Chapter 1
Elementary and Secondary Education

List of Sidebars

List of Tables

List of Figures

Highlights

Student Learning in Mathematics and Science

Improvements in U.S. student performance in mathematics and science have been uneven.

- In mathematics, average scores on national assessments rose from 1990 to 2003 and gains occurred in many demographic subgroups.
- In contrast, performance in science has not improved recently. Between 1996 and 2000, average science scores declined at grade 12 and remained the same at grades 4 and 8.
- In both mathematics and science, most students did not reach the proficient performance level, a level denoting solid performance for their grade based on judgments of what students should know and be able to do in the subject assessed. In both subjects, only about one-third of 4th and 8th grade students, and even fewer 12th grade students, reached the proficient level.

Performance disparities in mathematics and science are evident among many student subgroups.

- Students from disadvantaged backgrounds lagged behind, with these disparities starting as early as kindergarten, persisting across grades, and in some cases, widening over time.
- Substantial performance differences were also found between racial/ethnic groups, and those gaps generally remained stable from 1990 to 2003 in mathematics and from 1996 to 2000 in science.
- Sex differences were small but favored males in most cases.

International comparisons of mathematics and science performance present a mixed picture.

- Between 1995 and 2003, U.S. eighth grade students improved their performance on the Trends in International Math and Science Study (TIMSS) assessment, which measures mastery of curriculum-based knowledge and skills. However, scores of fourth graders generally remained flat over the same period. Both U.S. fourth and eighth grade students scored above the international average on the 2003 TIMSS, in which both developed and developing countries participated.
- On the 2003 Programme for International Student Assessment (PISA) tests, which measure students' ability to apply scientific and mathematical concepts and skills, U.S. 15-year-olds scored below the international average. It is important to note that TIMSS and PISA differ in age of participating students, extent to which test questions are aligned with curriculum, and number and type of participating countries. Although countries participating in TIMSS included both developed and developing nations, the international averages for PISA are based on scores from the 30 Organisation for Economic Co-operation and Development (OECD) countries that participated, all of which are industrialized.

Student Coursetaking in Mathematics and Science

Most 2000 U.S. high school graduates attended schools that offered advanced mathematics courses and nearly all had advanced science courses available at their schools.

- However, students attending rural or small schools were less likely to have access to some of the advanced courses than those enrolled in urban/suburban or large schools, particularly in mathematics. (Students are described herein as having access to courses if the school from which they graduated offered the course, but in practice, students usually have access only to those courses for which they have prepared.)

The proportions of students completing courses in many advanced mathematics and science subjects have increased since 1990 but remain relatively modest except in chemistry.

- The percentage of 2000 graduates who earned credits in advanced mathematics ranged from 6% for statistics/probability to 27% for precalculus.
- In science, the proportions earning any credits in chemistry, advanced biology, and physics in high school were 63%, 36%, and 33%, respectively. These figures may still overstate participation in advanced coursetaking because the definition of advanced used for this chapter sets a minimal bar: courses that not all students complete and that are not widely required for graduation. Some of these courses (e.g., certain chemistry and physics courses) may not meet other definitions of advanced that are based on content and skills.

Coursetaking varies by sex and race/ethnicity.

- In 2000, sex differences occurred in science coursetaking but not in mathematics. More females than males completed courses in advanced biology, Advanced Placement (AP) or International Baccalaureate (IB) biology, and chemistry. Males completed physics and AP/IB physics courses at higher rates than females.
- Racial/ethnic differences existed in both mathematics and science coursetaking. Asians/Pacific Islanders were generally more likely than students from other racial/ethnic groups to complete advanced mathematics and science courses, and whites were more likely than blacks and Hispanics to complete some courses.

Since 1990, the number of students taking AP tests has grown rapidly in mathematics and science subjects.

- Between 1990 and 2004, the number of students taking the Calculus AB Exam nearly tripled and the number taking Calculus BC increased nearly fourfold. In science, the number of students taking Physics C and Biology more than tripled, and those taking Physics B increased almost fivefold.

The majority of students who took AP tests received a passing score that would earn college credit, but gaps existed by sex and race/ethnicity.

- Male test takers were more likely than their female counterparts to earn passing scores, as were Asians/Pacific Islanders and whites compared with their black and Hispanic peers.

Mathematics and Science Teachers

College graduates who become teachers have somewhat lower academic skills on average than those who do not go into teaching.

- College graduates who became teachers took fewer rigorous academic courses in high school, had lower scores on 12th grade achievement tests, scored lower on college entrance examinations, and graduated from less-selective colleges.

Out-of-field teaching (as measured by either lacking a certificate or a college major or minor in the assigned teaching field) is common.

- Nationally, between 17% and 28% of public high school mathematics and science teachers lacked full certification in their teaching field in academic year 2002 (the school year that began in fall 2002). Proportions for the middle grades were even higher.
- Certification rates for high school mathematics and science teachers declined from 1990 to 2002. Certification rates for middle-level mathematics and science teachers increased in the mid-1990s but subsequently declined.
- In academic year 1999, between 23% and 29% of public middle-grade and high school mathematics and science teachers did not have a college major or minor in their teaching field.

Many states have implemented policies to promote participation in teacher professional development and improve its quality.

- By 2002, 48 states had required professional development for teacher license renewal, and 24 had adopted professional development policies aligned with state content standards. As of 2004, 37 states financed some professional development programs, 35 had standards in place for professional development, 27 provided professional development funds for all districts in the state, 16 required and financed mentoring programs for all novice teachers, and 13 required districts or schools to set aside teacher time for professional development
- However, professional development in many school districts in the late 1990s still consisted mainly of one-time workshops with little followup. Most teachers attended programs for only a few hours over the course of the school year, far below the minimum of 60 to 80 hours that some studies show as needed to bring about meaningful change in teaching behaviors.

Inflation-adjusted U.S. public school teacher salaries increased only slightly between 1972 and 2002.

- In 2002, the average salary of all public school K−12 teachers was $44,367, just about $2,598 above what it was in 1972 (after adjusting for inflation).

Dissatisfaction with working conditions was among the most common reasons mathematics and science teachers gave for deciding to change schools or leave the profession.

- Public school mathematics and science teachers who changed schools were less likely than those who stayed to report satisfaction with job security, safety, community support, administrative support, and the amount of autonomy they had, among other factors.
- Those who left the profession reported they did so to pursue another career, to get a better salary or benefits, or to retire. They also reported more satisfaction with their new nonteaching jobs than with teaching.

Information Technology in Education

Access to computers and the Internet has grown rapidly both at school and at home.

- The ratio of public school students to online school computers improved from 12:1 in 1998 to 4:1 in 2003.
- In 2003, 77% of K–12 students lived in a household with a computer and 67% had Internet access at home.

Home computer ownership and Internet access continue to differ by family income, parental education, and race/ethnicity, but rapid growth in access to computers and the Internet in school has helped equalize access for disadvantaged students.

- Students in high-income families were nearly three times more likely than those from low-income families to have home Internet access, 90% versus 32%.
- Not only are overall use rates higher at school than at home, these differences are also more pronounced for less advantaged students. Low-income students, for example, were more than twice as likely to use a computer at school than at home in 2003, while high-income students used computers at only slightly different rates at the two locations.

Most third graders frequently use computers at school.

- ♦ About 56% of third graders were given computer work at least three times weekly in 2002 and 22% were assigned Internet use at least three times a week.

From 1999 to 2002, the proportion of teachers who feel prepared to use computers in the classroom increased.

- ♦ About two-thirds of all public school K–12 teachers surveyed in 1999 indicated that their preparation for using computers in instruction was inadequate. However, in 2002, more than 60% of third grade teachers said they felt prepared to use information technology (IT) in instruction and 75% overall reported being fairly comfortable using computers.

In 2000–01, most public school teachers reported participating in some professional development on using computers for instruction during the previous year.

- ♦ Roughly half said they had trained on one or more of three topics: the mechanics of using IT, integrating computers into instructional activities, and using the Internet. However, such training tended to be brief rather than sustained.

Transition to Higher Education

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

- ♦ Between 1973 and 2003, the percentage of high school graduates enrolling in college in the fall following graduation grew from 47% to 64%, with increases occurring at both 2- and 4-year institutions. However, the trend began to flatten in the late 1990s.
- ♦ Enrollment rates increased faster for females than for males. Much of the growth in the overall rate was due to increases in the immediate enrollment rate of females at 4-year institutions.
- ♦ White high school graduates had consistently higher enrollment rates than their black and Hispanic peers over time, as did students from high-income families compared with those from low-income families.

Many college freshmen lack adequate preparation for higher education and need remedial assistance in their transition to college.

- ♦ In 2000, some 76% of postsecondary institutions offered remedial reading, writing, or mathematics courses. At these institutions, 22% of freshmen took remedial mathematics, 14% took remedial writing, and 11% took remedial reading. From 1995 to 2000, more institutions reported that students needed a year or more of remediation.
- ♦ Freshmen at public 2-year institutions had higher enrollment rates in remedial courses: 42% of freshmen at these institutions, compared with 12% to 24% of their peers at other types of institutions, enrolled in a remedial course in fall 2000.

Introduction

Chapter Overview

Across the United States, states, schools, and students are now fully immersed in efforts to meet the educational accountability requirements set forth by the federal No Child Left Behind Act of 2001 (NCLB), which took effect in 2002. NCLB requires the development of student performance standards and regular assessment of student learning. Schools that fail to show progress in improving achievement for all students receive assistance first, then sanctions. NCLB also emphasizes the importance of high-quality teaching and contains provisions encouraging states to see that teachers are adequately prepared for their teaching responsibilities.

States have already developed and published standards for mathematics achievement and were required to have standards for science in place by academic year 2005 (the school year that began in fall 2005). Beginning in academic year 2005, school districts must assess student mathematics performance yearly in grades 3 through 8. Beginning in academic year 2007, districts must assess student science performance once in elementary school and once in middle school. Over the next few years, the results of these assessments will provide new and important data about student performance in those crucial subjects.

Concern about the relationship of science and mathematics achievement to American global competitiveness, workforce preparation, and development of an educated citizenry continues to fuel efforts to improve student performance in those areas. This chapter draws on a variety of currently available data (mostly from 2000–04) to examine U.S. students' mathematics and science achievement; compare it with that of their international peers; and highlight developments, trends, and conditions influencing the quality of U.S. elementary and secondary mathematics and science education.

Chapter Organization

The chapter begins by summarizing the most recent available data on U.S. student achievement, including new indicators not available for previous *Science and Engineering Indicators* editions about student performance in mathematics during the first 4 years of schooling and performance in science in third grade. It continues by examining U.S. student performance in mathematics and science in grades 4, 8, and 12, and describes student achievement from an international perspective. The chapter next examines the availability of and participation in mathematics and science courses, including Advanced Placement (AP) testing, and characteristics of schools and students affecting this participation.

