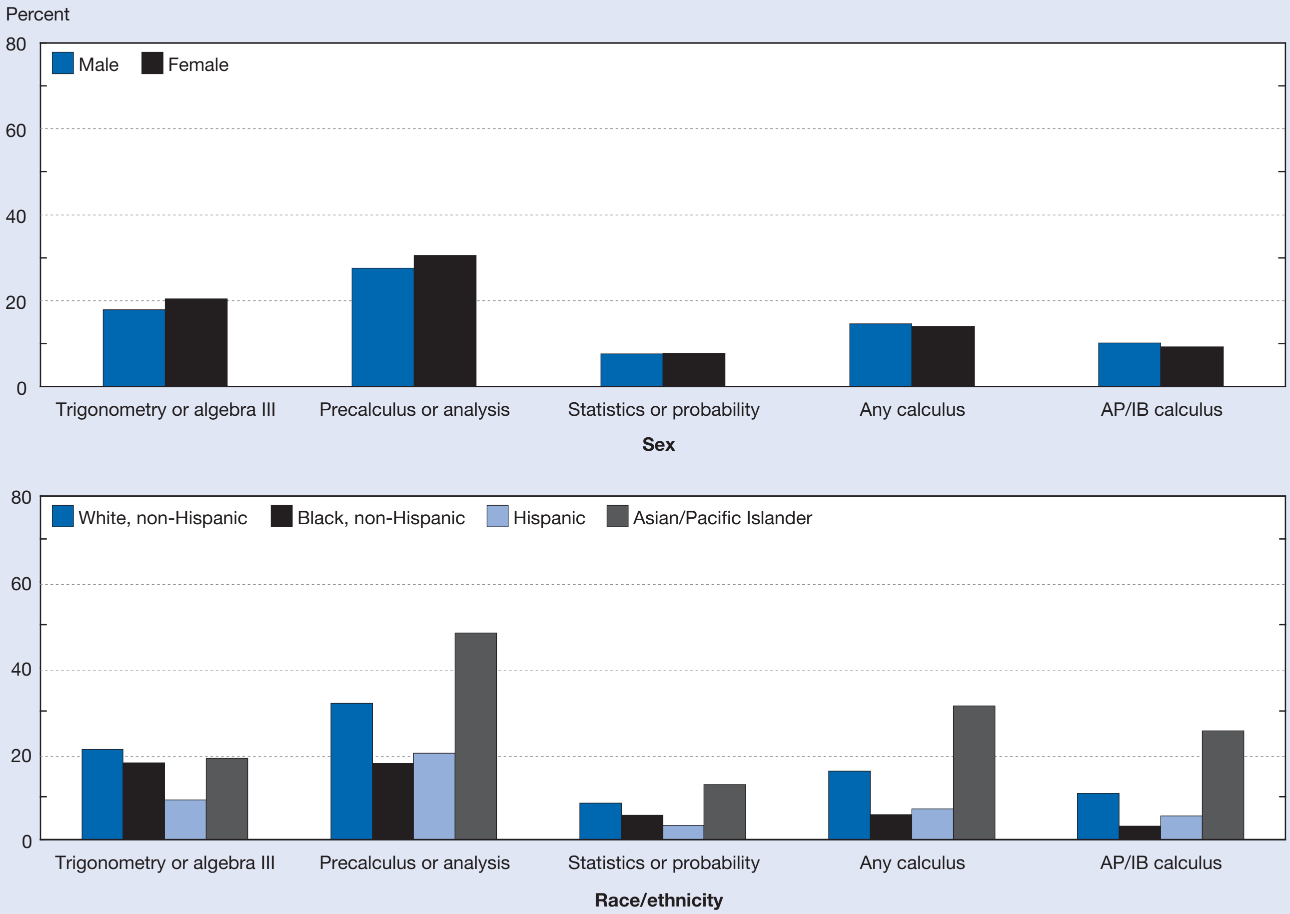
assignments when some students struggle. Students in such classes may have a reduced opportunity to learn some of the relevant material and skills.

Course Completions by Class of 2005

Course completion rates differed in the graduating class of 2005 by several demographic and school characteristics. Female graduates had a slight edge over males in completing courses in precalculus/analysis, and historical differences favoring boys for the other advanced mathematics topics disappeared by 2005 (figure 1-7; appendix table 1-9). Thirty-seven percent of males studied physics compared with 33% of females; males were also more likely to complete an AP/IB physics course but these differences were not great. Females studied advanced biology, AP/IB biology, and any chemistry at higher rates (figure 1-8; appendix table 1-10). For example, about 45% of young women studied advanced biology, compared with 33% of young men.

Among 2005 graduates, coursetaking rates also differed by racial/ethnic group for most course categories. In general, Asian/Pacific Islanders were the most likely to complete advanced mathematics and science courses (figures 1-7 and 1-8).[13] For example, 25% of Asian/Pacific Islander graduates studied AP/IB calculus, compared with 11% of whites and less than 10% of other groups. Asian/Pacific Islander students were the most likely of all groups to earn credits in precalculus/analysis, statistics/probability, calculus, chemistry, physics, and AP/IB classes in calculus, biology, chemistry, and physics. Black and Hispanic graduates were consistently less likely than Asian/Pacific Islander and white graduates to complete most of these advanced courses in mathematics and science; some exceptions to this pattern occurred with trigonometry/algebra III, chemistry, environmental science, engineering, and engineering/science technologies. Black graduates were the most likely to study environmental science, at 14%,

Figure 1-7
High school graduates completing advanced mathematics courses, by sex and race/ethnicity: 2005



AP = Advanced Placement; IB = International Baccalaureate.

SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 2005 High School Transcript Study; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-9.

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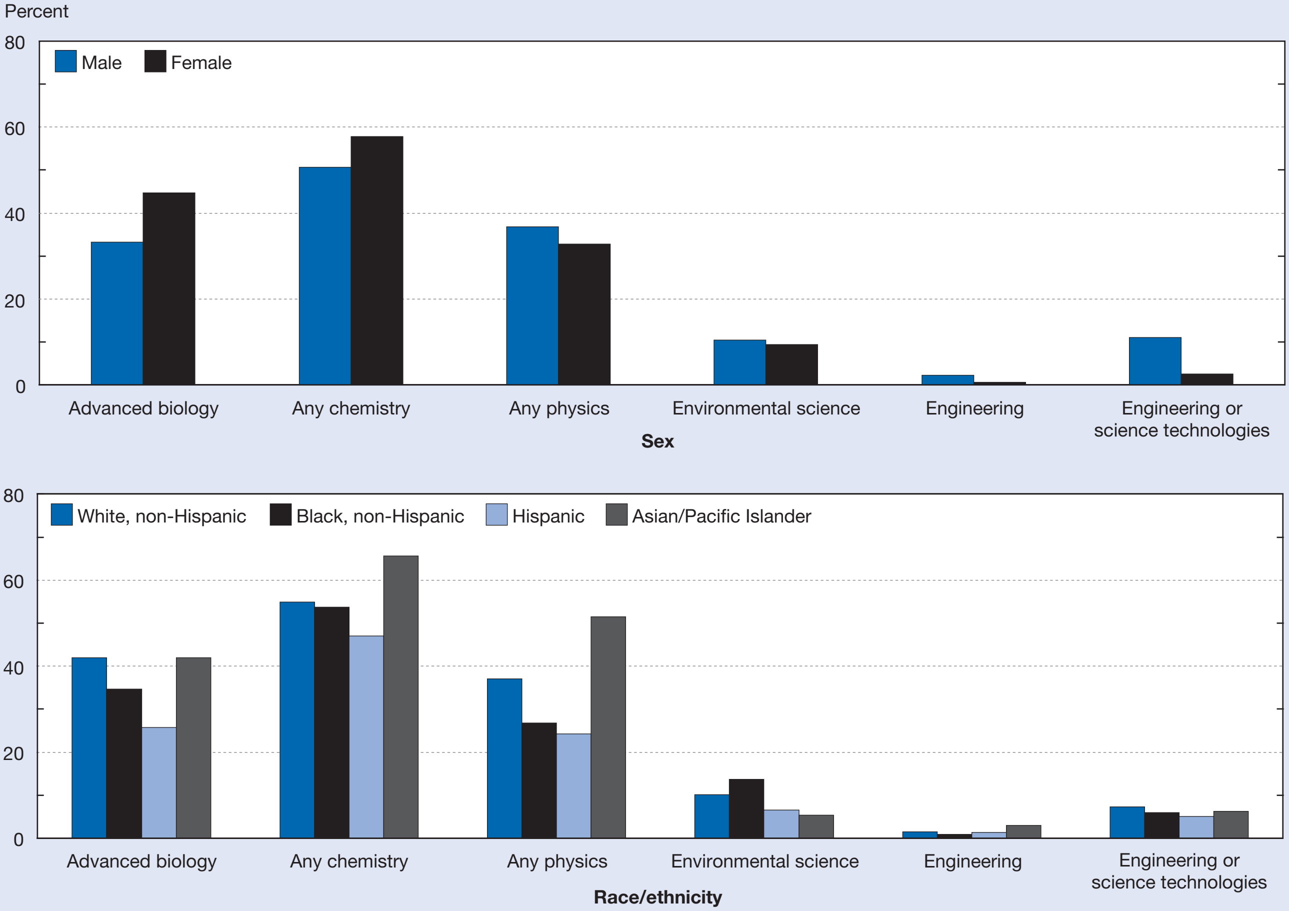
Figure 1-8
High school graduates completing advanced S&E courses, by sex and race/ethnicity: 2005



SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 2005 High School Transcript Study; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-10.

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compared with 10% for whites and lower percentages for other groups.

Coursetaking rates for engineering and engineering/science technologies differed less by race/ethnicity than they did for other course categories. The introduction of engineering-related courses in secondary schools is fairly recent and they remain uncommon; one national organization that promotes and supports such courses, Project Lead The Way, includes in its goals achieving proportionate racial/ethnic and sex composition of program participants (see sidebar “Project Lead The Way”).

In addition to graduates’ own demographic characteristics, certain characteristics of their high schools were linked to the chances that they studied advanced mathematics and science topics. Graduates of private schools were more likely than those of public schools to study each of the advanced mathematics subjects except statistics/probability, and each of the science subjects except advanced and AP/IB biology, environmental science (regular and AP/IB), and engineering-related courses (appendix tables 1-9 and 1-10), where apparent differences were not significant. As the school’s poverty rate diminished, graduates were more likely to complete many of the advanced mathematics, science, and engineering courses (figure 1-9). For some subjects, a significant difference existed only between schools with very low poverty rates and all other schools.

Summary

In 2006, nearly all states required at least 2 years of both mathematics and science for a high school diploma; 3 years was the most common requirement for both subjects. Standards governing coursework have expanded in some states to require specific courses and to raise course difficulty levels to prepare students for college and employment.

Project Lead The Way

Some prominent STEM professionals have expressed concern that, as members of the current engineering and science workforce retire, they will not be replaced in adequate numbers (Business Roundtable 2005; Committee on Prospering in the Global Economy of the 21st Century 2006). In the former report, 15 leading business organizations called for the nation to double the number of STEM graduates by 2015.* These organizations argue that not only has the total number of engineering degrees awarded in the United States decreased in recent years (NSB 2006), but the proportion of doctoral degrees in engineering earned by U.S. citizens or permanent residents has also been dropping.†

Project Lead The Way (PLTW) is a pre-engineering program that aims to attract more students to engineering and train them for college study. It requires students to tackle challenging academic content in middle and high school to prepare for postsecondary study in engineering and related technologies. The program, started in 1997–98 in a few schools, has expanded to more than 1,300 schools in 45 states plus the District of Columbia.

PLTW seeks participation by students of both sexes and all racial/ethnic groups roughly in proportion to their share of the population. Evaluation data show that in 2004–05, Asian/Pacific Islander and white students were overrepresented, and black and Hispanic students underrepresented, when compared with their proportions in the sampled schools. However, compared with the distribution of students completing postsecondary degrees in engineering, each group (particularly Hispanics) had closer to proportional representation in PLTW. Females are seriously underrepresented among PLTW completers, constituting about 15% of the total. Program planners expect that female participation will increase as they introduce four new biomedical science courses in 2008–09. The biomedical courses will address topics in microbiology, physiology, public health, and legal issues.

The curriculums reinforce high-level mathematics and science content aligned with national standards using engineering applications in electronics, robotics, and manufacturing processes. PTLW participants are required to study college-preparatory mathematics every year in grades 9–12. Students work, often in teams and using computers, on challenging problemsolving and analysis tasks. Students can qualify for college credit through performance on course exams, final grades, and project portfolios. The project provides curriculums for five 9-week units for grades 6–8 and eight high school courses. Middle-grade units address topics such as modeling, electrons, automation, robotics, the science of technology, and flight. High school courses offered currently include foundation courses such as Principles of Engineering, Engineering Design, and Digital Electronics; and specialization courses including Civil Engineering and Architecture, Computer Integrated Manufacturing, Aerospace Engineering, and Biotechnical Engineering. A capstone course requires advanced students to develop a solution to a complex engineering problem with guidance from a mentor and to defend their project to external reviewers.

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* Organizations contributing to the report (Tapping America's Potential) include the Business Roundtable, the U.S. Chamber of Commerce, the National Association of Manufacturers, and the Council on Competitiveness.

† Although the report presents a dire picture of sharp declines in STEM degrees earned (particularly in engineering), in reality STEM degrees as a percentage of all degrees has fluctuated in a fairly narrow range from 1994 to 2004 at the bachelor's, master's, and doctoral levels, and near the top of the four-decade range for all but master's degrees (NSB 2006). Indeed, doctorates in engineering were 13.7% of all doctorates awarded in 2004, near the high end of their range since 1966.