Teachers play an important role in helping students meet high standards, so the chapter next devotes attention to data on mathematics and science teachers, including their academic background and experience, the match or mismatch between academic preparation and teaching assignments, participation in professional development activities, and salaries and working conditions. New indicators in this section include transcript data on the academic backgrounds of new college graduates who entered teaching, state policies on teacher professional development, attrition and mobility of mathematics and science teachers, and perceptions of school working conditions by those who change schools or leave the profession.

Information technology (IT) affects all levels of education, and states are increasingly requiring and encouraging teachers to become more proficient in using technology for instruction. The chapter next looks at indicators of student access to and use of IT at school and at home, and the preparation of teachers for using IT in instruction. New indicators in this section include teachers' preparation for using IT in instruction in the early primary grades, and the use of IT among third grade students.

Finally, the chapter examines data on high school students' transition to postsecondary education, first-time entry rates into postsecondary education in the United States relative to rates in other countries, and the extent of remedial education at the college level as an indicator of student preparation for college-level work. A new indicator is information on the length of remedial coursetaking among freshmen.

This chapter focuses primarily on overall patterns, but it also reports variation in access to educational resources by school poverty level and minority concentration, and in student performance by sex, race/ethnicity, and family background characteristics (when data are available). Whenever the report cites a difference, it is statistically significant at the .05 probability level.

Student Learning in Mathematics and Science

The current performance of U.S. elementary and secondary students in mathematics and science is both encouraging and disappointing. Average mathematics scores on national assessments rose during the 1990s and early 2000s, and gains were widespread, with many demographic subgroups registering higher achievement. Performance in science has not improved recently, however. Substantial achievement gaps among some demographic subpopulations of students persist in both mathematics and science, and most 4th, 8th, and 12th grade students do not perform at levels considered proficient for their grade. On international assessments, recent data show that U.S. students performed above international averages that include scores from both developed and developing countries on tests closely aligned to the way mathematics and science are presented to them in the classroom. However, they performed below international averages for the 30 Organisation for Economic Co-operation and Development (OECD) nations in applying mathematical and scientific skills to situations they might encounter outside of a classroom.

This section presents information from recent national and international studies of U.S. student achievement in mathematics and science and compares them with earlier study results. It begins with a discussion of student performance during the primary grades, followed by a review of assessment results for students in grades 4, 8, and 12. The section ends by placing U.S. student achievement in a broader international context.

Early Formal Learning: Kindergarten Through Third Grade

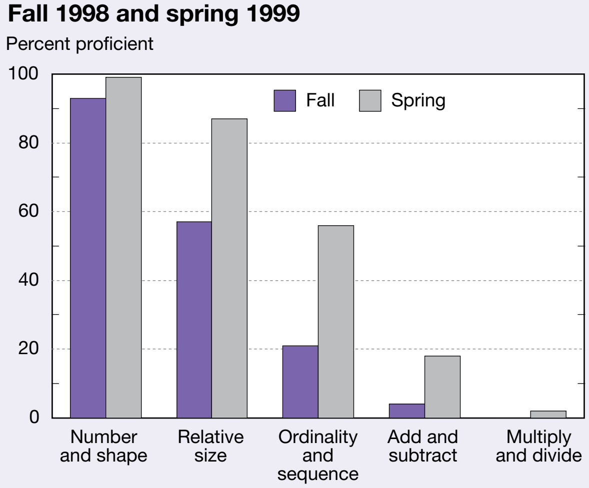
The mathematics and science performance of U.S. students in upper-elementary and secondary grades has been reported since the late 1960s (Campbell, Hombo, and Mazzeo 2000). Much less has been known about student learning in these subjects during the first years of formal education, but this is changing with the release of initial findings from an ongoing study of students who began kindergarten in 1998 (Early Childhood Longitudinal Study, Kindergarten Class of 1998–99, ECLS–K).[1]

Kindergarten: Mathematics Skills and Knowledge

Children begin formal schooling with varying levels of mathematics skills, and over the course of the kindergarten year, the percentage of students proficient in specific skill areas increases (West, Denton, and Germino-Hausken 2000; West, Denton, and Reaney 2000).[2] In 1998, most beginning kindergartners (93%) could recognize single-digit numbers and basic shapes in the fall, and almost all (99%) demonstrated these skills in the spring (figure 1-1). In the fall, just more than half (57%) of the students could count beyond 10, recognize the sequence in basic patterns, and compare the relative size of objects, but by spring, 87% could do so. Increases occurred in other skill areas as well, although gains in more advanced skills such as addition, subtraction, multiplication, and division were relatively small (see sidebar "Mathematics Skills Areas for Primary Grade Students").

Disparities among subpopulations of students were evident when they started kindergarten. Mathematics performance was related to several student background factors, and the association between social disadvantages and performance was cumulative. Lower proportions of black and Hispanic students were proficient at each skill level compared with their white and Asian/Pacific Islander peers (appendix table 1-1)[3]. Performance was also related to maternal education, with students whose mothers had less formal education demonstrating lower proficiency rates. For the kindergarten assessments, a family risk index was developed consisting of non-English primary home language, single-parent

Figure 1-1
First-time kindergartners demonstrating specific mathematics skills and knowledge: Fall 1998 and spring 1999



SOURCE: J. West, K. Denton, and L. Reaney, *The Kindergarten Year,* U.S. Department of Education, National Center for Education Statistics (2000). See appendix table 1-1.

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Mathematics Skills Areas for Primary Grade Students

The Early Childhood Longitudinal Study, Kindergarten Class of 1998–99 (ECLS–K) mathematics assessment measures core foundational mathematics skills, including conceptual understanding of numbers, shapes, mathematical operations, and processes for problem solving (West, Denton, and Germino-Hausken 2000). The assessment provides information on student performance in the form of an overall achievement score and proficiency in seven specific skill sets. The skill sets represent a progression of mathematics skills and knowledge. Levels 6 and 7 were first assessed in third grade. Each set of skills 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 hundredth place.

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

SOURCE: West, Denton, and Reaney 2000.

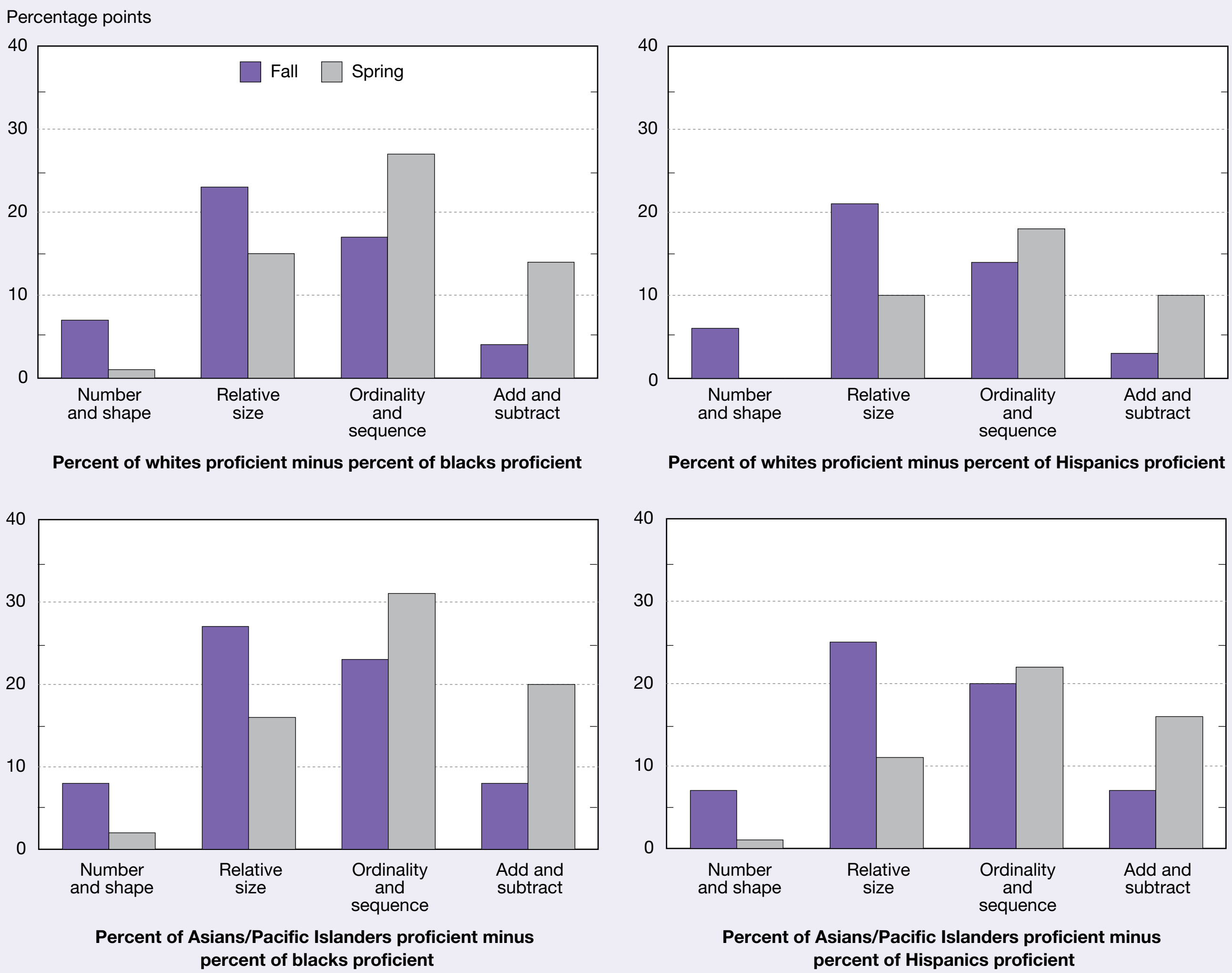
family, less than high school maternal education, and family receiving welfare assistance.[4] Students from families with no risk factors performed better than students from families with one risk factor, and students from families with one risk factor performed better than students from families with two or more risk factors.

As students progressed through kindergarten, gaps in basic mathematics skills decreased, but disparities in the more sophisticated skills increased. For example, by the end of kindergarten, blacks and Hispanics narrowed the proficiency gap with whites and Asians/Pacific Islanders in recognizing single-digit numbers and shapes and in comparing the relative size of objects (figure 1-2; appendix table 1-1). However, they did not acquire more advanced mathematics knowledge and skills, such as addition and subtraction, at the same rate as whites and Asians/Pacific Islanders. This resulted in even larger disparities in the more sophisticated skills by the end of kindergarten.

The First 4 Years of School

Mathematics. After 4 years of formal schooling, when most students were at the end of third grade, some performance gaps had widened (Rathbun and West 2004) (figure 1-3; appendix table 1-2).[5] Black students, who entered kindergarten with lower overall mathematics scores than white and Asian/Pacific Islander students, made smaller gains over the 4 years than did white, Asian/Pacific Islander, and Hispanic students, resulting in larger performance gaps. Students with one or more family risk factors started formal education with lower scores and made less progress than students with no family risk factors, also resulting in larger performance gaps.

Figure 1-2
Mathematics proficiency gaps between whites or Asians/Pacific Islanders and blacks or Hispanics among first-time kindergartners, by skill area: Fall 1998 and spring 1999



SOURCE: J. West, K. Denton, and L. Reaney, *The Kindergarten Year,* U.S. Department of Education, National Center for Education Statistics (2000). See appendix table 1-1.

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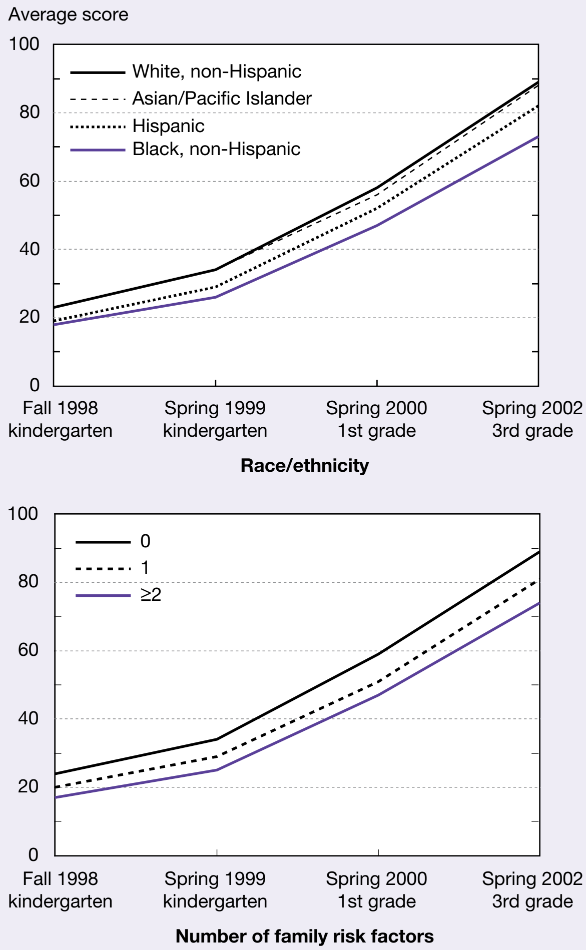
Figure 1-3
Average mathematics scores of fall 1998 first-time kindergartners from fall 1998 to spring 2002, by race/ethnicity and number of family risk factors: 1998–2000, 2002



NOTE: Family risk factors include living below federal poverty level, non-English primary home language, single-parent household, maternal education less than high school diploma or equivalent credential (e.g., General Educational Development certificate).

SOURCE: A. Rathbun and J. West, *From Kindergarten Through Third Grade: Children's Beginning School Experiences,* U.S. Department of Education, National Center for Education Statistics (2004). See appendix table 1-2.

Science and Engineering Indicators 2006

Other research has shown that widening achievement gaps as students progress through school is, 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.

Studies of upper-elementary and secondary students dating back to the late 1960s have documented some sex differences in science and mathematics performance (e.g., Campbell, Hombo, and Mazzeo 2000; NCES 2003a and 2003b).[6] The ECLS–K study, the first national study of primary grade students, found no sex differences in average overall mathematics performance during the first 4 years of schooling (Rathbun and West 2004; West, Denton, and Germino-Hausken 2000; West, Denton, and Reaney 2000). However, at the end of third grade, boys were more likely than girls to demonstrate proficiency in the advanced mathematics skills of place value concepts and knowledge of rate and measurement to solve word problems (appendix table 1-3). These advanced math skills were first assessed in the third followup, when most students were in third grade.

The ECLS–K study examined associations between mathematics performance and two aspects of students' early school experiences: whether they attended public or private schools, and whether they attended full- or half-day kindergarten. Performance differences in mathematics by school type were evident as students started formal schooling (West, Denton, and Germino-Hausken 2000). Students beginning kindergarten in private schools had stronger mathematics skills than those at public schools. Although achievement differences persisted through the third grade, the growth rate in mathematics did not differ. Therefore, performance gaps between public and private school students did not increase (Rathbun and West 2004).[7] Students in full-day kindergartens experienced greater gains in mathematics compared with their peers in half-day classes (Watson and West 2004). At the end of third grade, however, the benefit of full-day kindergarten could no longer be detected (Rathbun, West, and Germino-Hausken 2004).

Science. The ECLS–K study began assessing students in science in spring 2002, when most were in third grade. The assessment placed equal emphasis on life science, earth and space science, and physical science and asked students to demonstrate understanding of the physical and natural world, make inferences, and understand relationships (Rathbun and West 2004). Students were also required to interpret scientific data, form hypotheses, and develop plans to investigate scientific questions.[8] Performance gaps observed in mathematics were also generally found in science (appendix table 1-4): white and Asian/Pacific Islander students had higher average science scores than blacks and Hispanics; Hispanic third graders outperformed their black peers; and students with no family risk factors scored higher, on average, than those with one or more risk factors. No sex differences were observed in third grade science performance.

Performance of U.S. Students in Grades 4, 8, and 12

Many of the same performance gaps in mathematics and science achievement found among primary students also exist among upper-elementary and secondary students. Although mathematics performance in particular improved through the 1990s and early 2000s for many subgroups, substantial achievement gaps persist and, as will be detailed below, in some cases, have grown wider.

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.[9] This volume reports on recent trends, from 1990 to 2003 for mathematics and from 1996 to 2000 for science.[10] Previous *Science and Engineering Indicators* described long-term trends in mathematics and science results dating back to the first NAEP assessments.[11] Long-term trends in mathematics achievement from the 2004 administration were released too late for the text of this chapter but are reviewed briefly in the sidebar "Long-term Trends in Student Mathematics Achievement" at the conclusion of this section.

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 2003a). The mathematics assessment contains five broad content strands (number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions). It also assesses mathematical ability (conceptual understanding, procedural knowledge, and problem solving) and mathematical power (reasoning, connections, and communication). The science framework includes a content dimension divided into three major fields of science (earth, life, and physical), and a cognitive dimension covering conceptual understanding, scientific investigation, and practical reasoning (NCES 2001).

Student performance on the NAEP is measured with scale scores as well as achievement levels. The scale scores place students on a continuous ability scale based on their overall performance. For mathematics, the scale ranges from 0 to 500 across the three grades. For science, the scale ranges from 0 to 300 within each grade.

The 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 (NCES 2003a). The *basic* level represents partial mastery of the knowledge and skills needed to perform proficiently at each grade level. The *proficient* level represents solid academic performance and the *advanced* level represents superior performance. This review of NAEP results focuses on the proficient level (for definitions of the proficient level for grades 4, 8, and 12, see sidebars "Proficient Level in Mathematics in Grades 4, 8, and 12" and "Proficient Level in Science in Grades 4, 8, and 12").

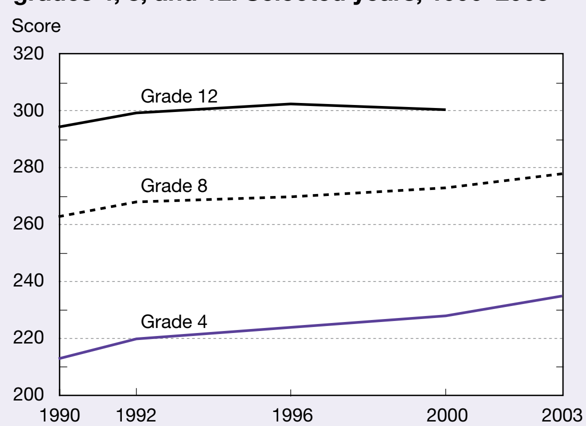
Disagreement exists about whether NAEP has appropriately defined these levels. A study commissioned by the National Academy of Sciences judged the process used to set these levels "fundamentally flawed" (Pellegrino, Jones, and Mitchell 1998), and NAGB acknowledges that considerable controversy remains 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. Nevertheless, they warn readers to use and interpret the levels with caution (NCES 2003a).

In this section, the NAEP results are examined in a number of ways, including changes in average scores and the proportion of students reaching the proficient level, both overall and among 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 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 only high-achieving students or whether it reflects broader improvements.

Mathematics Performance

The average mathematics scores of fourth and eighth grade students increased from 1990 (the first year in which the current assessment was given) to 2003 (NCES 2001, 2003a) (figure 1-4; table 1-1).[12] The average performance of 12th graders also improved between 1990 and 2000, when they were last assessed. The pattern of increased average scores was widespread (table 1-1; appendix table 1-5). At each grade level, average mathematics scores improved for both male and female students, and for all students regardless of eligibility for free or reduced-price lunch (a commonly used

Figure 1-4
Average mathematics score of students in grades 4, 8, and 12: Selected years, 1990–2003



NOTES: 2003 scores include English language learner and disabled students who took assessment with accommodations. Scores from 1990 to 2000 from National Assessment of Educational Progress samples where accommodations were not permitted.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); and *The Nation's Report Card: Mathematics 2000* (2001). See appendix table 1-5.

Science and Engineering Indicators 2006

Proficient Level in Mathematics in Grades 4, 8, and 12

The National Assessment of Educational Progress (NAEP) ranks student performance according to three achievement levels: basic, proficient, and advanced. The levels are set by the National Assessment Governing Board (NAGB) based on recommendations from panels of educators and members of the public of what students should know and be able to do in the subject assessed. NAGB's definition of the proficient level for mathematics for grades 4, 8, and 12 is directly quoted below. Descriptions of the other achievement levels can be found in the report cited at the end of the sidebar.

Grade 4

Fourth grade students performing at the Proficient level should consistently apply integrated procedural knowledge and conceptual understanding to problem solving in the five NAEP content strands.

Fourth graders performing at the Proficient level should be able to use whole numbers to estimate, compute, and determine whether results are reasonable. They should have a conceptual understanding of fractions and decimals; be able to solve real-world problems in all NAEP content areas; and use four-function calculators, rulers, and geometric shapes appropriately. Students performing at the Proficient level should employ problem-solving strategies such as identifying and using appropriate information. Their written solutions should be organized and presented both with supporting information and with explanations of how they were achieved.