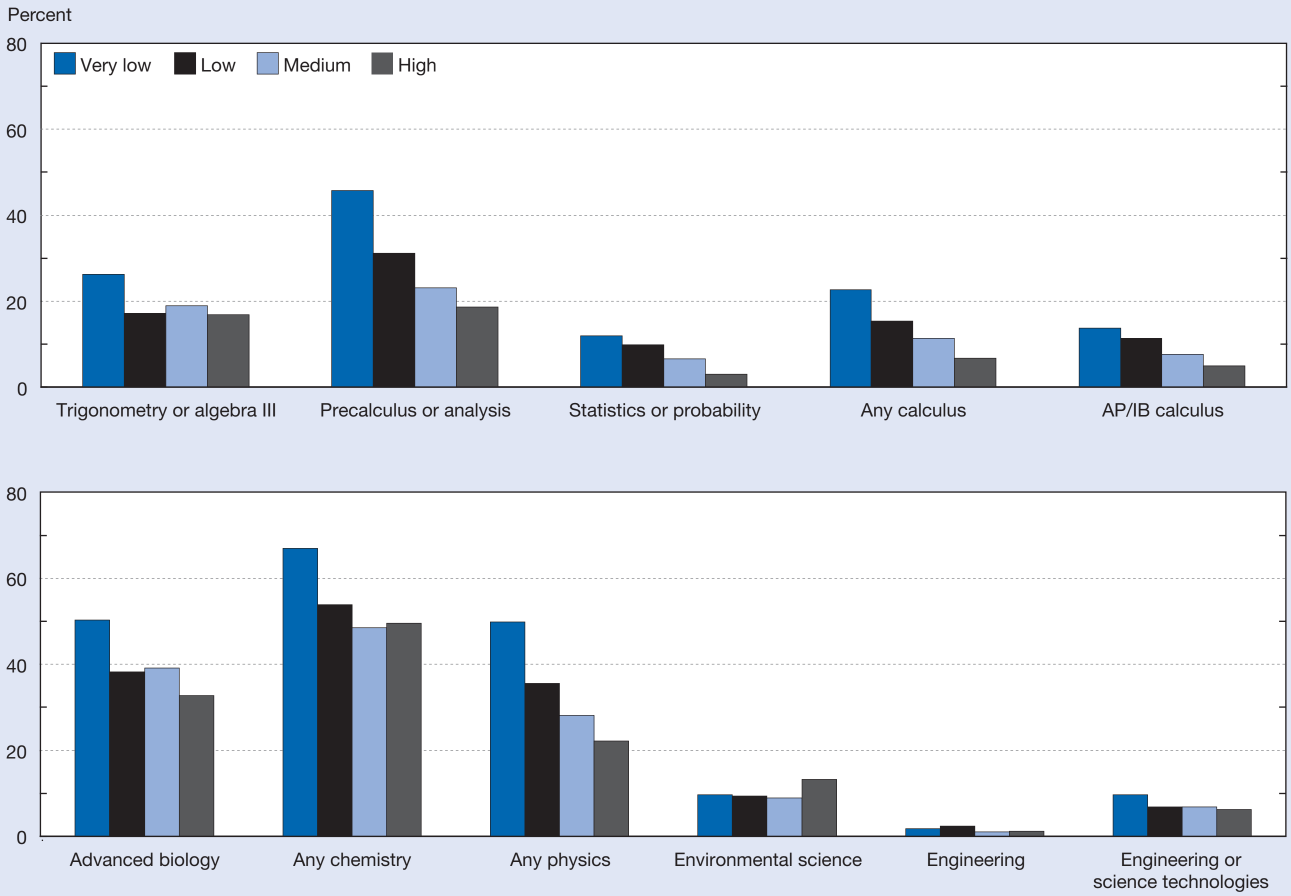
Trends from 1990 to 2005 show increasing proportions of students studying most advanced mathematics and science courses, with growth especially rapid in mathematics. Students also increased course completions since 1990 in advanced biology, chemistry, and physics. Despite growth in AP/IB course completions, fewer than 10% of graduates completed any AP/IB course.

Asian/Pacific Islander students were the most likely of all racial/ethnic groups to earn credits in many mathematics and science subjects, especially in several AP/IB classes. Graduates of private schools and schools with lower poverty rates were more likely than others to study most of these advanced subjects.

Mathematics and Science Teacher Quality

Of the many factors affecting student learning, teacher quality is believed to be one of the most important. Research shows that students learn more from teachers who are skilled, experienced, and know what and how to teach (Darling-Hammond 2000; Darling-Hammond and Youngs 2002; Goldhaber 2002; Hanushek et al. 2005; Rice 2003; Wayne and Youngs 2003). The recent federal NCLB Act has focused a great deal of attention on improving teacher quality in the nation's public schools. It legislates the goal of having a highly qualified teacher in every classroom, and provides a definition of a "highly qualified teacher" (No Child Left Behind Act of 2001).[15]

Figure 1-9
High school graduates completing advanced mathematics and other S&E courses, by school poverty level: 2005



AP = Advanced Placement; IB = International Baccalaureate

NOTE: School poverty level defined as percentage of students eligible for national free/reduced-priced lunch program: very low = ≤5%, low = 6%–25%, medium = 26%–50%, and high = 51%–100%.

SOURCES: National Center for Education Statistics, National Assessment of Educational Progress, 2005 High School Transcript Study; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix tables 1-9 and 1-10.

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This section uses data from SASS to examine indicators of teacher quality, focusing on preservice preparation, degree of congruity between teachers' field of preparation and teaching assignment, and years of teaching experience.[16] The main focus is on mathematics and science teachers in public middle and high schools[17] (see sidebar "Demographic Characteristics of Mathematics and Science Teachers in U.S. Public Schools"). Although this section draws heavily on data from the 2003–04 SASS, comparable data from the 1999–2000 SASS are also used to examine changes occurring over time. When possible, measures are analyzed separately for schools with differing concentrations of minority and low-income students.

Preparation for Teaching

Formal preparation for teaching is typically indicated by highest degree and types of certification. Although having a college degree and certification do not guarantee that a teacher has the deep grasp of subject matter and the repertoire of instructional skills necessary for effective teaching (Public Agenda 2006), they represent two indicators of teacher qualification and are the two basic elements in the NCLB definition of highly qualified teachers. Experts recommend that teachers not only study varied aspects of the profession during preservice education, but also engage in extensive practical training through practice teaching, which is often a requirement for completing an educational degree or state certification, or both (NCTAF 1996; Rice 2003). The following section examines these aspects of preparation that teachers engaged in before starting work in the profession.

Table 1-6
Educational attainment of public school teachers: Academic years 1999–2000 and 2003–04
(Percent distribution)

	Academic year 1999–2000		Academic year 2003–04	
Highest degree earned	All teachers	Mathematics and science	All teachers	Mathematics and science
All teachers	100.0	100.0	100.0	100.0
<Bachelor's	0.7	0.2	1.1	0.3
≥Bachelor's	99.3	99.8	98.9	99.7
Bachelor's	52.0	48.4	50.9	50.1
Master's	42.0	45.8	40.8	43.0
>Master's	5.3	5.6	7.2	6.6

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Highest Degree Attainment

In both 1999 and 2003, virtually all public school teachers, including those who taught mathematics and science, had attained at least a bachelor's degree and nearly half had also earned an advanced degree such as a master's or doctorate (table 1-6). However, mathematics and science teachers holding graduate degrees were not equally distributed across schools. In 2003, for example, mathematics and science teachers in low-poverty schools were more likely than their colleagues in high-poverty schools to have a master's degree or higher (appendix table 1-11).[18] Science teachers with a master's degree or higher were also more prevalent in low-minority schools than in high-minority schools.

Certification Status

In addition to teachers' formal education, certification is an important component of their qualifications. Certification is generally awarded by state education agencies to teachers who have completed specific requirements. These requirements vary across states but typically include completing a bachelor's degree, completing a period of practice teaching, and passing some type of formal test(s) (Kaye 2002). Most teachers complete regular certification programs before beginning to teach. In 2003, 88% of all public school teachers and 84% of mathematics and science teachers held regular or advanced certification (hereinafter called *full certification*) issued by their state (table 1-9). However, fully certified

Demographic Characteristics of Mathematics and Science Teachers in U.S. Public Schools

In 2003, about 3.2 million teachers were employed in U.S. public elementary and secondary schools (table 1-7). About 231,000 were mathematics teachers and 208,000 were science teachers, based on main assignment field (the subject in which they taught the most classes).

The U.S. public school teaching force increased by 7% from 1999 to 2003; the numbers of mathematics and science teachers increased even more, by 11% and 14%, respectively. Most of these increases have occurred in middle schools or in schools with the highest concentrations of minority and poor students. In contrast, and to place these increased staffing levels in perspective, public school enrollment rose by 3%, from 46.9 million in 1999 to 48.5 million in 2003 (NCES 2006c).

In both 1999 and 2003, three of every four public school teachers were female (table 1-8). However, the predominance of female teachers was less pronounced at the high school level. In 2003, for example, 56% of public high school teachers were women. The sex distribution among public school mathematics and science teachers reflects the overall pattern.

Public school teachers were also predominantly white. In both 1999 and 2003, black and Hispanic teachers accounted for 8% and 6%, respectively, and other racial/ethnic groups accounted for less than 3%. The racial and ethnic distributions among middle and high school mathematics and science teachers resemble the overall pattern. Although the share of black and Hispanic teachers among middle and high school mathematics and science teachers appeared to increase between 1999 and 2003, these changes were not statistically significant.

The average age of the teacher workforce increased slightly over this period. In 1999, 29% of public school teachers were at least 50 years old; that percentage rose to 33% in 2003. Similar trends were also observed among middle and high school mathematics and science teachers. These trends suggest that more teachers are approaching retirement age and that recruitment needs may exceed recent levels.

Table 1-7
Public school teachers, by minority enrollment and school poverty level: Academic years 1999–2000 and 2003–04

	All teachers			Mathematics teachers			Science teachers		
School characteristic	1999–2000	2003–04	Change (%)	1999–2000	2003–04	Change (%)	1999–2000	2003–04	Change (%)
All public schools	2,986,000	3,220,000	7.3	206,000	231,000	10.8	180,000	208,000	13.5
Middle schools	517,000	590,000	12.4	65,000	74,000	12.2	59,000	73,000	19.2
Minority enrollment (%)									
0–5	120,000	89,000	–34.8	15,000	10,000	–50.0	13,000	11,000	–18.2
>5–45	239,000	274,000	12.8	30,000	33,000	9.1	28,000	33,000	15.2
>45	157,000	227,000	30.8	20,000	30,000	33.3	17,000	29,000	41.4
School poverty level (%)[a]									
0–10	82,000	67,000	–22.4	12,000	9,000	–33.3	9,000	7,000	–28.6
>10–50	260,000	331,000	21.5	31,000	39,000	20.5	30,000	39,000	23.1
>50	140,000	190,000	26.3	17,000	25,000	32.0	15,000	26,000	42.3
High schools	892,000	888,000	–0.5	114,000	117,000	2.6	103,000	102,000	–1.0
Minority enrollment (%)									
0–5	219,000	159,000	–37.7	26,000	20,000	–30.0	27,000	17,000	–58.8
>5–45	424,000	390,000	–8.7	55,000	51,000	–7.8	49,000	47,000	–4.3
>45	245,000	339,000	27.7	32,000	47,000	31.9	26,000	39,000	33.3
School poverty level (%)[a]									
0–10	233,000	166,000	–40.4	30,000	22,000	–36.4	29,000	21,000	–38.1
>10–50	430,000	520,000	17.3	57,000	70,000	18.6	47,000	59,000	20.3
>50	142,000	165,000	13.9	17,000	22,000	22.7	16,000	18,000	11.1

[a]School poverty level is percentage of students in school qualifying for free/reduced-price lunch. Numbers may not add to total because of rounding.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Table 1-8
Demographic characteristics of public school teachers: Academic years 1999–2000 and 2003–04
(Percent)

	Sex		Race/ethnicity			Age (years)				
Public school teachers	Male	Female	White, non-Hispanic	Black, non-Hispanic	Hispanic	<30	30–39	40–49	50–59	≥60
Academic year 1999–2000										
All teachers	25.1	74.9	84.3	7.5	5.6	17.0	22.0	31.8	26.1	3.1
Middle school	28.9	71.1	83.8	9.0	5.3	18.6	21.1	33.4	24.7	2.2
Mathematics	29.1	70.9	85.2	9.7	3.2	20.8	20.4	31.7	24.6	2.6
Science	36.6	63.4	85.8	7.0	4.3	24.6	21.9	31.7	19.7	2.2
High school	45.1	54.9	86.1	6.4	5.1	16.1	21.6	30.5	28.6	3.2
Mathematics	47.5	52.5	87.1	6.0	3.8	21.2	24.7	25.5	26.3	2.4
Science	55.2	44.8	87.7	5.7	3.9	17.9	25.9	28.6	24.9	2.6
Academic year 2003–04										
All teachers	25.1	74.9	83.1	7.9	6.2	16.6	24.6	25.8	29.0	4.0
Middle school	31.1	68.9	82.6	10.1	5.1	16.6	25.1	26.9	27.9	3.4
Mathematics	32.4	67.6	82.1	12.5	3.7	19.1	28.5	22.6	27.3	2.6
Science	41.7	58.3	80.6	11.7	6.1	16.2	24.4	27.5	27.4	4.6
High school	43.7	56.3	84.5	7.2	5.5	15.1	24.6	25.3	30.1	5.0
Mathematics	43.5	56.5	83.6	7.1	6.1	16.6	29.1	24.2	26.3	3.9
Science	51.0	49.0	86.3	6.7	4.3	16.1	26.8	26.3	25.5	5.3

NOTES: Racial/ethnic categories Asians/Pacific Islanders, American Indians/Alaska Natives, and “more than one race” not shown because of small sample sizes. More than one race not a response category in 1999, and thus 1999 and 2003 data are not strictly comparable.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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teachers were more common in schools with lower proportions of minority and poor students (appendix table 1-12).

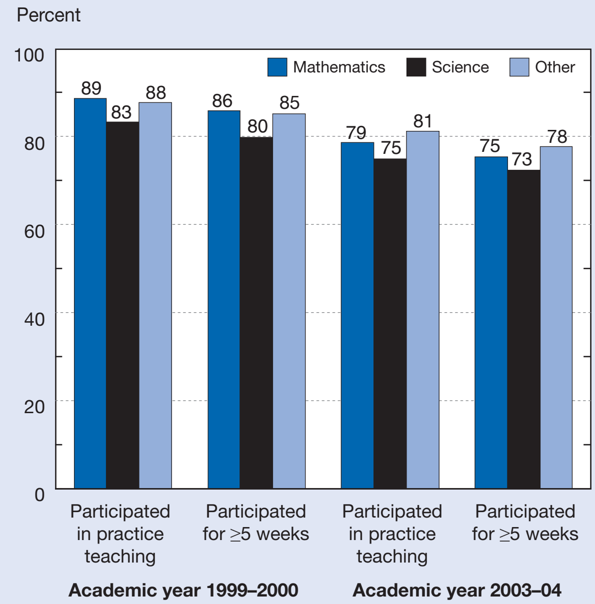
In response to a growing demand for teachers because of increased enrollment and reduced class size, many states have also developed various alternative certification programs allowing individuals to become teachers without first completing a regular certification program (Shen 1997). Depending on the particular requirements completed, these individuals are typically awarded probationary, provisional/temporary, or emergency licenses.[19] In 2003, 11% of all public school teachers and 15% of mathematics and science teachers held one of these kinds of certification (table 1-9).

Some states still allow public schools to hire teacher candidates who do not have a license. However, this practice has significantly decreased during recent years; between 1999 and 2003, the percentage of public school mathematics and science teachers who did not have a teaching certificate declined from 10% to 1%.

Practice Teaching

The majority of public middle and high school mathematics and science teachers with less than 5 years of teaching experience (hereinafter called *beginning teachers*) had participated in practice teaching before starting the job; many had practiced for at least 5 weeks (figure 1-10).[20] However, participation in practice teaching has declined in recent years. In 1999, 83%–89% of beginning mathematics and science teachers reported participation in practice teaching for some period of time. These percentages dropped to 75%–79% in 2003. In addition, teachers with practice teaching were not evenly distributed across schools: the percentage of beginning mathematics and science teachers who had any practice teaching was inversely related to school concentrations of minority and poor students (appendix table 1-13).

Figure 1-10
Practice teaching of public middle and high school teachers with less than 5 years of teaching experience: Academic years 1999–2000 and 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Self-Assessment of Preparedness

Public middle and high school teachers generally felt well prepared to perform various tasks during their first year of teaching (figure 1-11), particularly teaching the subject

Table 1-9
Type of certification of public school teachers: Academic years 1999–2000 and 2003–04
(Percent distribution)

Type of certification	Academic year 1999–2000: All teachers	Academic year 1999–2000: Mathematics and science	Academic year 2003–04: All teachers	Academic year 2003–04: Mathematics and science
All teachers	100.0	100.0	100.0	100.0
Regular or advanced	86.6	81.0	87.6	84.1
Probationary	2.8	3.4	3.8	4.7
Provisionary or alternative	3.2	3.6	4.3	6.3
Temporary	1.1	1.3	2.2	2.8
Emergency	0.6	1.0	0.7	0.7
None	5.8	9.8	1.5	1.3

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

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 1999–2000 and 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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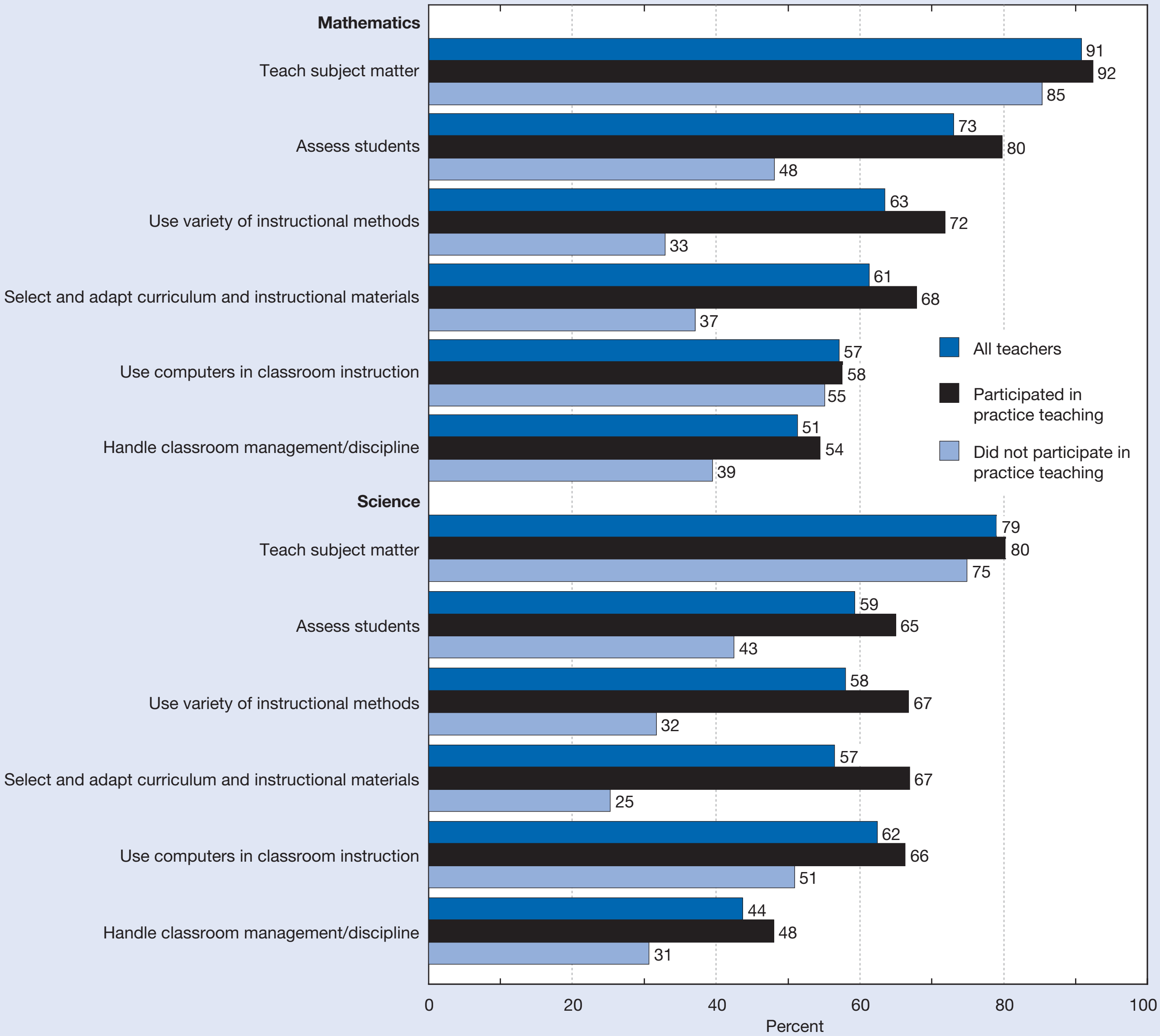
Figure 1-11
Preparedness for first-year teaching of public middle and high school mathematics and science teachers with less than 5 years of experience, by participation in practice teaching: Academic year 2003–04



NOTES: Teachers with <5 years of teaching experience asked about how well they were prepared to perform various tasks during first year of teaching. Response categories included "very well prepared," "well prepared," "somewhat prepared," and "not at all prepared." Percentages based on teachers who responded "very well prepared" or "well prepared."

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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matter (79%-91%). Mathematics teachers were more likely than science teachers to report feeling that they had strong preparation for various tasks except for using computers to teach. In general, beginning teachers who taught in schools with lower minority enrollment and poverty rates expressed more confidence about handling their first teaching assignment (appendix table 1-14).

Teacher confidence about preparation for their first teaching job was related to practice teaching. Beginning mathematics and science teachers who participated in practice teaching were more likely than their counterparts without any practice teaching to report feeling well prepared to perform various teaching tasks (figure 1-11).

Match Between Teacher Preparation and Assignment

Over the past decade, no issue related to teacher quality has received more attention than out-of-field teaching in the nation's middle and high schools (Ingersoll 2003; Jerald 2002; Peske and Haycock 2006). This issue is crucial because even well-educated and fully certified teachers may be unqualified, in practical terms, if they are assigned to teach subjects for which they have little formal preparation. To determine how many teachers are teaching their subjects without specific kinds of formal training in those subjects, efforts have focused on the nature of teacher qualifications (postsecondary coursework or state certification in their teaching assignment field) (Ingersoll 1999, 2003; NCTAF 1996). Teachers without qualifications in their teaching assignment fields are described as teaching *out of field.*

The following indicators use SASS data to examine the scope of out-of-field teaching among public middle and high school mathematics and science teachers in academic year 2003. The sidebar "In-Field and Out-of-Field Teaching" provides the detailed definitions used in this section.

Mathematics

In 2003, over half (54%) of mathematics teachers in public middle schools were teaching in field (table 1-10). Five percent were teaching out of field; that is, they taught mathematics with neither a major nor certification in mathematics, related fields, or general education. At the high school level, a substantial majority of mathematics teachers were in field (87%), and about 8% were teaching out of field.

Biological/Life Sciences

More than half (55%) of biology/life science teachers (hereinafter called *biology teachers*) at the middle school level were teaching in field. About 10% of middle school biology teachers were teaching out of field, about twice the proportion of middle school mathematics teachers. The vast majority of high school biology teachers (92%) were teaching in field, and 3% were teaching out of field.

In-Field and Out-of-Field Teaching

Different researchers (and previous editions of *Indicators*) have defined out-of-field teaching in different ways (Ingersoll 1999, 2003; McGrath, Holt, and Seastrom 2005; Seastrom et al. 2002). Estimates of how widespread out-of-field teaching is depend on how strictly the concept is defined. This section uses a four-level indicator of the linkage between preparation for teaching science and mathematics courses and the main teaching assignment reported by teachers in SASS.

In the following definitions *full certification* includes regular, advanced, or probationary certification status. *Major* refers to the field of study for an undergraduate or graduate degree. Unlike related concepts used in the research literature, this definition recognizes general preparation. State certification regulations vary about whether they treat middle-grade teachers more like elementary teachers (thus requiring a general education credential that covers some preparation in core academic subjects) or more like secondary teachers (requiring single-subject credentials). In some states, the most common type of certification for middle-grade teachers is a general elementary certificate.

The four levels of the indicator are as follows (in decreasing strength of linkage between teacher preparation and the teacher's main assignment field).

In-field. In-field teachers have either a major or full certification in their main teaching field, or both. For example, a mathematics teacher is in field if he or she majored in mathematics or is fully certified in mathematics.

Related-field. Related-field teachers have either a major or full certification in a field related to their main teaching field, or both. For example, a related-field mathematics teacher has a major or full certification in computer science, engineering, or physics.

General preparation. General preparation teachers have either a major or full certification in general elementary, middle, or secondary education. For example, a physics teacher has general preparation if he or she has a major or full certification in general elementary, middle, or secondary education.

Out-of-field. Out-of-field teachers have neither a major nor full certification in their main teaching field, a related field, or general elementary, middle, or secondary education. For example, a biology/life science teacher is teaching out-of-field if he or she has neither a major nor certification in biology, a related field (e.g., physics, chemistry, earth science), or general elementary, middle, or secondary education.

This indicator cannot be used as a gauge of teacher competence because indicators of quality teaching include many other characteristics that are difficult and costly to measure, such as commitment to the profession, sense of responsibility for student learning, and ability to motivate students and diagnose and remedy their learning difficulties. Nevertheless, research, policy, and legislation (e.g., NCLB) point to in-field teaching as a desirable national goal, and states, schools, and school systems administrators can look to this indicator as they engage in efforts to improve teaching.

The discussion in this section focuses on the polar categories of in-field and out-of-field teaching. Appendix table 1-15 also provides data on the nation's teachers of mathematics, biology/life science, and physical sciences who fall between these two extremes.

Table 1-10
In-field and out-of-field teaching of public middle and high school mathematics, biology/life science, and physical science teachers: Academic year 2003–04
(Percent)

Level/field	In-field teaching	Out-of-field teaching
Middle school		
Mathematics	53.5	5.1
Biology/life sciences	54.8	9.5
Physical sciences	32.7	3.1
High school		
Mathematics	87.4	7.5
Biology/life sciences	91.9	3.2
Physical sciences	78.1	1.5

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-15.

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Physical Sciences

Overall, physical science teachers were less qualified on this indicator than mathematics and biology teachers. At the middle school level, 33% of physical science teachers were teaching in field and 3% were teaching out of field. At the high school level, 78% of physical science teachers were teaching in field and 2%, out of field.

Variation Across Schools

In-field and out-of-field teachers were not distributed evenly across schools (appendix table 1-15). In general, mathematics and science teachers in schools with lower concentrations of minority and poor students were more likely to be teaching in field, and those in schools with higher concentrations of minority and poor students were more likely to be teaching out of field. Among high school mathematics teachers, for example, 10% of those in high-minority schools taught mathematics out of field compared with 3% of their counterparts in low-minority schools. Among high school physical science teachers, 86% in low-poverty schools were teaching in field, compared with 77% in high-poverty schools.

Teaching Experience

Although experience does not guarantee quality teaching, empirical evidence indicates that teachers who have at least several years of teaching experience are generally more effective than new teachers in helping students learn (Fetler 1999; Hanushek et al. 2005; Murnane and Phillips 1981; Rivkin, Hanushek, and Kain 2000; Rowan, Correnti, and Miller 2002). The following discussion focuses on new mathematics and science teachers (those with 3 or fewer years of teaching experience) and how they are distributed across schools.

In 2003, new teachers made up 17%–22% of mathematics teachers and 15%–19% of science teachers in public middle and high schools (appendix table 1-16). At the middle school level, the proportion of new teachers was greater among mathematics teachers (22%) than among science teachers or teachers in other fields (15% for both). The difference was not observed at the high school level, however. In general, high-minority and high-poverty schools were more likely than low-minority and low-poverty schools to have new mathematics and science teachers. This was particularly true for mathematics teachers in middle schools: in high-minority and high-poverty middle schools, 28%–33% of mathematics teachers were new teachers, but in low-minority and low-poverty schools, the percentages were 15%–18%.

Summary

Virtually all public school mathematics and science teachers had a bachelor's degree and nearly 9 in 10 held full state certification. The majority of beginning mathematics and science teachers in public middle and high schools had also participated in practice teaching before starting their first teaching job, although the percentage of teachers with practice teaching experience declined from 1999 to 2003. Teachers with preservice practice teaching had greater confidence about their ability to handle their first teaching assignment.

More than three-fourths of mathematics and science teachers in public high schools were teaching in field. However, in-field teaching was less common at the middle school level. Overall, out-of-field teaching ranged from 3% of physical science teachers to 10% of biology teachers in middle schools and from 2% of physical science teachers to 8% of mathematics teachers in high schools. All indicators examined in this section showed a general pattern of unequal access to the most qualified teachers: low-minority and low-poverty schools were more likely than high-minority and high-poverty schools to have teachers with more education, better preparation and qualifications in their field, and more experience.

Professional Development of Mathematics and Science Teachers

Teacher professional development is a major component of current reform policies (Cohen and Hill 2001; Darling-Hammond 2005; Hirsch, Koppich, and Knapp 2001; Little 1993) (see sidebar "State Professional Development Policies for Teachers"). To help all students meet the high educational standards necessary to participate in the global workforce, today's teachers are being called on to provide their students with a high-quality education and to teach in ways they have never taught before. The nature and magnitude of changes demanded by these reform policies require a great deal of learning on the part of teachers. Ongoing professional development provides a vehicle for teachers to gain such learning (NCTAF 1997; NRC 2007). Research has demonstrated that sustained and intensive participation in

State Professional Development Policies for Teachers

For two decades, the U.S. government has made teacher professional development a component of its reform efforts (Little 1993; Porter et al. 2000), and many states have developed and implemented policies designed to promote participation in professional development (CCSSO 2005, 2007; Editorial Projects in Education 2006). A total of 48 states required professional development for teacher license renewal in both 2002 and 2006 (table 1-11). Between 2004 and 2006, the number of states that had standards in place for professional development increased from 35 to 40, as did those that financed professional development programs (37 to 39), provided professional development funds for all districts in the state (27 to 31), and required districts or schools to set aside teacher time for professional development (13 to 15). In 2006, 15 states also required and financed mentoring programs for all novice teachers.

Table 1-11
States with various professional development policies for teachers: 2004 and 2006

Statewide policy	2004	2006
Required professional development for teacher license renewal	48[a]	48
Wrote professional development standards	35	40
Financed professional development	37	39
Financed professional development for all districts in state	27	31
Required and financed mentoring for all novice teachers	16	15
Required districts/schools to set aside time for professional development	13	15

[a]2002 count.