Grade 8

Eighth grade students performing at the Proficient level should apply mathematical concepts and procedures consistently to complex problems in the five NAEP content strands.

Eighth graders performing at the Proficient level should be able to conjecture, defend their ideas, and give supporting examples. They should understand the connections among fractions, percents, decimals, and other mathematical topics such as algebra and functions. Students at this level are expected to have a thorough understanding of basic-level arithmetic operations—an understanding sufficient for problem solving in practical situations. Quantity and spatial relationships in problem solving and reasoning should be familiar to them, and they should be able to convey underlying reasoning skills beyond the level of arithmetic. They should be able to compare and contrast mathematical ideas and generate their own examples. These students should make inferences from data and graphs, apply properties of informal geometry, and accurately use the tools of technology. Students at this level should understand the process of gathering and organizing data and be able to calculate, evaluate, and communicate results within the domain of statistics and probability.

Grade 12

Twelfth grade students performing at the Proficient level should consistently integrate mathematical concepts and procedures into the solutions of more complex problems in the five NAEP content strands.

Twelfth graders performing at the Proficient level should demonstrate an understanding of algebraic, statistical, geometric, and spatial reasoning. They should be able to perform algebraic operations involving polynomials, justify geometric relationships, and judge and defend the reasonableness of answers as applied to real-world situations. These students should be able to analyze and interpret data in tabular and graphical form; understand and use elements of the function concept in symbolic, graphical, and tabular form; and make conjectures, defend ideas, and give supporting examples.

Source: NAGB 2002.

indicator for poverty).[13] Generally, gains were observed for white, black, Hispanic, and Asian/Pacific Islander 4th and 8th grade students, although at grade 12, only the scores of white students improved.[14] Higher average scores for students at the 10th, 25th, 50th, 75th, and 90th percentiles in 2003, compared with 1990, provide further evidence that gains in mathematics were widespread. (Percentiles indicate the percentage of students whose scores fell below a particular score. For example, 75% of students had scores below the 75th percentile.)

Improvements in average mathematics scores were generally mirrored by increases in the percentage of students scoring at or above the proficient level for their grade (figure 1-5; table 1-1; appendix table 1-6). This growth was substantial at grades 4 and 8, with rates about doubling between 1990 and 2003.

Although gains in mathematics achievement are encouraging, despite the improvements, most students do not demonstrate solid mathematics skills and knowledge for their grade. In the latest NAEP mathematics assessments (2003 for grades 4 and 8, and 2000 for grade 12), only about one-third of 4th and 8th graders, and even fewer 12th graders (16%), reached the proficient level (figure 1-5; appendix table 1-6).

Proficient Level in Science in Grades 4, 8, and 12

The National Assessment of Educational Progress (NAEP) ranks student performance according to three achievement levels for their grade: basic, proficient, and advanced. The levels are set by the National Assessment Governing Board (NAGB) based on recommendations from panels of educators and members of the public of what students should know and be able to do in the subject assessed. NAGB's definition of the proficient level in science for grades 4, 8, and 12 is directly quoted below. Descriptions of the other achievement levels can be found in the report cited at the end of the sidebar.

Grade 4

Students performing at the Proficient level demonstrate the knowledge and reasoning required for understanding of Earth, physical, and life sciences at a level appropriate to grade 4. For example, they understand concepts relating to the Earth's features, physical properties, structure, and function. In addition, students can formulate solutions to familiar problems as well as show a beginning awareness of issues associated with technology.

Fourth grade students performing at the Proficient level are able to provide an explanation of day and night when given a diagram. They can recognize major features of the Earth's surface and the impact of natural forces. They are also able to recognize water in its various forms in the water cycle and can suggest ways to conserve it. These students recognize that various materials possess different properties that make them useful. Students at this level are able to explain how structure and function help living things survive. They have a beginning awareness of the benefits and challenges associated with technology and recognize some human effects on the environment. They can also make straightforward predictions and justify their position.

Grade 8

Students performing at the Proficient level demonstrate much of the knowledge and many of the reasoning abilities essential for understanding of Earth, physical, and life sciences at a level appropriate to grade 8. For example, students can interpret graphic information, design simple investigations, and explain such scientific concepts as energy transfer. Students at this level also show an awareness of environmental issues, especially those addressing energy and pollution.

Eighth grade students performing at the Proficient level are able to create, interpret, and make predictions from charts, diagrams, and graphs based on information provided to them or from their own investigations. They have the ability to design an experiment and have an emerging understanding of variables and controls. These students are able to read and interpret geographic and topographic maps. In addition, they have an emerging ability to use and understand models, can partially formulate explanations of their understanding of scientific phenomena, and can design plans to solve problems. Students at this level can begin to identify forms of energy and describe the role of energy transformations in living and nonliving systems. They have knowledge of organization, gravity, and motion within the solar system and can identify some factors that shape the surface of the Earth. These students have some understanding of properties of materials and have an emerging understanding of the particulate nature of matter, especially the effect of temperature on states of matter. They also know that light and sound travel at different speeds and can apply their knowledge of force, speed, and motion. These students demonstrate a developmental understanding of the flow of energy from the sun through living systems, especially plants. They know that organisms reproduce and that characteristics are inherited from previous generations. These students also understand that organisms are made up of cells and that cells have subcomponents with different functions. In addition, they are able to develop their own classification system based on physical characteristics. These students can list some effects of air and water pollution as well as demonstrate knowledge of the advantages and disadvantages of different energy sources in terms of how they affect the environment and the economy.

Grade 12

Students performing at the Proficient level demonstrate the knowledge and reasoning abilities required for understanding of the Earth, physical, and life sciences at a level appropriate to grade 12. In addition, they demonstrate knowledge of the themes of science (models, systems, and patterns of change) required for understanding how these themes illustrate essential relationships among the Earth, physical, and life sciences. They are able to analyze data and apply scientific principles to everyday situations.

Twelfth grade students performing at the Proficient level are able to demonstrate a working ability to design and conduct scientific investigations. They are able to analyze data in various forms and utilize information to provide explanations and to draw reasonable conclusions. Students at this level have a developmental understanding of both physical and conceptual models and are able to compare various models. They recognize some inputs and outputs, causes and effects, and interactions of a system. In addition, they can correlate structure to function for the parts of a system that they can identify. These students also recognize that rate of change depends on initial conditions and other factors. They are able to apply scientific concepts and principles to practical applications and solutions for problems in the real world and show a developmental understanding of technology, its uses, and its applications.

Source: NAGB 2000.

Table 1-1
Changes in mathematics and science performance of students in grades 4, 8, and 12, by student characteristics: 1990–2003

	Mathematics			Science		
	1990–2003		1990–2000	1996–2000		
Student characteristic	Grade 4	Grade 8	Grade 12	Grade 4	Grade 8	Grade 12
Average score						
Total	▲	▲	▲	•	•	▼
Sex						
Male	▲	▲	▲	•	▲	▼
Female	▲	▲	▲	•	•	•
Race/ethnicity						
White, non-Hispanic	▲	▲	▲	•	•	▼
Black, non-Hispanic	▲	▲	•	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	▲	•	NA	•	•
American Indian/Alaska Native[b]	•	•	•	•	▼	•
Free/reduced-price lunch[c]						
Eligible	▲	▲	▲	•	▼	•
Not eligible	▲	▲	▲	•	▲	▼
Percentile score						
10th	▲	▲	▲	•	▲	•
25th	▲	▲	▲	•	•	•
50th	▲	▲	▲	•	•	▼
75th	▲	▲	▲	•	•	•
90th	▲	▲	▲	•	•	•
Percent at or above proficient level						
Total	▲	▲	▲	•	•	•
Sex						
Male	▲	▲	▲	•	▲	•
Female	▲	▲	▲	•	•	•
Race/ethnicity						
White, non-Hispanic	▲	▲	▲	•	•	•
Black, non-Hispanic	▲	▲	•	•	•	•
Hispanic	▲	▲	•	•	•	•
Asian/Pacific Islander[a]	▲	▲	•	NA	•	•
American Indian/Alaska Native[b]	•	•	•	•	•	•
Free/reduced-price lunch[c]						
Eligible	▲	▲	•	•	•	•
Not eligible	▲	▲	•	•	▲	•
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
NA = not available

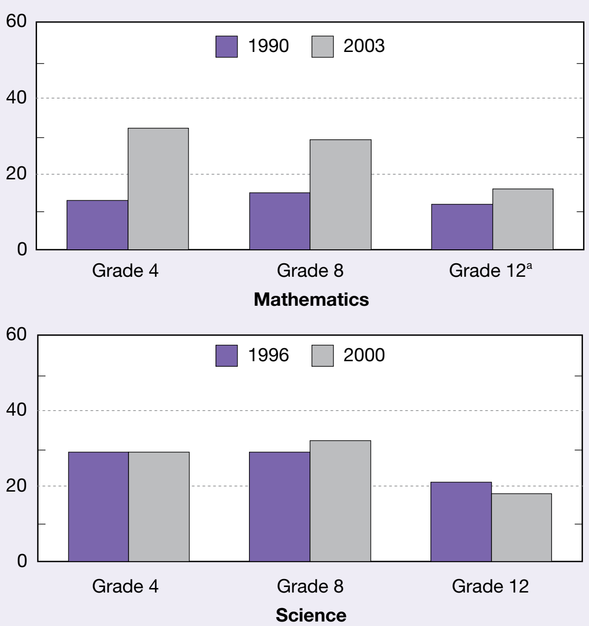
[a]National Center for Education Statistics (NCES) did not publish 2000 science scores for fourth grade Asian/Pacific Islander students because of accuracy and precision concerns.
[b]Insufficient samples sizes in earlier years of National Assessment of Educational Progress (NAEP) in mathematics and science precluded calculation of reliable estimates for American Indians/Alaska Natives. Mathematics comparisons shown here for this group are between 1996 and 2003 for grade 4, 2000 and 2003 for grade 8, and 1996 and 2000 for grade 12. Science comparison for American Indian/Alaska Natives are from 1996 to 2000.
[c]Information on student eligibility for free/reduced-price lunch first collected in 1996. Thus, comparisons shown for mathematics are from 1996 to 2003 and for science are from 1996 to 2000.

NOTE: Includes students in both public and private schools.

SOURCES: U.S. Department of Education, NCES, *The Nation's Report Card: Mathematics Highlights 2003,* NCES 2004-451 (2003); *The Nation's Report Card: Mathematics 2000,* NCES 2001-517 (2001); *The Nation's Report Card: Science Highlights 2000,* NCES 2002-452 (2001); and data from NAEP, 1990, 2000, and 2003 mathematics assessments and 1996 and 2000 science assessments. See appendix tables 1-5, 1-6, 1-7, and 1-8.

Science and Engineering Indicators 2006

Figure 1-5
Students performing at or above proficient level for their grade, by grade: 1990–2003



[a]For mathematics, latest assessment for grade 12 was 2000.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Science Performance

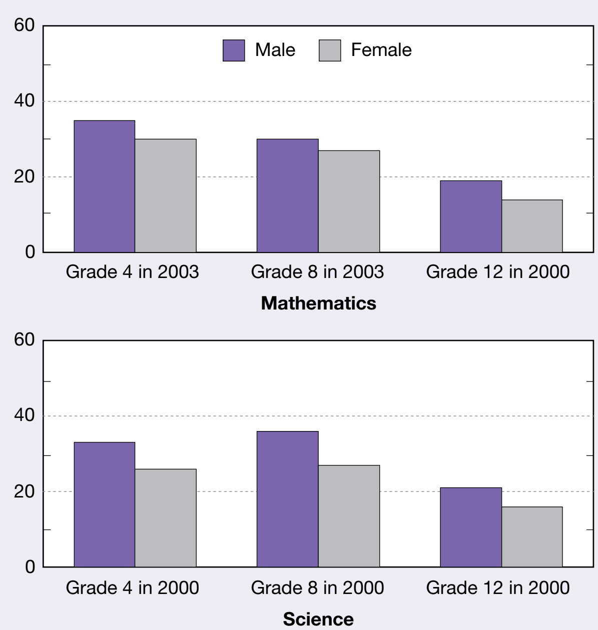
Recent trend lines for science are shorter than those for mathematics, and they suggest less improvement. Although average mathematics scores of fourth and eighth grade students increased from 1996 to 2000 (appendix table 1-5), average science scores did not change (NCES 2003b) (table 1-1; appendix table 1-7). At grade 12, average science scores declined. The proportion of students reaching the proficient level in science did not change for any of the three grades. Subgroup results in science were also generally flat between 1996 and 2000, both in terms of average scores and in the percent at or above the proficient level.[15] (The current national NAEP science assessment was administered in 1996, 2000, and 2005. The 2005 data were not available in time to be included in this report.)

In results similar to the 2003 mathematics findings, only about one-third of fourth and eighth grade students reached the proficient level in science for their grade in 2000 (figure 1-5; appendix table 1-8). Rates were lower among 12th graders, with only 18% of these students scoring at or above the proficient level.

Achievement Gaps Between Demographic Subgroups

Gender Achievement Gaps. The most recent NAEP assessments report only small sex differences in mathematics and science performance at grades 4, 8, and 12, with boys performing slightly better than girls (appendix tables 1-5, 1-6, 1-7, and 1-8).[16] For example, in 2003, 35% of fourth grade boys reached the proficient level in mathematics, compared with 30% of fourth grade girls (figure 1-6). The small gender gaps in mathematics have generally remained stable since 1990. However, the small gender gaps among fourth and eighth graders observed in science in 2000, for the most part, represent an increase from those observed in 1996 (table 1-1; appendix tables 1-5, 1-6, 1-7, and 1-8).

Figure 1-6
Students performing at or above proficient level for their grade, by sex: 2000 and 2003



SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Racial/ethnic Achievement Gaps. Substantial performance gaps exist between some racial/ethnic subgroups. At each grade level, white and Asian/Pacific Islander students performed better than black, Hispanic, and American Indian/Alaska Native students in both mathematics and science, both in terms of average scores and in percentage of students reaching the proficient level (figure 1-7; appendix tables 1-5, 1-6, 1-7, and 1-8). These achievement differences were relatively large. For example, in 2003, between four and five times as many white and Asian/Pacific Islander fourth grade students reached the proficient level in mathematics as did black students (see sidebar "Tenth Graders' Proficiency in Specific Mathematics Skill and Knowledge Areas").

Tenth Graders' Proficiency in Specific Mathematics Skill and Knowledge Areas

Achievement disparities by student and family backgrounds are observed in other national studies, such as the Education Longitudinal Study of 2002 (ELS: 2002). This base-year study assessed mathematics achievement of 10th grade students and placed their performance in one of five proficiency levels: simple arithmetical operations with whole numbers; simple operations with decimals, fractions, powers, and roots; simple problem solving requiring the understanding of low-level mathematical concepts; understanding of intermediate-level mathematical concepts and multistep solutions to word problems; and complex multistep word problems and advanced mathematics material (Ingels and Scott 2004). The skill levels represent a progression of mathematics skills and knowledge.

In 2002, a vast majority of 10th grade students (92%) were proficient in simple arithmetical operations with whole numbers, and 67% were also proficient in simple operations with decimals, fractions, roots, and powers (table 1-2). However, the proportions demonstrating proficiency in more advanced mathematics skills were lower and decreased with the progression of skill levels. The differences in proficiency in each skill area for male and female students were small, but they were larger for racial/ethnic and family socioeconomic subgroups. White and Asian/Pacific Islander students were more likely than black and Hispanic students to demonstrate proficiency in each level of mathematics skills, as were students from high-socioeconomic families compared with those from low-socioeconomic families. Followup data collection is under way. When these longitudinal data are available and can be used with other longitudinal studies such as High School and Beyond (HS&B) and the National Education Longitudinal Study (NELS), they will provide more valuable information about growth in student achievement and factors related to this growth.

Table 1-2
Tenth graders demonstrating mathemathics proficiency, by student characteristics: 2002
(Percent)

Student characteristic	Simple operations: whole numbers	Simple operations: decimals, fractions, roots, and power	Simple problem solving	Understanding intermediate-level concepts, multistep problem solving	Complex problem solving, advanced knowledge
Total	91.7	67.1	46.4	20.4	1.0
Sex					
Male	91.7	68.4	48.0	22.3	1.3
Female	91.6	65.7	44.7	18.5	0.6
Race/ethnicity					
White, non-Hispanic	95.5	77.9	57.9	27.0	1.2
Black, non-Hispanic	83.8	42.3	19.4	4.7	0.1
Hispanic	83.7	46.9	25.5	8.8	0.3
Asian/Pacific Islander	95.2	77.6	60.2	31.7	4.0
Other	90.5	63.2	39.2	14.4	0.6
Family socioeconomic status					
Low	84.8	46.6	25.0	7.6	0.2
Middle	92.4	67.8	44.9	17.9	0.6
High	97.2	86.0	70.5	38.4	2.5

NOTES: Socioeconomic status based on five equally weighted components: father's/guardian's education, mother's education, family income, father's/guardian's occupation, and mother's/guardian's occupation. Low socioeconomic status defined as bottom 20% of socioeconomic status index, middle socioeconomic status is between 20% and 80%, and high socioeconomic status is top 20%.

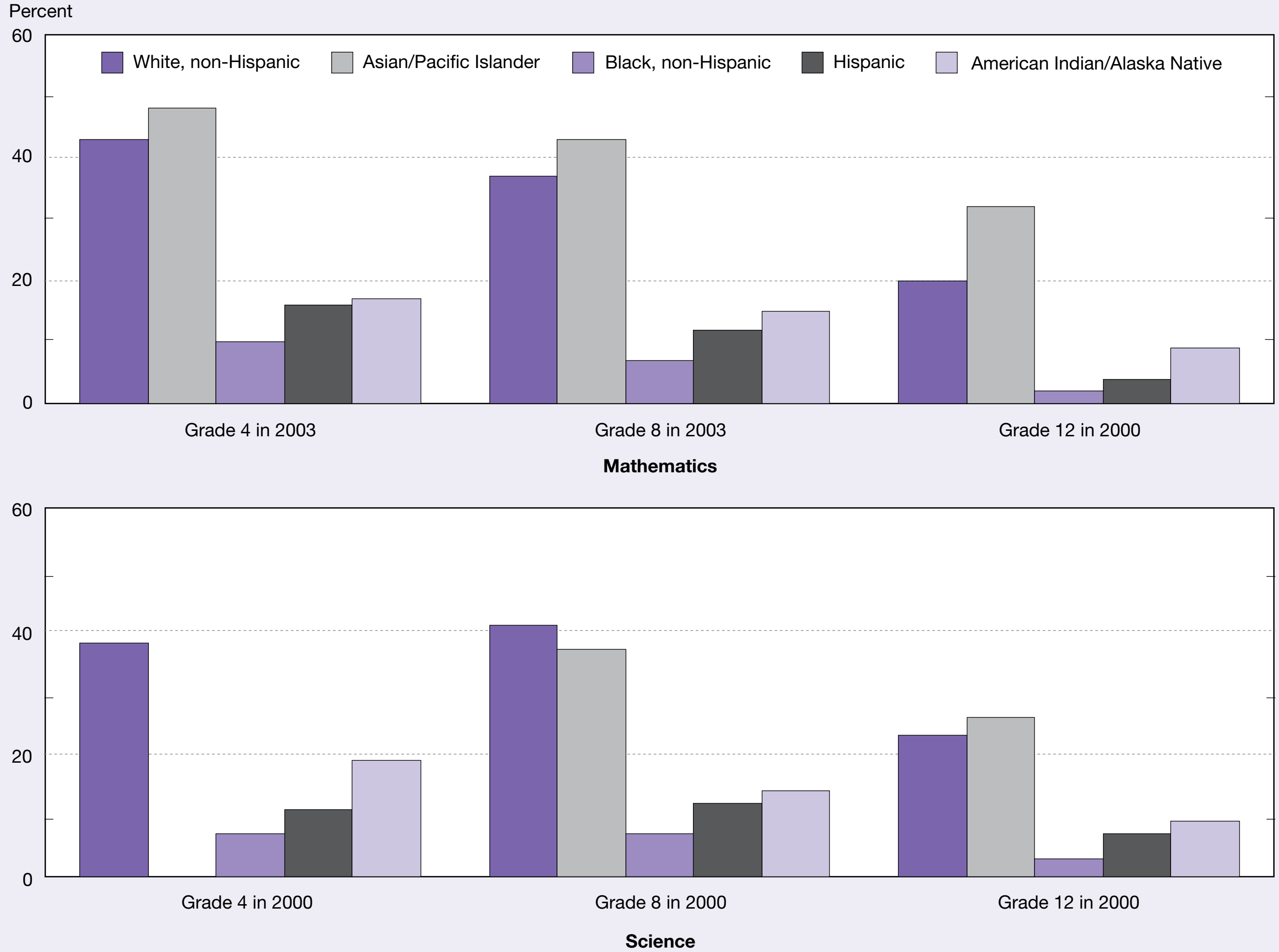
SOURCE: U.S. Department of Education, National Center for Education Statistics, Education Longitudinal Study of 2002.