SOURCES: Council of Chief State School Officers, Key State Education Policies on PK-12 Education: 2002 (2002); Key State Education Policies on PK-12 Education: 2006 (2007); Editorial Projects in Education 2005, State of the states, *Education Week: Quality Counts* 24(17); and Quality counts at 10: A decade of standards-based education, *Education Week: Quality Counts 2006* 25(17).

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high-quality professional development can change teacher attitudes, behaviors, and the instructional practices they use in the classroom (Banilower et al. 2005; Garet et al. 2001; Guskey 2003; Hawley and Valli 2001; Porter et al. 2000). Furthermore, student learning increased when their teachers changed in these ways (Cohen and Hill 2000; Desimone et al. 2002; Holland 2005; Wenglinsky 2002).

This section examines several indicators of teacher professional development, including new teacher induction; features of teacher participation in professional development (i.e., content, duration, format, and extent of collaboration); teacher assessments of the usefulness of professional development activities; and their priorities for future activities. These indicators help determine the extent to which effective features of professional development exist at the national level.

New Teacher Induction

Research suggests that teachers with less experience, particularly those in their first year of teaching, are less effective in the classroom (Murnane and Phillips 1981). Without sufficient support and guidance, novice teachers may reduce their commitment to teaching and may leave the profession altogether (Smith and Ingersoll 2004; Smith and Rowley 2005). Teacher induction programs are designed at the school, local, or state level to assist and support beginning teachers in their first few years of teaching (Fulton, Yoon, and Lee 2005).[21] The purpose is to help new teachers improve professional practice, deepen their understanding of teaching, and prevent early attrition (Britton et al. 2003; Smith and Ingersoll 2004). One key component of such programs is that new teachers are paired with mentors or other experienced teachers to receive advice, instruction, and support.

Participation in induction and mentoring programs has been fairly common and has become more so in recent years. In 2003, 68%–72% of beginning mathematics and science teachers in public middle and high schools reported that they had participated in a formal teacher induction program or had worked closely with a mentor teacher during their first year of teaching (appendix table 1-17). However, smaller proportions of these teachers had worked closely with a mentor in the same subject field (50%–52%). Teacher participation in induction and mentoring programs was lower in schools with high concentrations of minority and low-income students.

Ongoing Professional Development

Almost all teachers participate in some form of professional development activities every school year (Choy, Chen, and Bugarin 2006; Scotchmer, McGrath, and Coder 2005). It is important not only to make professional development accessible to teachers, but also to identify features that bring about positive changes in teaching practices and student learning and to build these features into the activities (Elmore 2002; Garet et al. 2001; Guskey 2003; Hawley and Valli 2001; Loucks-Horsley et al. 2003). Recognizing this new need, the education research community began to develop a knowledge base of what constitutes effective professional development programs. Several key features have been identified that are linked to positive change in teacher knowledge and instructional practices, including content focusing on teacher subject-matter knowledge or how students learn the subject content; programs of long and sustained duration (recent research suggests at least 80 hours); program content integrated into teachers' daily work, rather than removed from the context of direct teaching (as in traditional workshops); and emphasis on a team approach and collaboration among teachers (Banilower et al. 2005; Clewell et al. 2004; Cohen and Hill 2000; Desimone et al. 2002; Garet et al. 2001; Porter et al. 2000). The following indicators examine the extent to which public middle and high school mathematics and science teachers participated in professional development that had these characteristics.

Content

Professional development activities tend to focus on a few topics and teaching skills, frequently on the teacher's main teaching subject. In 2003, more than 70% of mathematics, science, and other subject-area teachers in public middle and high schools reported participation in professional development that focused on the content of the subjects they taught (figure 1-12). Another frequent topic of professional development is using computers for instruction: 64%–67% of teachers reported receiving professional development on this topic. Relatively fewer teachers (38%–45%) participated in professional development related to student discipline and classroom management.

Participation rates varied across schools. Mathematics and science teachers who taught in high-minority and high-poverty schools were more likely than those in low-minority and low-poverty schools to report receiving professional development on subject matter and on student discipline and classroom management (appendix table 1-18).[22]

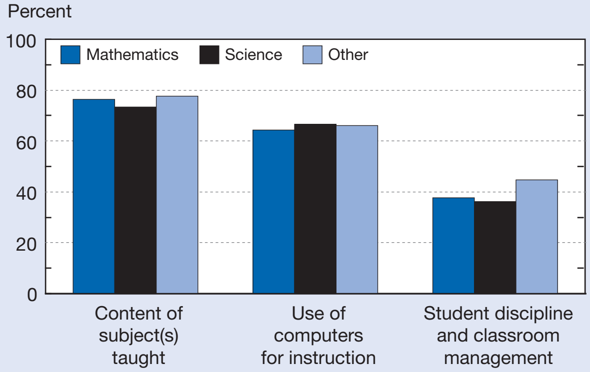
Duration

Recent research emphasizes intensive participation as a critical feature of effective professional development. Teachers are likely to benefit more from professional development programs that are sustained over an extended period of time and involve a significant number of hours. Some studies recommend at least 60–80 hours to bring about meaningful change in teaching practice (Banilower et al. 2005; Supovitz and Turner 2000; Weiss, Banilower, and Shimkus 2004). However, few teachers participated in professional development programs for this amount of time. In 2003, between 4% and 28% of mathematics and science teachers in public middle and high schools reported attending professional development on various topics for 33 or more hours over the course of a school year (figure 1-13). Most teachers received 9–32 hours of professional development on their subject matter or 8 or fewer hours of professional development on using computers for classroom instruction or on student discipline and classroom management.[23] Thus, the amount of time teachers devoted to professional development may be less than research suggests may be optimal.

Formats

The *format* of professional development refers to the way in which a professional development activity is delivered. For many years, teacher professional development has been primarily through district- or school-sponsored workshops, conferences, and training sessions (Choy and Chen 1998; Choy, Chen, and Bugarin 2006; Parsad, Lewis, and Farris 2001). In 2003, more than 90% of public middle and high school mathematics, science, and other subject-area teachers participated in professional development through workshops, conferences, and training sessions (figure 1-14). Although

Figure 1-12
Professional development of public middle and high school teachers during past 12 months, by topic: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations. See appendix table 1-18.

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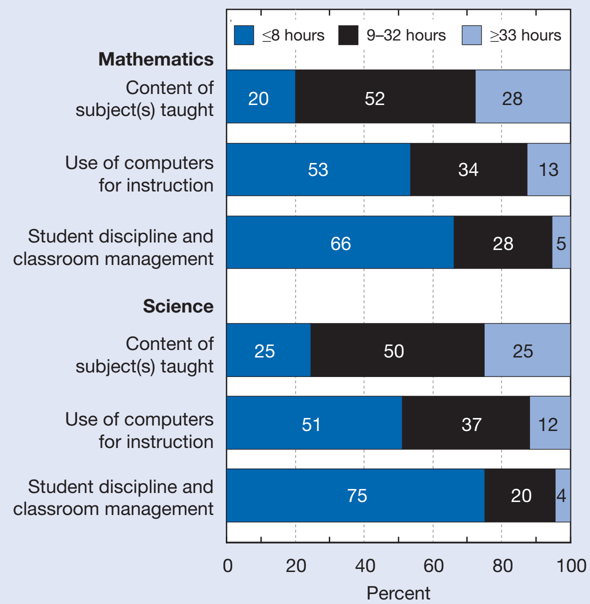
Figure 1-13
Professional development of public middle and high school teachers during past 12 months, by topic and time spent: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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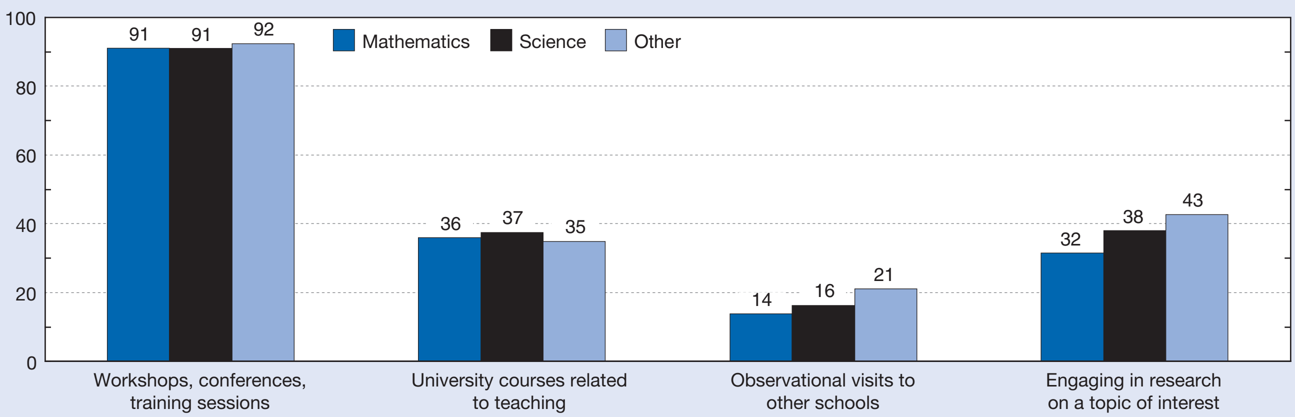
Figure 1-14
Professional development of public middle and high school teachers during past 12 months, by format: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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some teachers took postsecondary courses, the percentages were much lower (35%-37%). Participation in such activities as visiting other schools or conducting research on a topic of interest was also not common (14%–43%).[24]

Collaborative Participation

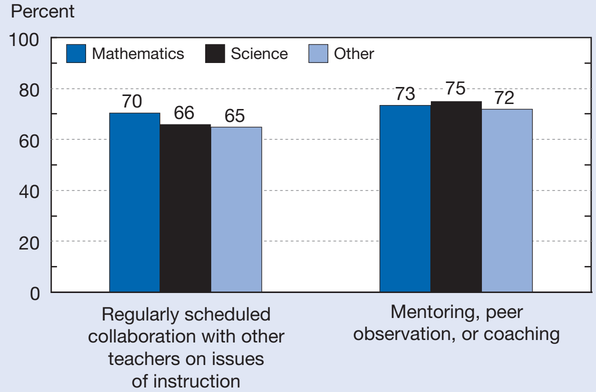
Collaborative participation, which involves professional development designed for groups of teachers from the same school, department, and grade level, fosters cooperation and interaction among teachers (Garet et al. 2001; Desimone et al. 2002). Two constructs were used here to measure this concept, regularly scheduled collaboration with other teachers on issues of instruction and participation in mentoring, peer observation, or coaching. Based on these measures, teacher collaboration was common. In 2003, about two-thirds of public middle and high school mathematics, science, and other subject-area teachers reported that they had collaborated regularly with other teachers on matters of instruction (figure 1-15). More than 70% of these teachers reported that they had participated in peer observation, mentoring, or coaching activities.[25]

Teacher Assessment of Professional Development

Were professional development activities useful to teachers? Teachers' assessments of their professional development activities were generally positive. In 2003, 62%–69% of mathematics, science, and other subject-area teachers in public middle and high schools rated activities on subject content and use of computers for instruction as "useful" or "very useful" (appendix table 1-19). Between 53% and 59% of participants gave similar ratings to the topic of student discipline and classroom management.

Teachers' assessments were strongly related to the amount of time they spent on these activities. For each topic, the more time teachers spent in professional development, the more likely they were to indicate that it was useful or very useful. This relationship held for mathematics, science, and other subject-area teachers.

Figure 1-15
Collaborative professional development activities of public middle and high school teachers: Academic year 2003–04



SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Teacher Priorities for Professional Development

In addition to assessing the usefulness of the programs they attended, teachers identified their priorities for future professional development. Public middle and high school mathematics and science teachers rated their main subject field and the use of technology for instruction as their top interest for future professional development (appendix table 1-20). Teachers in other subject areas had somewhat different priorities. Although the main subject field was also their top pick (24%), many also chose student discipline and classroom management (19%) and teaching students with special needs or limited English proficiency (18%).

Teachers in different types of schools had different priorities. For example, mathematics and science teachers in high-minority and high-poverty schools were more likely to identify student discipline and classroom management as their top priority, whereas their colleagues in low-minority and low-poverty schools were more likely to pick the content of the main subject field.

Summary

Induction and mentoring programs are designed to help new teachers become more effective and stay in teaching. These programs are presently widely implemented in public schools. Teacher participation in professional development was also common. In 2003, for example, more than 70% of public middle and high school mathematics and science teachers reported participation in professional development that focused on the content of the subject matter they taught. However, although recent research has found that intensive participation lasting at least 60–80 hours might be necessary to bring about meaningful change in teaching practice, just 4%–28% of mathematics and science teachers in public middle and high schools attended a professional development program for 33 hours or more over a school year, suggesting that the current amount of time devoted to teacher professional development may not be enough.

The majority of teachers participated in professional development by attending workshops, conferences, and training sessions. Most teachers indicated that the professional development programs in which they participated were useful, especially those that emphasized the content of their subject matter and the use of computers for instruction. Teachers also rated more highly professional development programs that were of longer duration.

Teacher Salaries, Working Conditions, and Job Satisfaction

The challenge of staffing the nation's schools with highly qualified teachers has turned policymaker and researcher attention to the issues of hiring and retention. Reports of difficulty in hiring teachers in elementary and secondary schools began to emerge in the early 1990s and have continued in recent years (Arnold and Choy 1993; BHEF 2007; Broughman and Rollefson 2000; Carroll, Reichardt, and Guarino 2000; Guarino, Santibanez, and Daley 2006; Murphy, DeArmond, and Guin 2003; NCTAF 1996, 2003). Although there have been various explanations for this situation,[26] current research suggests that in recent years hiring difficulty was primarily caused by large numbers of teachers leaving the profession before regular retirement age (Cochran-Smith 2004; Ingersoll 2001, 2004, 2006; Merrow 1999; Wayne 2000) (see sidebar "Attrition From Teaching"). Filling vacancies, seeking qualified candidates, and introducing and mentoring new teachers all involve financial costs (Brenner 2000). The consequences could be even worse if unqualified or partially qualified individuals have to be hired to replace those who leave (NCTAF 2003).

Why do teachers leave their jobs before retirement? What makes them want to stay in the profession? Researchers have addressed these important questions (Guarino, Santibanez, and Daley 2006). Although many factors can influence teachers' decisions about leaving or staying in their jobs, results from past research consistently indicate that teacher working conditions and salary levels are critical in such decisions (Boyd et al. 2005; Dolton and Wilbert 1999; Hanushek, Kain, and Rivkin 2004; Ingersoll 2006; Loeb, Darling-Hammond, and Luczak 2005; Perie and Baker 1997). The research evidence suggests that adequate compensation and safe and supportive school environments serve to attract and retain teachers, whereas low pay and poor working conditions undermine teachers' long-term commitment to their jobs.

This section examines several indicators related to teacher working conditions, including their salaries, perceptions of their work environments, overall job satisfaction, and willingness to continue to teach. To provide a context for such a discussion, the section begins by examining whether there has been an insufficient number of teachers in mathematics and science in recent years. It concludes by looking at how various aspects of teacher work environments are linked to their long-term commitment to teaching as a career and profession.