Science and Engineering Indicators 2006

More subtle racial/ethnic differences in achievement were also observed.[17] For example, Asians/Pacific Islanders demonstrated slightly higher performance than whites in mathematics at each grade level, but the reverse was true for science at grades 4 and 8. In addition, in some instances, American Indian/Alaska Native and Hispanic students registered slightly higher performances than did black students (see sidebar "Projected School-Age Population of the United States").

Family Income Achievement Gaps. Mathematics and science performance also differed by family income (as measured by whether or not a student was eligible for the free or reduced-priced school lunch program) (figure 1-8; appendix tables 1-5, 1-6, 1-7, and 1-8). At each grade level, in both mathematics and science, students eligible for the subsidized lunch program (i.e., students from low-income families) had lower average scores and were less likely to reach the proficient level than

Figure 1-7
Students performing at or above proficient level for their grade, by race/ethnicity: 2000 and 2003

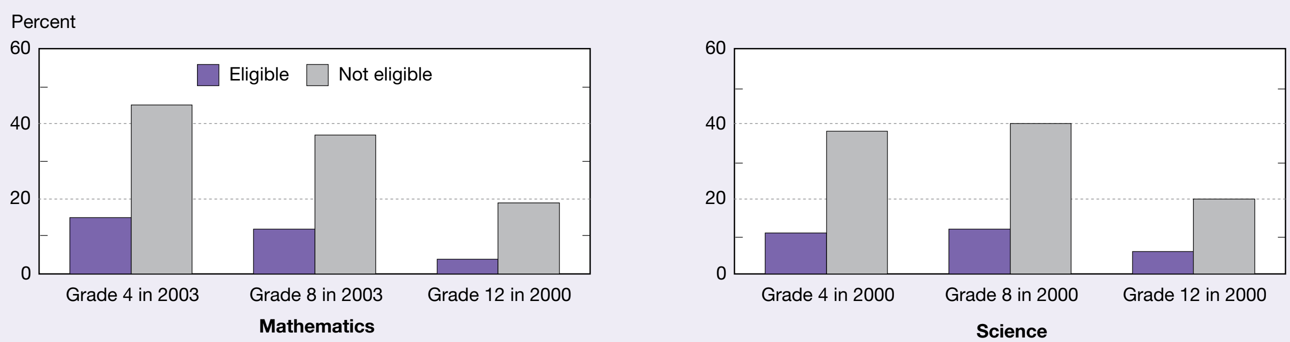


NOTE: National Center for Education Statistics (NCES) did not publish 2000 science scores for fourth grade Asian/Pacific Islander students because of accuracy and precision concerns.

SOURCES: U.S. Department of Education, NCES, *The Nation's Report Card: Mathematics Highlights 2003* (2003); *The Nation's Report Card: Mathematics 2000* (2001); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Figure 1-8
Students performing at or above proficient level for their grade, by eligibility for subsidized lunches: 2000 and 2003



NOTE: Eligibility for federal free/reduced-price lunch program is a commonly used indicator for family poverty.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); *The Nation's Report Card: Mathematics 2000* (2001); and *The Nation's Report Card: Science Highlights 2000* (2001). See appendix tables 1-6 and 1-8.

Science and Engineering Indicators 2006

Long-Term Trends in Student Mathematics Achievement

This chapter presents indicators of student achievement in mathematics and science based on the *national* NAEP assessments. This sidebar briefly introduces indicators of mathematics learning based on the NAEP 30-year *long-term trend* assessment of 2004 that became available in July 2005, too late for incorporation into the text of this volume.[9]

Major differences between these two NAEP programs include:

- ♦ Content in the long-term trend assessments has remained the same across administrations, whereas the national assessments have been updated periodically as the world and curricula have changed.
- ♦ The long-term trend assessment is administered to 9-, 13-, and 17-year-olds, whereas the national assessments are given to students in the 4th, 8th, and 12th grades.
- ♦ The long-term trend assessment reports achievement at the national level, whereas the national assessment reports achievement at the national and state levels and produces some district-level data.

This sidebar discusses scores on mathematics performance of representative samples of more than 11,000 students at each of the three ages assessed. More detailed data, as well as scores on reading, are available in the full report (Perie, Moran, and Lutkus 2005).

Overall Trend in Mathematics

Average scores on the long-term trend assessment in mathematics increased for 9- and 13-year olds in 2004 over the last assessment in 1999. The average score of 9-year-olds, after remaining flat throughout the 1990s, increased 9 points in 2004; the 2004 scores were 22 points higher than 30 years earlier. Thirteen-year-olds' average scale score increased 5 points in 2004 over 1999 and 15 points over 1973.

However, mathematics scores of 17-year-olds did not change from 1999 to 2004. The average score of 17-year-olds has increased 9 points since the lowest score in 1982, but has remained flat for more than a decade and is not significantly different from the average score for the first long-term trend mathematics assessment in 1973.

Trends in Mathematics Score Gaps

Samples of students for the NAEP long-term trend assessments are sufficiently large to allow reporting of scores separately for whites, blacks, and Hispanics. As table 1-3 shows, whites have, on average, scored higher than blacks and Hispanics throughout the 30-year assessment period. Although the gaps in achievement have decreased over the 30-year period, few of these declines occurred in the past 20 years.

Across the 30 years of the testing program, the gap in scores between whites and blacks decreased by 12, 19, and 12 points for 9-, 13-, and 17-year-olds, respectively. However, for each age group, the gap has remained significantly unchanged for at least the past decade.

The gap in average scores between white and Hispanic 9-year-olds was lower in 2004 than 1999 but did not differ from the 1973 gap. The gap in scores between white and Hispanic 13- and 17-year-olds decreased 12 and 9 points, respectively, between 1973 and 2004. However, this improvement was registered early in the assessment program; no statistically significant improvement has been measured since the 1970s.

Table 1-3
Trends in average mathematics scale score gaps between white students and black and Hispanic students 9, 13, and 17 years old: 1973–2004

Group	1973	1978	1982	1986	1990	1992	1994	1996	1999	2004
White versus black										
Age 9	*35*	*32*	*29*	25	27	27	25	25	28	23
Age 13	*46*	*42*	*34*	24	27	29	29	29	32	27
Age 17	*40*	*38*	32	29	*21*	26	27	27	31	28
White versus Hispanic										
Age 9	23	21	20	21	21	23	*27*	22	*26*	18
Age 13	*35*	*34*	22	19	22	20	25	25	24	23
Age 17	*33*	30	27	24	26	20	22	21	22	24

NOTES: Extrapolated data for 1973 and 1978. Data with statistically significant difference from 2004 data shown in italics. The average national score during the period ranged from 219 to 308.

SOURCE: M. Perie, R. Moran, and A.D. Lutkus, *NAEP 2004 Trends in Academic Progress: Three Decades of Student Performance in Reading and Mathematics* NCES 2005-464, figures 3-5 and 3-6. U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics (2005).

Science and Engineering Indicators 2006

Projected School-Age Population of the United States

The No Child Left Behind Act of 2001 grew out of concerns about disparities in performance among subpopulations of students. Current population projections indicate increasing student population in coming decades, particularly among several racial/ethnic subgroups currently underperforming in mathematics and science. The number of children ages 5 to 17 is expected to increase by 33% between 2000 and 2050. Population growth is estimated to occur among each group shown in table 1-4 with the exception of non-Hispanic whites, whose population is projected to decline by 6% between 2000 and 2050.

Differential growth rates across these groups are expected to change the racial/ethnic distribution of the U.S. school-age population. In 2000, Hispanic children made up 16% of the population ages 5 to 17 years, but by 2050, this percentage will almost double to 29%. The proportion of the school-age population that is white, non-Hispanic will decrease from 62% in 2000 to 44% in 2050. The percentage of the population that is Asian/Pacific Islander is expected to almost double, from 4% to 7%. The proportion of children in the "all other races" category is also expected to grow substantially from 4% to 8%. The percentage of the school-age population that is black is not forecast to change from 2000 to 2050.

Table 1-4
Projected U.S. school-age population, by race/ethnicity: 2000–50

Race/ethnicity	2000	2010	2020	2030	2040	2050
School-age population	53,155,308	53,005,348	57,367,750	61,435,403	65,382,782	70,468,455
White alone	40,914,449	40,201,343	42,604,512	44,870,848	46,576,189	49,013,479
Black alone	8,356,094	8,087,548	8,852,161	9,454,646	10,139,775	11,047,928
Asian alone	1,887,191	2,244,825	2,740,269	3,263,557	4,047,076	4,862,165
All other races	1,997,574	2,471,632	3,170,808	3,846,352	4,619,742	5,544,883
Hispanic (of any race)	8,687,080	11,050,896	13,358,135	15,435,633	17,974,565	20,579,244
White alone, non-Hispanic	32,997,850	30,165,624	30,549,998	31,046,223	30,629,572	30,937,254
Percentage of school-age population						
White alone	77.0	75.8	74.3	73.0	71.2	69.6
Black alone	15.7	15.3	15.4	15.4	15.5	15.7
Asian alone	3.6	4.2	4.8	5.3	6.2	6.9
All other races	3.8	4.7	5.5	6.3	7.1	7.9
Hispanic (of any race)	16.3	20.8	23.3	25.1	27.5	29.2
White alone, non-Hispanic	62.1	56.9	53.3	50.5	46.8	43.9

NOTES: School age is 5–17 years. "Alone" racial categories include people identified as being of one race and include both Hispanics and non-Hispanics. All other races include American Indian/Alaska Natives alone, Native Hawaiian/other Pacific Islanders alone, and those of two or more races. Both Hispanics and non-Hispanics are included in all other races.

SOURCE: U.S. Census Bureau, http://www.census.gov/ipc/www/usinterimproj/ (2004).

Science and Engineering Indicators 2006

students who were not eligible. These gaps related to family income were substantial. For example, students eligible for free or reduced lunch were at least three times less likely to score at or above the proficient level for their grade in both mathematics and science.

International Comparisons of Mathematics and Science Performance

Two mathematics and science assessments conducted in 2003 place U.S. student achievement in these subjects in an international context: the Trends in International Mathematics and Sciences Study (TIMSS) and the Programme for International Student Assessment (PISA). Results from the two assessment programs paint a complex picture. As detailed below, U.S. students scored above international averages on the TIMSS assessment and below international averages on the PISA assessment. The two programs are designed to serve different purposes, and each provides unique information about U.S. student performance relative to other countries in mathematics and science (Scott 2004). The differences in design and purpose of the assessments should be kept in mind when reviewing these divergent results.

One such difference is the grade/age of the students assessed. TIMSS provides data on mathematics and science achievement of students in primary and middle grades (grades 4 and 8 in the United States).[18] PISA reports the performance of students in secondary schools by sampling 15-year-olds, an age near the end of compulsory schooling in many countries.