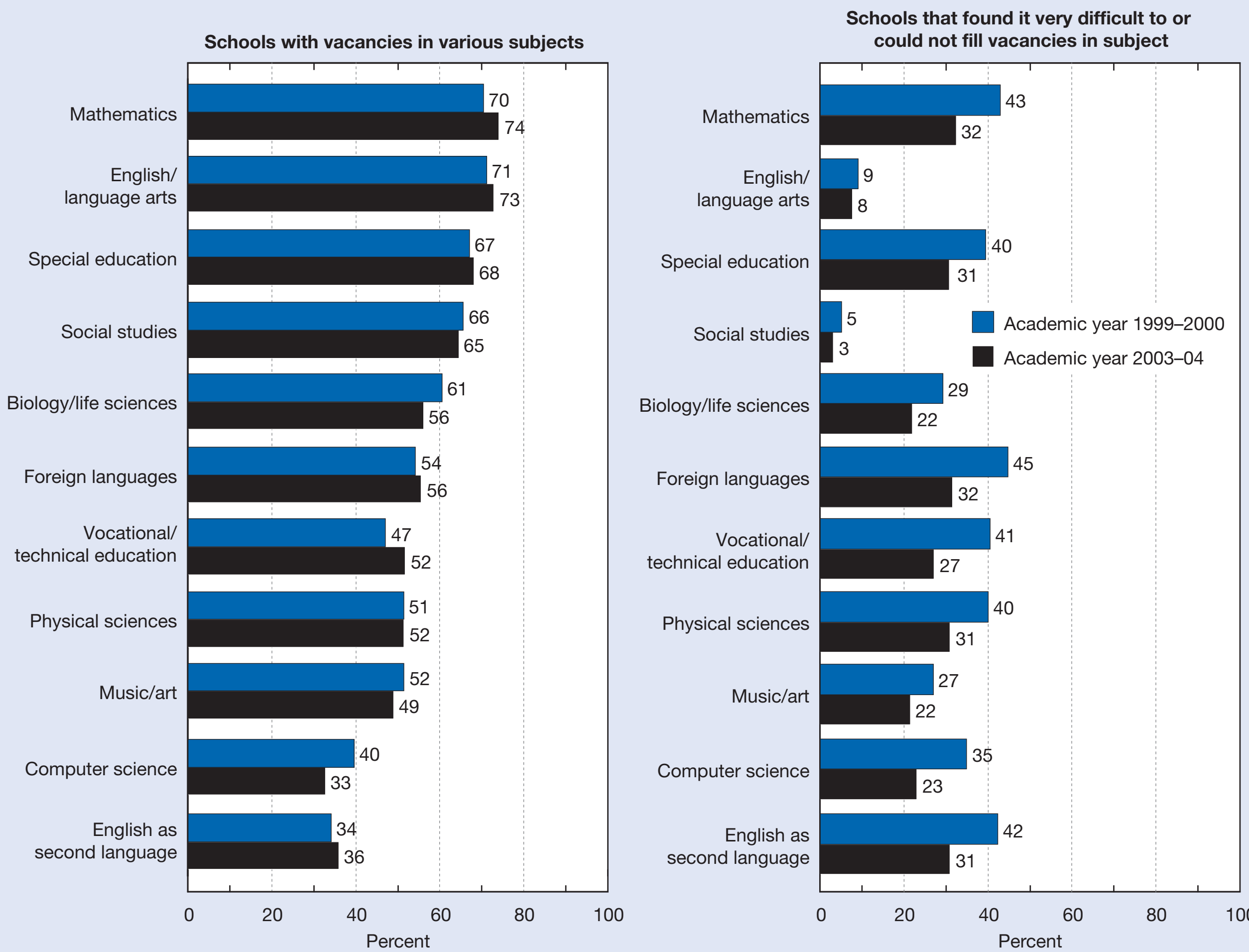
Teaching Vacancies in Mathematics and Science

Researchers have used various methods to determine the extent of any possible teacher shortage,[27] including counting the number of teachers holding alternative or emergency licenses; estimating the net effects of student enrollment, teacher retirement, and teacher attrition; and assessing teaching vacancy rates (Arnold and Choy 1993; Broughman and Rollefson 2000; Carroll, Reichardt, and Guarino 2000; Guarino, Santibanez, and Daley 2006; Henke et al. 1997; Murphy, DeArmond, and Guin 2003). Although none of these methods has proven perfect, researchers found some consistent patterns: teacher shortages existed in specific subject fields, in geographic locations, and in some individual schools. For example, teacher shortages occurred more frequently in certain states where the population grew fast because of immigration and high rates of childbirth (e.g., California, Texas, and Florida); in specific subjects such as mathematics, science, special education, and bilingual education; and in schools located in high-poverty areas (Boe et al. 1998; Howard 2003; Wayne 2000). The following analysis uses school reports of teaching vacancies to evaluate whether there were insufficient numbers of mathematics and science teachers in public secondary schools.

Administrators of schools that participated in SASS were asked whether, in the current school year, their schools had vacancies in various fields (i.e., teaching positions needing to be filled) and how difficult it was to fill these vacant positions. The majority of public secondary schools experienced teaching vacancies in one or more fields (figure 1-16). The vacancy rate decreased somewhat during recent years; still, 80% of public secondary schools reported teaching vacancies in 2003. In both 1999 and 2003, mathematics was one of the fields that had a relatively high vacancy rate. In 2003, for example, 74% of public secondary schools with any teaching vacancy reported at least one vacant position in mathematics. Vacancy rates for biology/life and physical sciences were also high, with 52%-56% reporting at least one vacant position in these fields.

The data in figure 1-16 further reveal that mathematics and physical sciences were among the most difficult fields in which to find teachers in both 1999 and 2003.[28] Although this situation has improved during recent years, close to one-third of public secondary schools with teacher vacancies in mathematics and physical sciences in 2003 either found them very difficult to fill or were unable to do so. Although secondary schools had a high teacher vacancy rate in biology/

Figure 1-16
Teaching vacancies at public secondary schools, by subject: Academic years 1999–2000 and 2003–04



NOTES: Teaching vacancies are teaching positions needing to be filled in current school year. Secondary schools had any of grades 7–12 and none of grades K–6. Schools with any vacancy are base (denominator) in left panel (88% in 1999–2000, 80% in 2003–04); schools with vacancy in subject listed in left panel are base for corresponding subject in right panel.

SOURCES: National Center for Education Statistics (NCES), Schools and Staffing Survey, 1999–2000; and Strizek GA, Pittsonberger JL, Riordan KE, Lyter DM, Orlofsky GF, Characteristics of Schools, Districts, Teachers, Principals, and School Libraries in the United States: 2003–04, NCES 2006-313 (2006).

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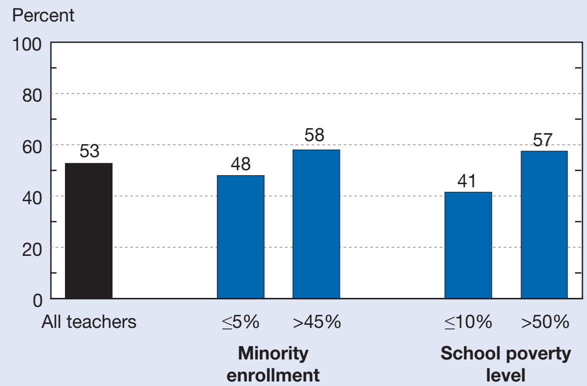
life sciences, teachers in these fields were relatively easier to find than they were in mathematics or physical sciences.

Teacher Salaries

Teachers (particularly mathematics and science teachers) who leave the profession or move to other schools often cite low pay as a main reason for doing so (Bobbitt et al. 1994; Guarino, Santibanez, and Daley 2006; Ingersoll 2006; Leukens, Lyter, and Fox 2004; NSB 2006). Indeed, among professions requiring a minimum of a bachelor's degree, teaching is a relatively low-paying profession. In 2003, the annual median salaries for full-time high school mathematics and science teachers and all full-time elementary school teachers were $43,000 and $41,000, respectively, far below those of professions requiring comparable educational backgrounds (e.g., computer systems analysts, engineers, accountants or financial specialists, and protective service workers) (table 1-12). Moreover, the salary increases for teachers lagged behind those who worked in other professions. Between 1993 and 2003, full-time high school mathematics and science teachers had a real salary gain of 8%, compared with increases of 21%-29% for computer systems analysts, accountants or financial specialists, and engineers. Similar results have been reported elsewhere (AFT 2005; Allegretto, Corcoran, and Mishel 2004). Although the difference in the number of weeks worked between teachers and those in other professions may explain some of the salary gaps, it cannot explain why these gaps grew over the years. If teaching salaries are not competitive with those offered in other professions requiring comparable education and skills, it may be difficult to retain teachers (especially those in mathematics and science) who may find more lucrative opportunities elsewhere.

When asked to rate their satisfaction with their salaries, more than one-half of public middle and high school mathematics and science teachers expressed dissatisfaction (figure 1-17). Those in high-poverty schools were more likely than their colleagues in low-poverty schools to be unhappy with their salaries.

Figure 1-17
Public middle and high school mathematics and science teachers not satisfied with salary, by minority enrollment and school poverty level: Academic year 2003–04



NOTE: School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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Table 1-12
Median annual salaries of full-time school teachers and selected other professions: 1993 and 2003
(2003 constant dollars)

Full-time professionals	1993	2003	Change (%)
Teachers			
High school mathematics and science	40,000	43,000	7.5
Elementary school	38,000	41,000	7.9
Selected other professions			
Computer systems analysts	56,000	72,000	28.6
Accountants, auditors, and other financial specialists	50,000	61,000	22.0
Engineers	62,000	75,000	21.0
Protective service workers	46,000	50,000	8.7
Social workers	36,000	40,000	11.1
Retail sales occupations	34,000	40,000	17.6
Clergy and other religious workers	35,000	38,000	8.6

NOTES: 1993 salaries indexed to 2003 salaries using chain-type price index for personal consumption expenditures from Economic Report of the President 2006, table B-7 (column C), http://www.gpoaccess.gov/eop/index.html, accessed 27 December 2006. All respondents had bachelor's or higher degree.

SOURCE: National Science Foundation, Division of Science Resources Statistics, National Survey of College Graduates 1993 and 2003, special tabulations.

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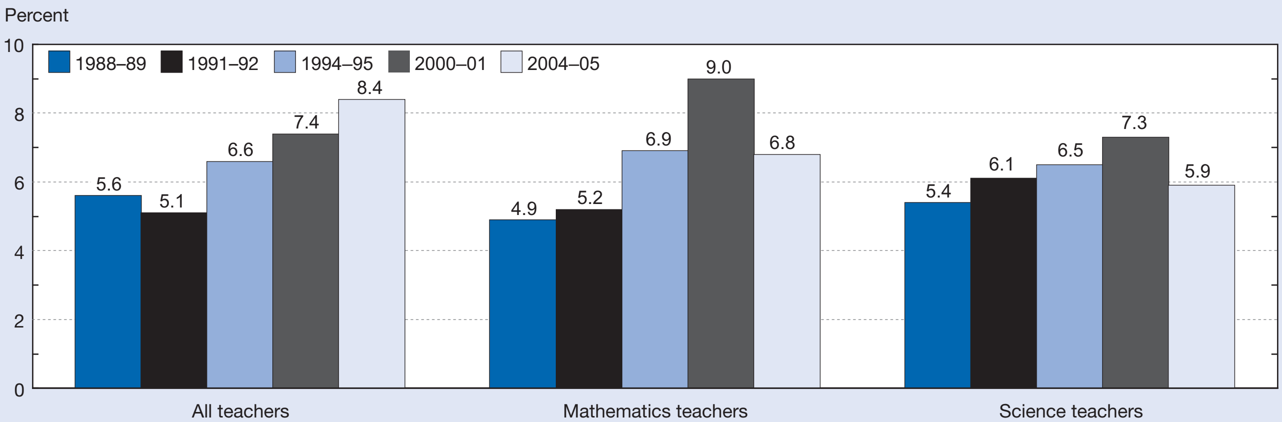
Attrition From Teaching

Concerns about K–12 teacher shortages, teacher quality, and the cost of keeping high-quality instructors in the nation's schools have led policymakers to focus attention on teacher attrition and to identify it as one of the most serious problems occurring today in the teaching profession (NCTAF 2003). A recent national study revealed that 8% of all public K–12 school teachers in the 2003–04 academic year had left the teaching profession by the following year (Marvel et al. 2007). For public school mathematics and science teachers, about 6%–7% had left. Although the attrition rates of all teachers have continued to increase over time, the attrition rates for mathematics and science teachers appeared to level off in recent years (figure 1-18).

Another study (Henke, Cataldi, and Nevill forthcoming) focused on the attrition of a segment of new teachers (recent college graduates who taught any of grades K–12 immediately following receipt of a bachelor's degree) and compared their occupational stability with individuals in other occupations. The results of this study suggest that movement among different occupations is common and that teaching is actually one of the more stable occupations in terms of attrition. As shown in figure 1-19, among recent college graduates working in April 1994, 34% were working in the same occupational category in 2003, and 54% had made a change in occupation. In contrast, of those working as K–12 teachers in 1994, 61% were still doing so in 2003, and only 21% had left teaching for nonteaching jobs. Teachers were more likely to remain in the same occupation than most other professionals, including those with comparable education such as legal professionals and legal support personnel, engineers, scientists, laboratory and research assistants, and computer and technical workers. Although recent college graduates do not represent the teaching workforce as a whole, in this study they indicate the job stability of teachers relative to that of other professionals.

Figure 1-18
One-year attrition rate of public school teachers: Selected academic years, 1988–89 to 2004–05



SOURCES: Whitener SD, Gruber KJ, Lynch H, Tingos K, Perona M, Fondelier S, Characteristics of Stayers, Movers, and Leavers: Results From the Teacher Follow-up Survey: 1994–95, National Center for Education Statistics (NCES), NCES 97-450 (1997); Luekens MT, Lyter DM, Fox EE, Teacher Attrition and Mobility: Results from the Teacher Follow-up Survey, 2000–01, NCES 2004-301 (2004); and Marvel J, Lyter DM, Peltola P, Strizek GA, Morton BA, Teacher Attrition and Mobility: Results from the 2004–05 Teacher Follow-up Survey, NCES 2007-307 (2006).

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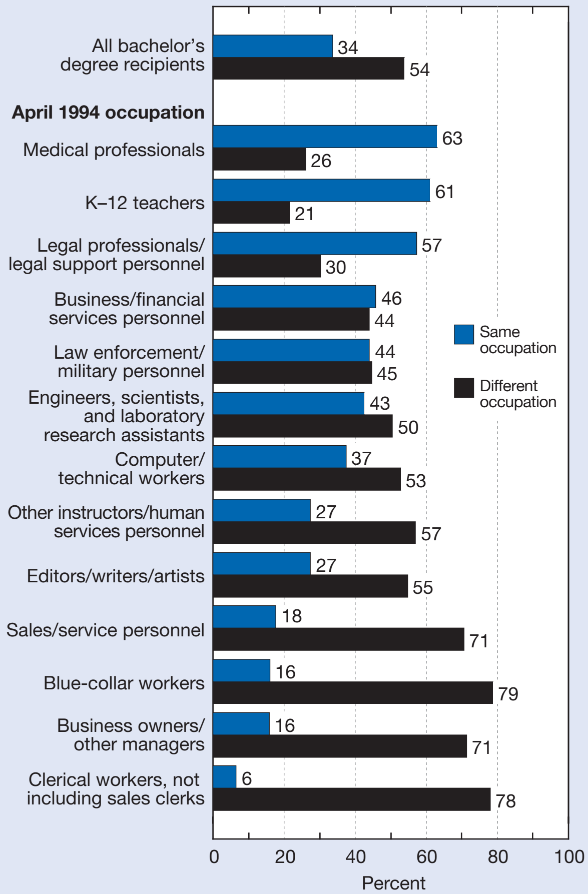
Teacher Perceptions of Working Conditions

Like salaries, working conditions also play a critical role in determining the supply of qualified teachers and in influencing their decisions about remaining in the profession. Research shows that safe environments, strong administrative leadership, collegial cooperation, high parental involvement, and sufficient learning resources can improve teacher effectiveness, enhance their commitment to school, and promote their job satisfaction (Darling-Hammond 2003; Guarino, Santibanez, and Daley 2006; McGrath and Princiotta 2005). Characteristics of a school's student body are also important in increasing teacher satisfaction and keeping them in the profession. Students who go to school ready to learn, obey school rules, show respect for their teachers, and exhibit good learning behaviors not only can contribute to a positive school climate, but also can increase teacher enthusiasm, effectiveness, and commitment (Hanushek, Kain, and Rivkin 2004; Kelly 2004; Stockard and Lehman 2004).

SASS asked teachers whether they agreed with a number of statements about their school environments and working conditions. A majority of public middle and high school mathematics and science teachers expressed positive views of their school administrators' leadership and support, cooperation among colleagues, and availability of instructional

Figure 1-19
1992–93 bachelor's degree recipients working in April 1994 in same or different occupation in 2003



NOTE: Those unemployed in 2003 or who had left labor force omitted from figure.

SOURCE: Henke R, Cataldi E, Nevill S, Occupation Characteristics and Changes in Labor Force Status and Occupation Category: Comparing K–12 Teachers and College Graduates in Other Occupation Categories, National Center for Education Statistics (NCES), NCES 2007-170 (forthcoming).

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resources (figure 1-20). Although teachers overall held generally positive perceptions of their school environments, these perceptions tended to be less prevalent in schools with more minority and poor students than in schools with fewer such students. This was particularly the case for teacher perceptions of parental support: 42%–44% of mathematics and science teachers in high-minority and high-poverty schools said that they had received a great deal of support from parents, compared with 67%–71% of their counterparts in low-minority and low-poverty schools.

In addition to school environments, teachers were asked to indicate whether particular student attitudes and behaviors were serious problems in their schools. The problem that public middle and high school mathematics and science teachers most often reported as serious concerned students coming to school unprepared to learn: 37% of the teachers viewed this issue as a serious problem in their schools (figure 1-21). They also frequently cited student apathy, student absenteeism, and student tardiness as serious problems. Teachers who taught in schools with high concentrations of minority and low-income students cited various student problems (especially that students came unprepared to learn) as serious more frequently than did those who taught in schools with low concentrations of such students.

Job Satisfaction and Commitment to Teaching

Although teachers are paid less than those in many comparable professions and sometimes have to work in environments that are less than ideal, the large majority of them are happy about being teachers. When asked whether they were satisfied with being a teacher at their school, 90% of public middle and high school teachers gave a positive answer (table 1-13). Responses from mathematics and science teachers were similar.

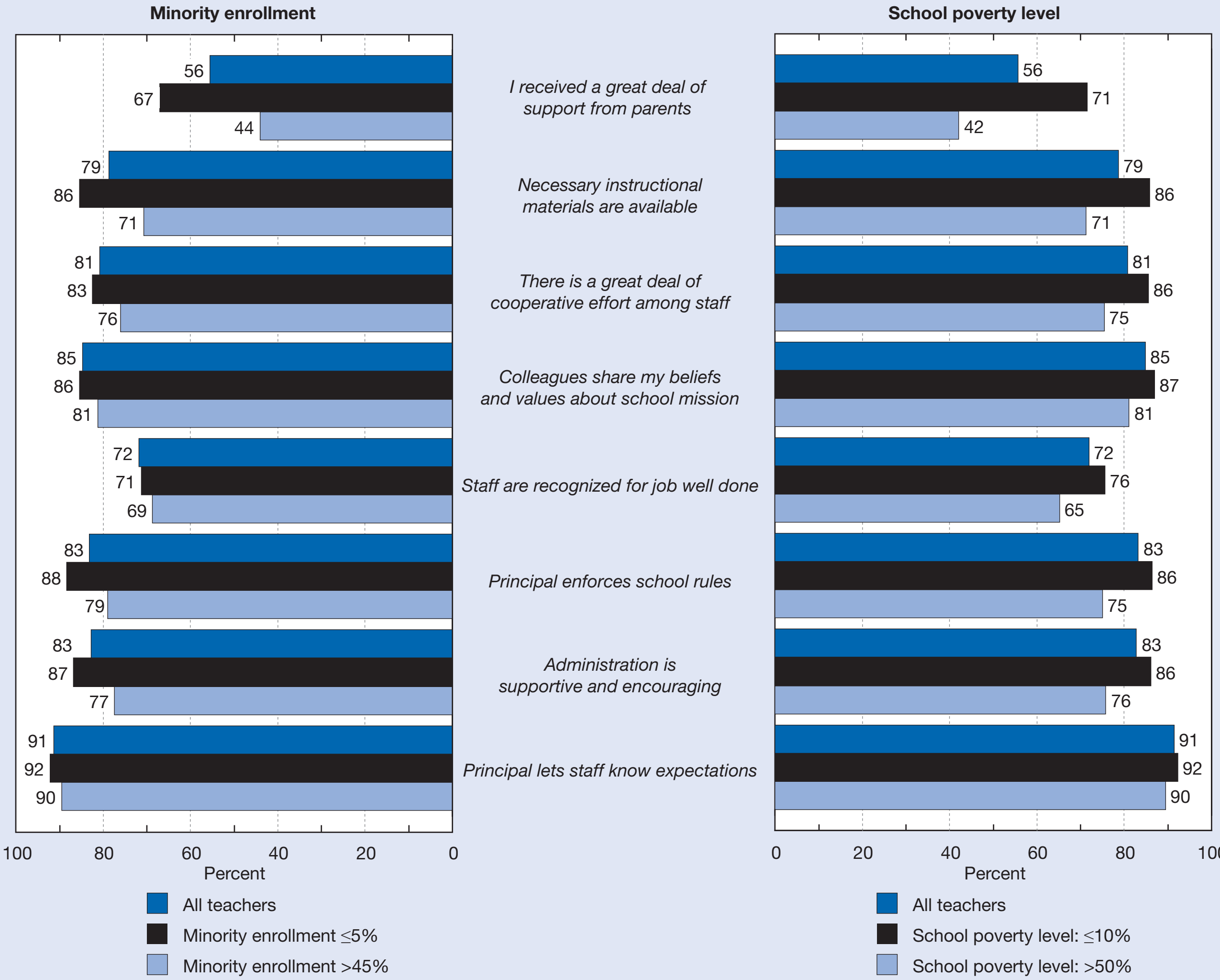
When asked how long they planned to remain in teaching, many teachers responded that they planned to remain as long as they were able (42%) or until they were eligible for retirement (34%). Just 3% had definite plans to leave teaching as soon as possible. When asked whether they would become teachers again if they could start over, 66% indicated that they certainly or probably would, and only 5% responded they certainly would not. Responses from mathematics and science teachers to these questions resembled the overall patterns, although less science teachers (32%) than mathematics and other teachers (42% and 40%, respectively) said they would certainly go into teaching again.

Working conditions were strongly associated with teacher commitment to teaching. Regardless of what they taught, teachers who worked in a positive school environment tended to be more likely to consider teaching as a long-term career and to believe they would choose the profession again (appendix table 1-21). For example, among public middle and high school mathematics teachers who thought that their school administrators were supportive and encouraging, 48% said that they planned to continue teaching as long as they could, and 49% said that they would certainly become a teacher again if they could start over, compared with 22% and 20%, respectively, of those who did not share this perception about their school administrators.

Summary

College graduates who entered teaching were more likely to stay in that occupation than graduates who entered most other professions requiring comparable education, including legal professionals and legal support personnel, engineers, scientists, laboratory and research assistants, and computer

Figure 1-20
Perceptions of working conditions of public middle and high school mathematics and science teachers, by minority enrollment and school poverty level: Academic year 2003–04



NOTES: Teachers asked to indicate their agreement with various statements about their school conditions. Response categories included "strongly agree," "somewhat agree," "somewhat disagree," and "strongly disagree." Percentages based on teachers responding "strongly agree" or "somewhat agree" to various statements. School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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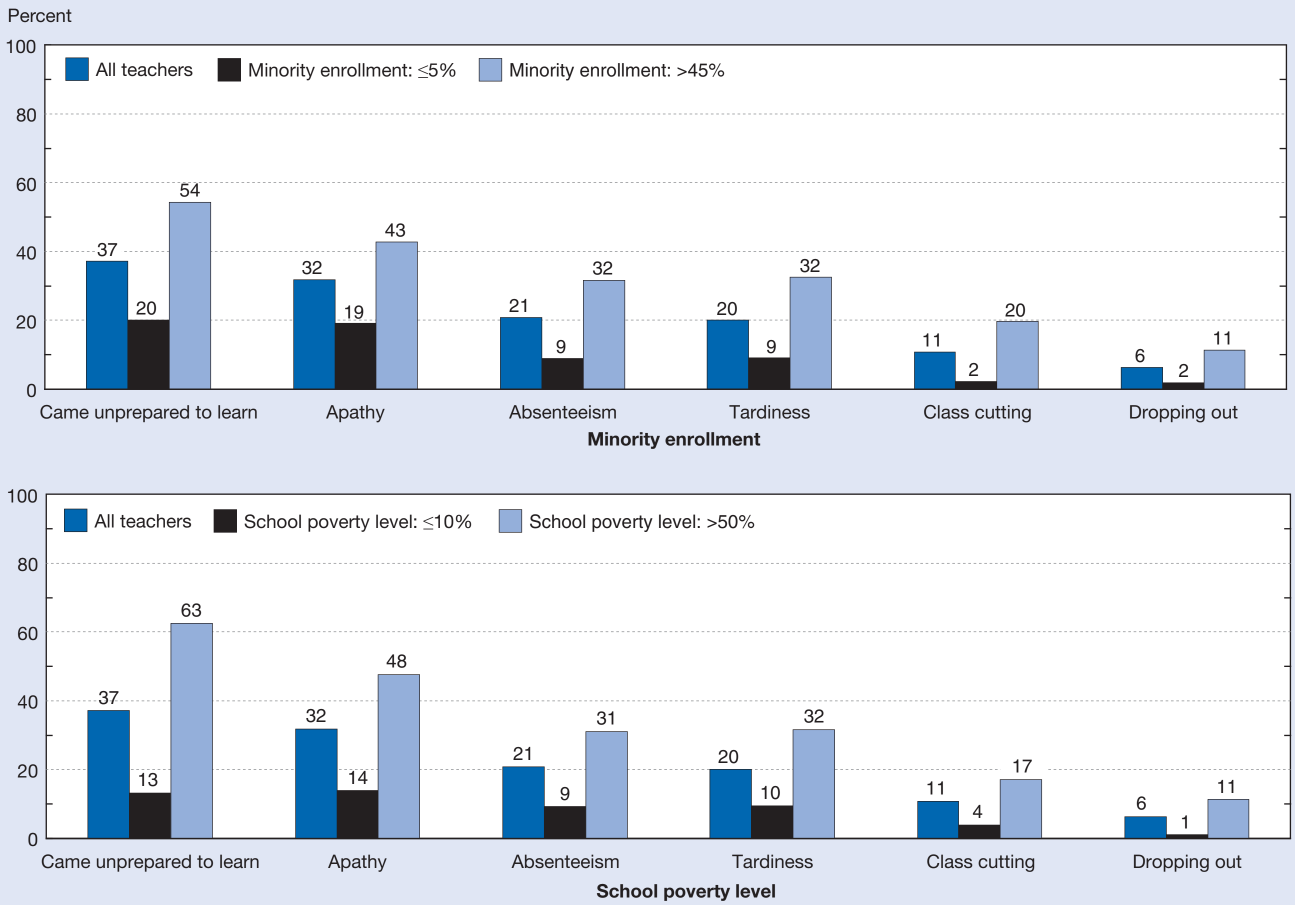
and technical workers. Between academic years 2003 and 2004, about 6%–7% of mathematics and science teachers in public schools left teaching, compared with 8% of all teachers. Regardless, public secondary schools continued to experience various degrees of difficulty in hiring mathematics and science teachers in recent years.

Teacher salaries lagged behind those of many comparable professionals. These gaps have widened substantially in recent years, and about half of public middle and high school mathematics and science teachers were not satisfied with their pay. Although public school teachers generally had favorable perceptions of their working conditions, those in schools with high concentrations of minority or poor students viewed their work environments as less satisfactory. The findings that working conditions and pay were associated with teacher long-term commitment to teaching signify that high-minority and high-poverty schools may face greater challenges than others in recruiting and retaining qualified teachers.

Transition to Higher Education

More and more high school students expect to attend college at some point, and many do so immediately after finishing high school. In 2003–04, about 7 in 10 high school seniors expected to attain at least a bachelor's degree (NCES 2006c), and in fall 2004, approximately 1.8 million high

Figure 1-21
Serious student problems reported by public middle and high school mathematics and science teachers, by minority enrollment and school poverty level: Academic year 2003–04



NOTES: Teachers asked to indicate the seriousness of various student problems in their schools. Response categories include "serious problem," "moderate problem," "minor problem," and "not a problem." Percentages based on teachers viewing various student problems as "serious." School poverty level is percentage of students in school qualifying for free/reduced-price lunch.

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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school graduates (two-thirds of this population) enrolled in a 2- or 4-year institution directly after high school (NCES 2006d). However, despite heightened educational expectations and rising college enrollment rates, students from disadvantaged socioeconomic backgrounds attend college at substantially lower rates than other students, and many of them discontinue their education before graduating from high school (Berkner and Chavez 1997; Laird et al. 2007).