Another difference between TIMSS and PISA is the relationship of the assessments to mathematics and science curriculum. TIMSS measures student mastery of curriculum-based knowledge and skills. Mathematics and science content experts and educators from many countries developed the framework behind the TIMSS assessment, and representatives from each participating country were asked to review and comment. The goal is to assess the mathematics and science content and skills that students are taught in school.[19] It is important to note that many of the participating countries have centralized, nationally mandated curriculums, whereas in the United States, curriculum, in the form of content standards, is developed at the state and local levels (Schmidt et al. 2001).

PISA, on the other hand, places more emphasis on students' ability to apply scientific and mathematical concepts and thinking skills to problems they might encounter, particularly in situations outside of a classroom. To some degree, PISA mathematics questions tend to demand more complex reasoning and problem solving skills than those in TIMSS (Neidorf et al. forthcoming) (see sidebar "Sample Mathematics and Science Items From the Curriculum-Based TIMSS Assessment and the Literacy-Based PISA Assessment").

A third difference is the composition of the participating countries. The 46 countries participating in the 2003 TIMSS include 13 highly industrialized nations, as well as many industrializing and developing ones. TIMSS international averages are based on all of these participating countries. In contrast, the PISA results reviewed in this chapter are based on average scores from 30 OECD countries. Thus, although the TIMSS averages include scores from both developed and developing countries, the PISA averages reflect only the performance of industrialized countries.[20] In addition to comparing the performance of U.S. students to these two sets of international averages, the text and tables 1-5 and 1-6 compare the United States with other OECD and Group of 8 (G-8) nations. The G-8 are the eight most industrialized countries in the world that meet regularly to discuss economic and other policies issues: Canada, France, Germany, Italy, Japan, the Russian Federation, the United Kingdom, and the United States.

TIMSS 2003 Results for Students in Grades 4 and 8: Curriculum-Based Knowledge in Mathematics and Science

Curriculum-Based Mathematics Performance. In 2003, the average curriculum-based mathematics score of U.S. fourth and eighth grade students exceeded the TIMSS international averages for these two grades, which included scores from both developed and developing countries (Gonzales et al. 2004) (appendix tables 1-9 and 1-10). Compared with other participating G-8 nations, U.S. fourth graders were outperformed by their counterparts in England, Japan, and Russia but registered higher average scores than students in Italy (table 1-5). At grade 8, the average score of U.S. students was lower than the average score of students in Japan but higher than the average score of students in Italy. The average mathematics score of eighth grade U.S. students was approximately equivalent to the average scores of students in Russia.

TIMSS also was conducted in 1995, permitting an examination of changes in performance over time. The average mathematics score of U.S. fourth graders on this curriculum-based assessment did not change from 1995 to 2003, but eighth graders' scores improved (data not shown, see Gonzales et al. 2004). Based on these results and on changes in average performance in some of the other countries (both improvement and decline), the relative ranking of the United States in mathematics declined slightly at grade 4 but improved slightly at grade 8.[21]

Curriculum-Based Science Performance. Examination of science results shows that in 2003, the average science score of U.S. fourth and eighth grade students was higher than the

Table 1-5
Average mathematics performance of 4th graders, 8th graders, and 15-year-olds for all participating OECD and/or G-8 countries, relative to U.S. average: 2003

Country	TIMSS 4th grade	TIMSS 8th grade	PISA 15-year-olds
Australia	▼	•	▲
Austria	na	na	▲
Belgium	▲	▲	▲
Canada	na	na	▲
Czech Republic	na	na	▲
Denmark	na	na	▲
England[a]	▲	na	na
Finland	na	na	▲
France	na	na	▲
Germany	na	na	▲
Greece	na	na	▼
Hungary	▲	▲	•
Iceland	na	na	▲
Italy	▼	▼	▼
Ireland	na	na	▲
Japan	▲	▲	▲
Luxembourg	na	na	▲
Mexico	na	na	▼
Netherlands	▲	▲	▲
New Zealand	▼	•	▲
Norway	▼	▼	▲
Poland	na	na	•
Portugal	na	na	▼
Russian Federation	▲	•	▼
Scotland[a]	▼	•	na
Slovak Republic	na	•	▲
South Korea	na	▲	▲
Spain	na	na	•
Sweden	na	•	▲
Switzerland	na	na	▲
Turkey	na	na	▼

▲ = score is higher than U.S. score; • = score is equivalent to U.S. score; ▼ = score is lower than the U.S. score; na = nonparticipation in assessment

OECD = Organisation for Economic Co-operation and Development; PISA = Programme for International Student Assessment; TIMSS = Trends in International Mathematics and Science Survey

[a]Participated separately in TIMSS 2003 at both grade levels but jointly as United Kingdom (including Northern Ireland) in PISA 2003. However, England did not meet response rate standards for grade 8 in TIMSS 2003 or for United Kingdom in PISA 2003.

SOURCES: E. Scott, *Comparing NAEP, TIMSS, and PISA in Mathematics and Science,* U.S. Department of Education, National Center for Education Statistics, figure 2 (2004); data from OECD, PISA 2003; and International Association for the Evaluation of Educational Achievement, TIMSS 2003. See appendix tables 1-9, 1-10, and 1-13.

Science and Engineering Indicators 2006

Sample Mathematics and Science Items From the Curriculum-Based TIMSS Assessment and the Literacy-Based PISA Assessment

Example items from the two international assessments are provided below. Trends in International Mathematics and Sciences Study (TIMSS) assesses mathematics and science skills of fourth and eighth graders in a manner closely aligned with the way these subjects are typically presented in school. The Programme for International Student Assessment (PISA) measures 15-year-olds' abilities to apply mathematics skills and knowledge.

TIMSS Eighth Grade Mathematics Item

If n is a negative integer, which of these is the largest number?

(A) $3 + n$
(B) $3 \times n$
(C) $3 - n$
(D) $3 \div n$

Correct Answer: C

Percent correct:
United States 48
International average 40

TIMSS Eighth Grade Science Item

The burning of fossil fuels has increased the carbon dioxide content of the atmosphere. What is a possible effect that the increased amount of carbon dioxide is likely to have on our planet?

(A) A warmer climate
(B) A cooler climate
(C) Lower relative humidity
(D) More ozone in the atmosphere

Correct Answer: A

Percent correct:
United States 56
International average 44

PISA 15-Year-Old's Mathematics Item

(See illustration below)

A carpenter has 32 meters of timber and wants to make a border around a garden bed. The carpenter is considering several designs for the garden bed.

Circle either "Yes" or "No" for each design to indicate whether the garden bed can be made with 32 meters of timber.

Correct Answers: Design A, Yes; Design B, No; Design C, Yes; Design D, Yes

Percent full credit:
United States 15
International average 20

PISA 15-Year-Old's Science Item

Drivers are advised to leave more space between their vehicles and the ones in front when they are traveling more quickly than when they are traveling more slowly because faster cars take longer to stop.

Explain why a faster car can take more distance to stop than a slower one.

Reasons: ____________________

Full credit: Answers that mention that:

The greater momentum of a vehicle when it is moving more quickly means that it will move further while slowing down than a slower vehicle, given the same force;

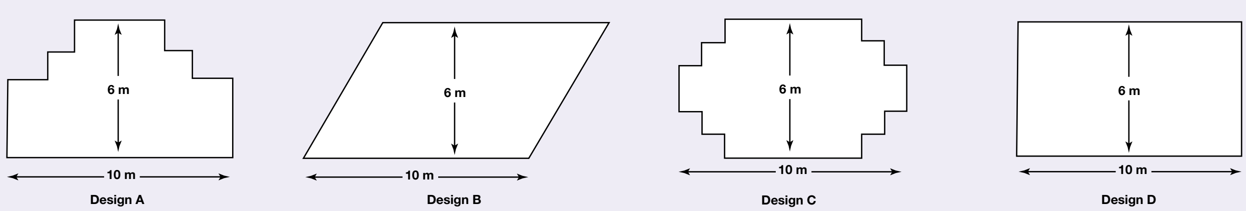
AND

It takes longer to reduce speed to zero from a greater speed, so the car will travel further in this time.

Partial credit: Answers that mention only one of the points above.

Results for this item not published.

SOURCES: Gonzales et al. 2004; OECD 2003b; and http://nces.ed.gov/surveys/pisa/Items.asp?SectionID=2&CatID=4.



Garden bed design	Using this design, can the garden bed be made with 32 meters of timber?
Design A	Yes / No
Design B	Yes / No
Design C	Yes / No
Design D	Yes / No

Table 1-6
Average science performance of 4th graders, 8th graders, and 15-year-olds for all participating OECD and/or G-8 countries, relative to U.S. average: 2003

	TIMSS		PISA
Country	4th grade	8th grade	15-year-olds
Australia	▼	•	▲
Austria	na	na	•
Belgium	▼	▼	▲
Canada	na	na	▲
Czech Republic	na	na	▲
Denmark	na	na	▼
England[a]	▲	na	na
Finland	na	na	▲
France	na	na	▲
Germany	na	na	▲
Greece	na	na	▼
Hungary	•	▲	▲
Iceland	na	na	•
Italy	▼	▼	•
Japan	▲	▲	▲
Luxembourg	na	na	▼
Mexico	na	na	▼
Netherlands	▼	•	▲
New Zealand	▼	•	▲
Norway	▼	▼	•
Poland	na	na	•
Portugal	na	na	▼
Russian Federation	•	▼	•
Scotland[a]	▼	▼	na
Slovak Republic	na	▼	•
South Korea	na	▲	▲
Spain	na	na	•
Sweden	na	•	▲
Switzerland	na	na	▲
Turkey	na	na	▼

▲ = score is higher than U.S. score; • = score is equivalent to U.S. score; ▼ = score is lower than U.S. score; na = nonparticipation in assessment

OCED = Organisation for Economic Co-operation and Development; PISA = Programme for International Student Assessment; TIMSS = Trends in International Mathematics and Science Survey

[a]Participated separately in TIMSS 2003 at both grade levels but jointly as United Kingdom (including Northern Ireland) in PISA 2003. However, England did not meet response rate standards for grade 8 in TIMSS 2003 or for United Kingdom in PISA 2003.

SOURCES: Data from OECD, PISA 2003; and International Association for the Evaluation of Educational Achievement, TIMSS 2003. See appendix tables 1-11, 1-12, and 1-14.

Science and Engineering Indicators 2006

TIMSS international averages, which were based on scores from both developed and developing countries (Gonzales et al. 2004) (appendix tables 1-11 and 1-12). Compared with the participating G-8 countries, the average score of U.S. students was higher than that of students in Italy in both grades 4 and 8 (table 1-6). In addition, U.S. eighth graders had higher average scores than their counterparts in Russia. However, Japan outperformed the United States at both grade levels and England outperformed the United States at grade 4.