This section presents several indicators related to student transitions from high school to college, including high school graduation rates in the United States and in other countries and long-term trends in immediate college enrollment rates among U.S. high school graduates. These indicators provide a broad picture of how effective the nation is in providing education at the secondary level and making higher education accessible to high school students.[29]

Completion of High School

Who is counted as having completed high school in the United States? In a broad sense, a high school completer is anyone who has met the requirements of high school completion and received a regular diploma or earned an equivalent credential such as a GED certificate. Based on this definition, an NCES report (Laird et al. 2007) estimated that in 2005, 88% of those 18–24 years old not enrolled in high school had received a high school diploma or equivalency credential (figure 1-22). Between 1975 and 2005, completion rates increased in all racial/ethnic groups. The rate for blacks increased faster than that for whites, narrowing the gaps between the two groups. However, although the Hispanic completion rate increased overall between 1975 and 2005, the gap between Hispanics and whites remained wide.

Table 1-13
Professional satisfaction and commitment of public middle and high school teachers: Academic year 2003–04
(Percent)

Professional satisfaction and commitment	All teachers	Mathematics	Science	Other teachers
I am satisfied with being a teacher	89.6	89.6	87.2	89.9
How long do you plan to remain in teaching?				
As long as I am able	41.8	41.8	39.7	42.1
Until I am eligible for retirement	33.9	32.4	33.8	34.1
Continue unless something better comes along	9.0	9.2	11.0	8.7
Definitely plan to leave as soon as I can	3.0	3.3	3.7	2.9
Undecided at this time	12.3	13.2	11.8	12.2
If you could start over again, would you become a teacher?				
Certainly	39.3	41.5	32.0	40.1
Probably	26.4	24.4	28.5	26.4
Even chances	17.6	15.6	21.6	17.3
Probably not	12.0	12.1	13.2	11.8
Certainly not	4.6	6.3	4.7	4.3

SOURCES: National Center for Education Statistics, Schools and Staffing Survey, 2003–04; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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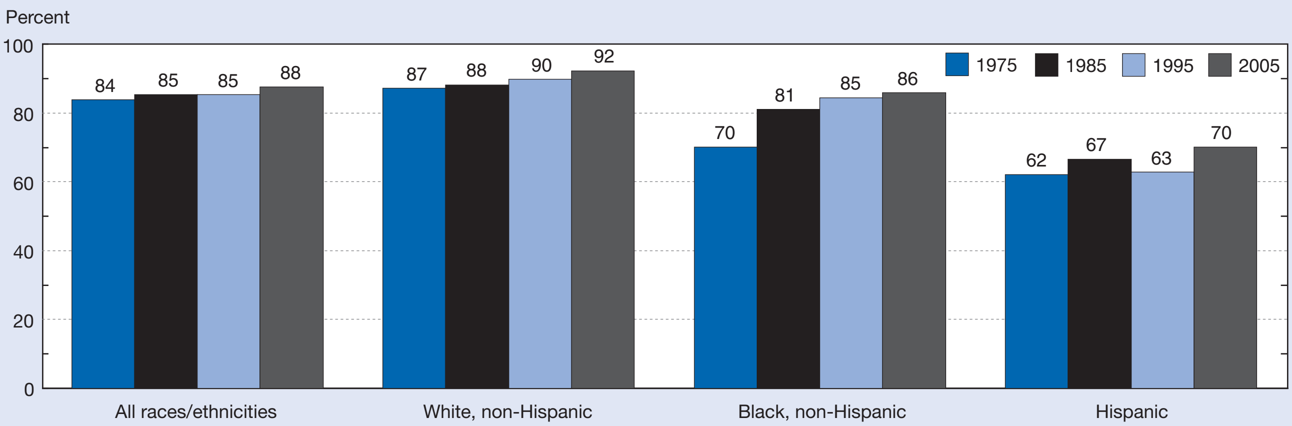
Figure 1-22
High school completion rates of 18–24-year-olds, by race/ethnicity: Selected years, 1975–2005



NOTES: High school completion rates measure percentage of 18–24-year-olds not enrolled in high school and holding a high school diploma or equivalent credential such as a General Equivalency Diploma (GED) certificate. Those still enrolled in high school excluded from analysis.

SOURCE: Laird J, DeBell M, Kienzl G, Chapman C, Dropout Rates in the United States: 2005, National Center for Education Statistics (NCES), NCES 2007-059 (2007).

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Largely in response to the federal NCLB Act,[30] researchers and educators have been trying to create a more rigorous definition of high school graduates. To do so, they have been focusing on on-time graduation rates and counting only students with regular diplomas as graduates (Seastrom et al. 2006a; Swanson 2003; WestEd 2004). To examine on-time graduation rates, researchers used the percentage of the incoming freshman class that graduates with a regular diploma 4 years later as a measure (Seastrom et al. 2006b).[31] Based on this measure, it was estimated that 74% of public high school students who entered ninth grade in academic year 1999 graduated with a regular diploma 4 years later in academic year 2003 (table 1-14). On-time graduation rates changed little from 2000 to 2004, staying in the range of 72%–74%. (See sidebar "International Comparisons of High School Completion.")

Enrollment in Postsecondary Education

On completing high school, young adults make critical choices about the next stage of their lives. Today, a majority of high school graduates choose to go to college immediately after high school (NCES 2007d). In 2005, 69% of

Table 1-14
On-time graduation rates of public high school students: Academic years 2000–01 to 2003–04
(Percent)

Academic year	On-time graduation rate
2000–01	71.7
2001–02	72.6
2002–03	73.9
2003–04	74.3

SOURCES: Seastrom M, Chapman C, Stillwell R, McGrath D, Peltola P, Dinkes R, Xu Z, User's Guide to Computing High School Graduation Rates, National Center for Education Statistics (NCES), NCES 2006-604 and 2006-605 (2006a); Seastrom M, Hoffman L, Chapman C, Stillwell R, The Averaged Freshman Graduation Rate for Public High Schools from the Common Core of Data: School Years 2002–03 and 2003–04, NCES 2006-606rev (2006b).

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students ages 16–24 enrolled in a 2- or 4-year postsecondary institution in the fall immediately after high school graduation, compared with 51% in 1975 (figure 1-23). From 1975 to 2005, the immediate enrollment rate increased faster for females than for males. Much of the growth in the overall rate for females was because of increases between 1981 and 1997 in the rate of females attending 4-year institutions. During this period, the rate at which females enrolled at 4-year institutions increased faster than it did for their male counterparts, and faster than for either males or females at 2-year institutions.

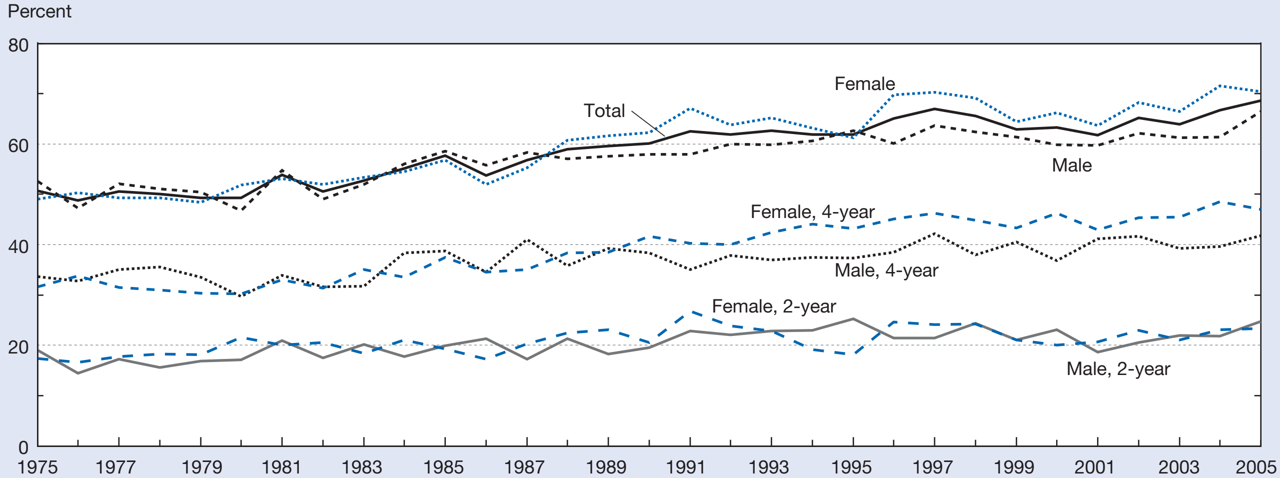
Although the growth in immediate college enrollment over the past three decades looks impressive, wide gaps by student socioeconomic background persisted. In each year between 1975 and 2005, low-income students lagged considerably behind their high-income peers in college enrollment (appendix table 1-22). Wide gaps also existed among racial/ethnic groups, with black and Hispanic students trailing far behind their white peers. Enrollment rates differed by parent education, as well, although students whose parents had only a high school education increased their enrollments considerably.

The type of institution was also related to student racial/ethnic and family background. Berkner and Chavez (1997) found that the proportion of 1992 high school graduates who enrolled in 4-year colleges and universities increased with family income and the level of their parents' education. Four-year college enrollment rates were also higher among white and Asian/Pacific Islander students than among black and Hispanic students. On the other hand, Hispanic students and those from low-income and less-educated families were more likely to attend 2-year institutions after high school graduation. Persistent inequality on many indicators of postsecondary education (e.g., gaining access and attaining a degree) is discussed extensively in chapter 2.

Summary

Over the past three decades, high school completion rates have been increasing gradually and the white-black gaps in completion rates have been narrowing. However, on-time graduation rates, which measure the rates at which high school freshmen graduate with a regular diploma 4 years later, remained in the range of 72%-74% in the early 2000s. Although more and more students choose to enroll in college right after high school, students from disadvantaged socioeconomic backgrounds continue to attend college at substantially lower rates than their more advantaged classmates.

Figure 1-23
High school graduates enrolled in college in October after completing high school, by sex and type of institution: 1975–2005



NOTE: Includes students ages 16–24 years completing high school in survey year.

SOURCE: National Center for Education Statistics (NCES), The Condition of Education 2007, NCES 2007-064 (2007).

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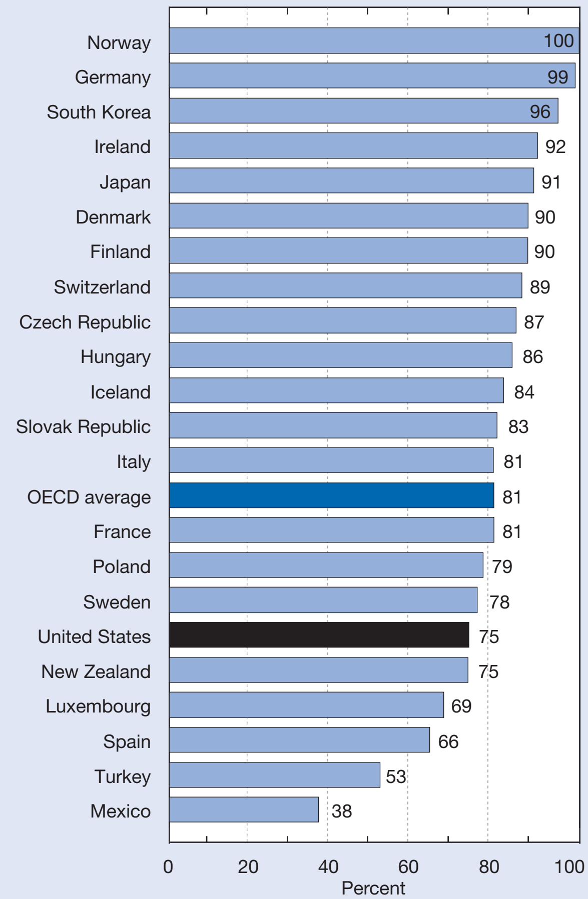
International Comparisons of High School Completion

How does the United States compare with other nations in terms of the rates at which young people graduate from high school? A 2006 report from the Organisation for Economic Co-Operation and Development (OECD) found that the United States is falling behind other industrialized nations on this indicator (OECD 2006). In 2004, the high school graduation rate was 75% in the United States, which was lower than the overall average rate of 81% for the 22 OECD countries with available data (figure 1-24). The United States ranked 17th in the overall high school graduation rate among OECD countries, behind such top-ranked countries as Norway, Germany, South Korea, Ireland, Japan, and Denmark.*

* One reason for the lower U.S. rate is that the U.S. high school student population may be more inclusive than in some OECD countries. In other words, some OECD countries may have more students dropping out before entering high school and therefore have a more selective high school student population than does the United States.

Figure 1-24
High school graduation rates, by OECD country: 2004



OECD = Organisation for Economic Co-operation and Development

NOTES: High school graduation rate is percentage of population at typical upper secondary graduation age (e.g., 18 years old in United States) completing upper secondary education programs. OECD average based on all OECD countries with available data.

SOURCE: OECD, Education at a Glance: OECD Indicators 2006 (2006).

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Conclusion

When they start kindergarten, students in the United States already exhibit differing mathematics knowledge and skills, and most of the achievement gaps between groups either remain or grow over the years students spend in school. Mathematics and science performance gaps widened between racial/ethnic groups, between students from financially disadvantaged and advantaged families, and between students whose mothers differ in educational attainment.

However, trends between 1990 and 2005 indicate rising test scores, particularly in mathematics in grades 4 and 8 (measured with cross-sectional data). The rise in scores occurred across the board: for both sexes, across racial/ethnic groups, and for students in all ranges of performance. Notably, some mathematics achievement discrepancies narrowed; for example, the difference between white and black fourth grade student scores decreased. Average science scores on fourth grade tests also increased since 1996 (particularly those in lower and middle score ranges), but science achievement in grades 8 and 12 has been resistant to improvement.

As educators and policymakers strive to improve student learning, they continue to make changes in schooling resources and school environments. Coursetaking and content standards, teacher qualifications, and continuing professional development for teachers are among the primary elements featured in efforts to promote student achievement.

Coursetaking and Content Standards

States have been increasing academic course requirements for high school graduation since the 1980s. By 2006, most states required 3 years of both mathematics and science courses, and nearly all required at least 2 years. Coursework standards have expanded in the past decade or so to require specific courses (such as algebra) and to enhance the rigor of course content.

Coursetaking Trends

Trends from 1990 to 2005 show higher proportions of students completing advanced mathematics and science courses with growth especially strong in mathematics. Students also increased course completions in advanced biology, chemistry, and physics. Even so, completion rates were relatively low in 2005 for most of these advanced course categories. For the AP/IB courses, rates doubled for some and increased substantially for others; still, the most common AP/IB course, calculus, was completed by less than 10% of 2005 graduates.

Teacher Preparation and Qualifications

Most public school teachers have a bachelor's degree and are fully certified. Majorities of beginning mathematics and science teachers in public middle and high schools also participated in practice teaching before starting their first teaching job and were confident of their ability to handle its challenges. However, practice teaching declined in recent years by about 8–10 percentage points, even though participation contributes to new teachers' confidence. In high schools, large majorities of mathematics and science teachers were teaching in field; that is, they had a postsecondary major or certification in that field. However, in middle schools, about one-half of mathematics and biology science teachers and two-thirds of physical science teachers lacked these in-field qualifications. Across all mathematics and science fields, a pattern of unequal access to the most highly qualified teachers (including those with more than a few years of teaching experience) was the rule, favoring low-minority and low-poverty schools.

Participation in Professional Development

Most beginning teachers participated in induction programs or worked closely with a mentor teacher during their first year of teaching. Participation in professional development was also widespread, most often on a teacher's subject matter or on using computers for instruction. The most common formats were workshops, conferences, and training sessions. Overall, the amount of time that most teachers devoted to professional development did not reach the levels recommended by researchers.

Teacher Supply, Salaries, Working Conditions, and Job Satisfaction

Attrition from teaching is typically lower than from other professions, and attrition rates for mathematics and science teachers have mostly leveled off in recent years. Nevertheless, public secondary schools continued to experience some difficulty filling teacher vacancies in mathematics and physical sciences, and to a lesser degree, in biology/life sciences. Overall, a majority of public school teachers were satisfied with their jobs and planned to remain in teaching as long as they could. Science and mathematics teacher pay still falls behind that of many professionals with comparable education, even more so in recent years. Although dissatisfaction with pay is on the rise, public school teachers had mostly favorable perceptions of their working conditions.

High School Graduation Rates and Enrollment in Postsecondary Education

Since 1975, high school completion rates have increased slightly. In 2005, among 18–24-year-olds not enrolled in high school, nearly 90% held either a high school diploma or an equivalency credential. However, the on-time graduation rate changed little from 2000 to 2004, staying in the range of 72%–74%. Increasingly students are entering postsecondary education directly after high school. Between 1975 and 2005, the percentage of students ages 16–24 enrolling in a 2- or 4-year institution in the fall following high school graduation rose from 51% to 69%.

Notes

1. Differences between two estimates were tested using the Student's t statistic to minimize the chances of concluding that a difference exists based on the sample when no true difference exists in the population from which the sample was drawn. Setting the significance level at 0.05 indicates that a reported difference would occur by chance no more than once in 20 samples when there was no actual difference between the population means.

2. In the 2004 followup for the ECLS kindergarten class of fall 1998, 86% of cohort members were in fifth grade, 14% were in a lower grade, and less than 1% were in a higher grade. For the sake of simplicity, students in the ECLS followups are referred to by the expected grade; that is, they are referred to as first graders in the spring 2000 assessment, as third graders in the spring 2003 assessment, and as fifth graders in the spring 2004 assessment.

3. The poverty status variable in ECLS is based on information provided by the parent. The variable is derived from household income and total number of household members (Princiotta, Flanagan, and Germino Hausken 2006). Federal poverty thresholds are used to define households below the poverty level. For example, if a household contained two members, and the household income was lower than $12,015, the student was considered to be living below the poverty threshold.

4. Socioeconomic status was based on five equally weighted components: father's education, mother's education, family income, father's occupational prestige score, and mother's occupational prestige score.

5. NAEP consists of three assessment programs. The *long-term trend assessment* is based on nationally representative samples of 9-, 13-, and 17-year-olds. It has remained the same since it was first given in 1969 in science and 1973 in mathematics, permitting analyses of trends over three decades. A second testing program, the *national* or main NAEP, assesses national samples of 4th, 8th, and 12th grade students. The national assessments are updated periodically to reflect contemporary standards of what students should know and be able to do in a subject. The third program, the *state* NAEP, is similar to the national NAEP but involves representative samples of students from participating states.

6. These recent trends are based on data from the national NAEP program. The current national mathematics assessment for grades 4 and 8 was first administered in 1990 and was given again in 1992, 1996, 2000, 2003, and 2005. In 2003, only fourth and eighth grade students were assessed. The current grade 12 mathematics assessment has only been administered once: in 2005. Trend analyses for grade

12 mathematics are therefore not available. The current national science assessment was first administered in 1996 and was given again in 2000 and 2005.

7. Although the NAEP program collects information about eligibility for the free or reduced-price lunch program for grade 12 students, it does not report these data. Because other reasons for not applying for school lunch programs (including food preferences, ability to buy lunch outside school, and wanting to avoid embarrassment) generally increase with student age, program eligibility becomes an increasingly unreliable indicator of poverty at higher grade levels. For example, approximately 35%–45% of fourth grade and 30%–40% of eighth grade public school students have been eligible in recent years for the subsidized lunch program. In contrast, only about 15%–25% of 12th grade public school students have been eligible (determined using the online NAEP Data Explorer tool at http://www.nces.ed.gov/nationsreportcard/naepdata/). The relatively low percentage of grade 12 students noted as eligible for the program raises concerns that it is not a reliable indicator of low family income for these students.

8. Insufficient sample size in 1990 for Asian/Pacific Islanders and American Indians/Alaska Natives precluded calculation of reliable estimates for this group. Increases in average scores for Asian/Pacific Islanders in grades 4 and 8 were observed between 2003 and 2005. Scores increased for grade 4 American Indians/Alaska Natives between 2003 and 2005, but not for grade 8 American Indians/Alaska Natives.

9. Many states developed initial standards for at least some subjects starting after about 1980, while others revised existing standards and/or curricular guidelines; in some states both of these activities occurred.

10. Although effects were somewhat different for men and women, Trusty's analysis also adjusted for variables such as previous test scores, previous course completions, and confidence about their mathematics and science skills. These factors sometimes interact in both directions, with strong performance in early grades often leading to greater self-confidence and interest in the subjects, which in turn lead to greater coursetaking, which may increase performance, and so on. Studies may not measure other relevant characteristics like students' motivation and career aspirations.

11. The fairly flat pattern for trigonometry/algebra III does not necessarily mean that fewer students studied these topics; some schools may have reconfigured courses so that rather than providing a full semester of trigonometry, for example, they may include that material in a precalculus or other course.

12. Except for biology, AP/IB science course data are available only for 2000 and 2005.

13. In some course categories, the difference between Asian/Pacific Islander and white graduates was not significant, whereas in others, differences between Asians/Pacific Islanders and one or more of the other groups proved to be not significant. These findings are likely due in part to large standard errors associated with smaller population groups.

14. Poverty rate is defined as the percentage of students in the school who were eligible for the national subsidized lunch program. For reasons explained above, school lunch program eligibility can be an unreliable indicator of individual families' poverty, particularly for high school students. It is used here as a rough proxy for poverty at the school level because it is the only available measure, but the caveat stands.

15. NCLB defines a *highly qualified* elementary or secondary school teacher as someone who holds a bachelor's degree and full state-approved teaching certificate or license (excluding emergency, temporary, and provisional certificates) and who demonstrates subject-matter competency in each academic subject taught by having an undergraduate or graduate major or its equivalent in the subject; passing a test on the subject; holding an advanced teaching certificate in the subject; or meeting some other state-approved criteria. NCLB requires that 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 or graduate major or advanced certification in their fields.

16. Teacher quality can include many characteristics that are not discussed here, such as teachers' commitment to the profession; sense of responsibility for student learning; and ability to motivate students, manage classroom behavior, maximize instructional time, and diagnose and remedy students' learning difficulties (Goldhaber and Anthony 2004; McCaffrey et al. 2003; Rice 2003). These characteristics are rarely examined in nationally representative surveys because they are difficult and costly to measure.

17. Research on how elementary school teachers are prepared to teach mathematics and science is emerging but limited (National Research Council 2007). Based on an extensive literature review on science education, the National Research Council (2007) concludes that K–8 teachers had limited training in science education and insufficient knowledge of science. However, some evidence suggests that K–5 teachers are confident about their ability to teach their subjects including mathematics and science (Weiss et al. 2003). Much more research is needed to increase understanding about elementary teacher preparation for teaching mathematics and science.

18. To simplify the discussion, schools in which 10% or fewer of the students were eligible for the federal free and reduced-price lunch program are called low-poverty schools; and schools in which more than 50% of the students were eligible are called high-poverty schools. Similarly, low-minority schools are those in which 5% or fewer of the students were members of a minority, and high-minority schools are those in which more than 45% of the students were members of a minority.

19. In general, probationary certification is awarded to those who have completed all the requirements except for a

probationary teaching period. Provisional or temporary certification is awarded to those who still have requirements to meet. Emergency certification is issued to those with insufficient teacher preparation who must complete a regular certification program in order to continue teaching (Henke et al. 1997).

20. Practice teaching (also called student teaching) offers prospective teachers hands-on classroom experience that allows them to transform the knowledge learned from coursework into teaching exercises in the classroom. Currently, 39 states require public school teachers to complete a minimum of 5 weeks of practice teaching, through either traditional teacher education programs or licensure requirements (Editorial Projects in Education 2006).

21. It should be noted that induction programs have great variability in terms of program goals, content, duration, and format. This variability cannot be addressed by using the SASS data.

22. Similar results have been reported elsewhere (Choy, Chen, and Bugarin 2006; Scotchmer, McGrath, and Coder 2005). This finding suggests that schools and districts, and perhaps teachers themselves, were attempting to address the needs of teachers in high-minority and high-poverty schools.

23. The amount of time teachers devoted to professional development was generally not associated with schools' minority enrollment and poverty levels.

24. Teacher participation in various formats of professional development was generally not significantly associated with schools' minority enrollment and poverty levels.

25. Teacher participation in these activities was generally not significantly related to schools' minority enrollment and poverty levels.

26. For example, these explanations include the retirement of an aging teaching force, increased student enrollments, reforms such as the reduction of class sizes, high rates of attrition, and lack of qualified candidates willing to enter the profession (Broughman and Rollefson 2000; Howard 2003; Hussar 1999).

27. Teacher shortages occur in a labor market when demand is greater than supply. This can be the result of either increases in demand or decreases in supply or of both simultaneously (Guarino, Santibanez, and Daley 2006).

28. Teaching vacancies in foreign languages, English as a second language, and special education were also difficult to fill in secondary schools, according to SASS data.

29. The 2004 and 2006 editions of *Science and Engineering Indicators* included an indicator of college remediation. However, this indicator cannot be updated for this edition because there were no new data available at the time of preparation for this chapter.

30. NCLB requires that states include graduation rates in determining adequate yearly progress and calls for measurement of on-time graduation that explicitly excludes GEDs and other types of nonregular diplomas from the counts of graduates.

31. Researchers examined several proxy measures of on-time graduation rates (Seastrom et al. 2006a). Although none of them is as accurate as the on-time graduation rate computed from a cohort of students using student record data, one of the methods, called Averaged Freshman Graduation Rates (AFGR), most closely approximates the true cohort rate and is used here. AFGR measures the percentage of an incoming freshman class that graduates with a regular diploma 4 years later. The incoming freshman class size is estimated by averaging the enrollment of 8th graders 5 years earlier, enrollment of 9th graders 4 years earlier, and enrollment of 10th graders 3 years earlier. This averaging is intended to adjust for higher grade retention rates in the 9th grade.

Glossary

Student Learning in Mathematics and Science

Eligibility for National School Lunch Program: Students' eligibility for this program, which provides free or reduced-price lunches, is a commonly used indicator for family poverty. Eligibility information is part of the administrative data kept by schools and is based on parent-reported family income and family size.

Longitudinal studies: Researchers follow the same group of students over a period of years, such as from kindergarten through fifth grade. These studies can show achievement gains in a particular subject from grade to grade.

Repeating cross-sectional studies: This type of research focuses on how a specific group of students performs in a particular year, then looks at the performance of a similar group of students at a later point in time. An example would be comparing fourth graders in 1990 to fourth graders in 2005.

Scale score: Scale scores place students on a continuous achievement scale based on their overall performance on the assessment. Each assessment program develops its own scales. For example, NAEP used a scale of 0–500 for the mathematics assessment and a scale of 0–300 for the science assessment, and the ECLS mathematics scale ranged from 0 to 153.

Standards and Student Coursetaking

Advanced Placement: Courses that teach college-level material and skills to high school students who can earn college credits by demonstrating advanced proficiency on a final course exam. The curricula and exams for AP courses, available for a wide range of academic subjects, are developed by the College Board.

Core subjects: Fundamental academic subjects that students spend the most time on and are the focus of coursetaking requirements and achievement tests: mathematics, science, English/language arts, and social studies. Computer science and foreign language are sometimes included in the category.

International Baccalaureate: An internationally recognized pre-university academic subject course designed for high school students.

Poverty rate: A school's poverty rate is defined as the percentage of students eligible for subsidized lunches through the National School Lunch Program. It is considered a less accurate measure of family poverty at higher grade levels.

Mathematics and Science Teacher Quality

High schools: Schools that have at least one grade higher than 8 and no grade in K–6.

In-field and out-of-field teachers: This report defines in-field teachers as those who had either a college major or full certification (i.e., regular, advanced, or probationary certification) in their main teaching assignment field or both and out-of-field teachers as those who had neither a college major nor full certification in their main teaching assignment field, a related field, or general education.

Main teaching assignment field: The field in which teachers teach the most classes in school.

Major: A field of study in which an individual has taken substantial academic coursework at the postsecondary level, implying that the individual has substantial knowledge of the academic discipline or subject area.

Middle schools: Schools that have any of grades 5–8, and no grade lower than 5 and no grade higher than 8.

Practice teaching: Programs designed to offer prospective teachers hands-on classroom practice. Practice teaching is often a requirement for completing an educational degree or state certification, or both.

Secondary schools: Schools that have any of grades 7–12 and no grade in K–6.

Teaching certification: A license or certificate awarded to teachers by the state to teach in a public school. The SASS surveys include five types of certification: 1) regular or standard state certification or advanced professional certificate; 2) probationary certificate issued to persons who satisfy all requirements except the completion of a probationary period; 3) provisional certificate issued to persons who are still participating in what the state calls an "alternative certification program;" 4) temporary certificate issued to persons who need some additional college coursework, student teaching, and/or passage of a test before regular certification can be obtained; and 5) emergency certificate issued to persons with insufficient teacher preparation who must complete a regular certification program in order to continue teaching.

Professional Development of Mathematics and Science Teachers

Professional development: In-service training activities designed to help teachers improve their subject-matter knowledge, acquire new teaching skills, and stay informed about changing policies and practices.

Teacher induction: Programs designed at the school, local, or state level for beginning teachers in their first few years of teaching. The purpose of the programs is to help new teachers improve professional practice, deepen their understanding of teaching, and prevent early attrition. One key component of such programs is that new teachers are paired with mentors or other experienced teachers to receive advice, instruction, and support.

Teacher Salaries, Working Conditions, and Job Satisfaction

Teacher attrition: Teachers leaving the teaching profession for another occupation.

Teaching vacancy: Open teaching positions needing to be filled.

Transition to Higher Education

Postsecondary education: The provision of formal instructional programs with a curriculum designed primarily for students who have completed the requirements for a high school diploma or its equivalent. This includes programs with an academic, vocational, and continuing professional education purpose, and excludes vocational and adult basic education programs.

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