Mirroring results for mathematics, average science scores of fourth graders did not change from 1995 to 2003, but science performance among eighth graders improved over this period (data not shown, see Gonzales et al. 2004). The relative ranking of U.S. students in science fell slightly between 1995 and 2003 for grade 4 but rose slightly for grade 8.[22]

PISA 2003 Assessments of Mathematics and Science Literacy of 15-Year-Olds

Although TIMSS measures how well students have mastered the mathematical and scientific content presented in school, PISA assesses students' literacy in these subjects (Lemke et al. 2004). PISA uses the term *literacy* to denote the program's goal of assessing how well students can apply their knowledge and skills to problems they might encounter, particularly in situations outside of a classroom.

In 2003, U.S. 15-year-olds performed below the OECD average in both mathematics and science literacy (appendix tables 1-13 and 1-14).[23] Among OECD nations, U.S. students were near the bottom in mathematics literacy, outperformed by students in Canada, France, Germany, the Netherlands, South Korea, Japan, and 14 other countries (table 1-5; appendix table 1-13). The United States was at rough parity with Hungary, Poland, and Spain, and scored higher than Greece, Italy, Mexico, Portugal, and Turkey. In science, average literacy scores were higher in 15 other OECD countries compared with the United States and lower in 6 (table 1-6; appendix table 1-14).

U.S. students' average science literacy scores did not change from 2000, the first year PISA was administered, to 2003 (data not shown, see Lemke et al. 2004). However, several other OECD countries registered improvements in science, and as a result, the relative position of the United States compared with the OECD average declined.[24] In 2000, the average score of U.S. 15-year-olds' science literacy did not differ from OECD averages, but in 2003, it was lower. U.S. performance in mathematics did not change from 2000 to 2003, and in both years, the U.S. average fell below the OECD average.[25]

Student Coursetaking in Mathematics and Science

Responding to calls for higher educational standards in the 1980s, many states began to increase the number of courses required for high school graduation, particularly in the core academic subjects of mathematics, science, English, and social studies, as well as in foreign language. These policies reflect widespread concern that too few U.S. students were adequately preparing for college study or self-supporting employment and that the nation's global competitive edge was threatened (National Commission on Excellence in Education 1983). Many high school graduates were also thought to lack the numeracy and literacy skills needed to make informed decisions in their adult roles as parents, citizens, and consumers (Barth 2003).

Policies requiring students to spend more time in academic courses are largely intended to push more students to complete advanced courses, which can substantially boost achievement (Adelman 1999; Campbell, Hombo, and

Mazzeo 2000; Meyer 1998; Schmidt et al. 2001). Since 1987, many states have increased the number of years that students must study mathematics and science to graduate from high school (table 1-7). In 1987, most states required 2 or fewer years of high school mathematics and science, whereas in 2002, 29 states required 3 or more years of mathematics and 23 states required 3 or more years of science. The remaining states either required fewer than 3 years or allowed school districts to set these policies. In states with requirements, school districts may also require students to take additional courses as well as to complete specific courses.

Curriculum reform efforts in the past 15–20 years have gone beyond time-based course requirements to setting standards for the skills and content that students need to learn. Organizations such as the National Council of Teachers of Mathematics, the American Association for the Advancement of Science, and the National Research Council began to develop content standards in the 1980s and 1990s. State education agencies have used these standards to develop their own standards and curriculum guides, and in some cases model lesson plans specific to subject and grade level. Along with aligned instructional, teacher training materials and assessments to test students' mastery of course material, curriculum standards are primary building blocks for accountability-based reform. Efforts to set curriculum standards have sought to make clear what students need to learn (and thus to make course content more consistent) and to raise the bar so that all high school graduates meet standards comparable to those in other industrialized nations (Achieve, Inc. 2004; Carnoy, Elmore, and Siskin 2003).

Standards documents vary greatly in their specificity and clarity as well as their level of rigor (Achieve, Inc. 2002; Cross et al. 2004). In addition, alignment between content standards and tests used for accountability is lacking in many states (AFT 2001; Barton 2004; Crossetet al. 2004). In academic year 2004, 49 states and the District of Columbia had content standards for mathematics and science, as well as for English/language arts and social studies (Editorial Projects in Education 2005, p. 86). Many states continue to revise their standards, curriculum frameworks, and instructional materials as they gain information about their classroom use. By 2004, 31 states had set a regular timeline for reviewing and modifying their standards.

Despite these initiatives, most states do not specify the courses students must complete in all academic subjects to graduate. In mathematics, for example, 22 states do not require specific courses, and only 3 states require algebra I, geometry, and algebra II,[26] which some standards advocates consider less than the minimum needed to prepare adequately for college (Achieve, Inc. 2004). Furthermore, for most students, a significant gap currently separates high school graduation requirements from the skill levels that students need to succeed in college and to prepare for jobs that can support a family (Achieve, Inc. 2004; American Diploma Project 2004; Barth 2003).

Even some students who meet college admission requirements (which are often higher than those for high school graduation) must take remedial courses before they can earn college credits (remedial coursetaking is discussed in the "Transition to Higher Education" section). To better prepare students for postsecondary study, educators are striving to increase the rigor of high school courses and encouraging more high school students to take higher-level courses. For some students, a higher level of rigor means taking college preparatory, honors, or other advanced courses, whereas others earn college credits during high school through AP or dual-enrollment courses.

This section examines the degree to which high schools offered advanced mathematics and science courses, and the proportions of graduates who completed such courses, including trends and differences by student characteristics.[27] The section concludes with a look at recent growth in the AP program of courses and exams.

Table 1-7
States requiring less than 3, 3, or 4 years of mathematics and science study for high school graduation: 1987 and 2002

Subject requirement (years)	1987	2002
Mathematics		
<3	29	16
3	9	25
4	0	4
Science		
<3	41	21
3	4	20
4	1	3

NOTE: States not included had no statewide requirement for subject and allowed districts or schools to set their own.

SOURCE: A. Potts, R.K. Blank, and A. Williams, *Key State Education Policies on PK–12 Education: 2002,* Council of Chief State School Officers (2002).

Science and Engineering Indicators 2006

Advanced Coursetaking in High School

Trends in Course Offerings

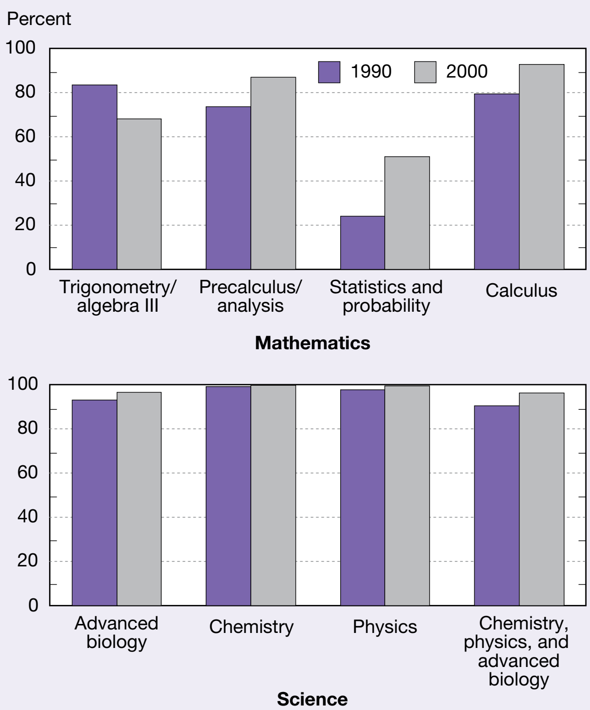
Curriculum and the degree of course difficulty influence both the content students learn and their level of skill development (Barth 2003; Cogan, Schmidt, and Wiley 2001). Not only has rigorous high school study been identified as the best predictor of making progress in college (Horn and Kojaku 2001) and completing a bachelor's degree, advanced mathematics study may be particularly useful in preparing students for college (Adelman 1999). Adelman found, for example, that although college degree completion rates differ substantially by racial/ethnic group, the gaps narrow considerably for college entrants who have completed advanced high school courses and are therefore well prepared.

In this section, students are described as having access to courses if the school from which they graduated offers the courses, but in practice, students usually have access only to those courses for which they can demonstrate preparation. Decisionmaking about which students may enroll in specific courses, particularly in mathematics, differs across schools, but in many high schools guidance counselors play a gatekeeping role and are influenced to varying extents by students, their parents, and teachers. By the time students reach high school, some courses are already closed to them, or are at least difficult to reach, because of earlier decisions and students' previous performance in courses and on tests. Sorting of students into curricular groups, or tracks, that differ in speed and depth of curriculum coverage is often done by teachers and counselors in consultation with parents starting as early as elementary school grades; these decisions and their repercussions are often difficult to change after the middle grades.

Students' access to advanced mathematics courses at their high school—specifically, to precalculus, statistics, and calculus—has increased since 1990 (figure 1-9; appendix table 1-15) (see sidebar "Advanced Mathematics and Science Courses"). The percentage of students attending high schools that provided a statistics/probability course has more than doubled, from 24% in 1990 to 51% in 2000. On the other hand, fewer 2000 graduates attended schools offering trigonometry or algebra III courses than graduates of a decade earlier. This decrease does not necessarily mean that fewer schools taught these topics; some schools may have reconfigured courses so that rather than providing a full semester of trigonometry, they may include that material in a precalculus or other course. Overall in 2000, 93% of graduates attended schools offering at least one calculus course and 87% were offered a precalculus or analysis course.[28]

Science course offerings showed little or no trend changes over the decade, largely because the availability of these courses was already widespread. The percentage of students who were offered advanced biology courses fluctuated between 93% and 96% over the decade, and nearly all students had access to chemistry and physics courses in every year examined. Schools have increased their offerings of AP or International Baccalaureate (IB) courses in calculus, biology, chemistry, and physics since 1998, when NAEP began coding these courses separately from other advanced courses. Almost all 2000 graduates attended schools offering courses in chemistry, physics, and advanced biology; AP and IB courses were less common but still widely available. The percentage of graduates with access to AP/IB classes was 67% for biology, 57% for chemistry, and 47% for physics. About 10% of students could take a relatively new offering, AP/IB environmental science (appendix table 1-16).

Figure 1-9
High school graduates who attended schools offering advanced mathematics and science courses: 1990 and 2000



SOURCE: U.S. Department of Education, National Center for Education Statistics. National Assessment of Educational Progress, 1990 and 2000 High School Transcript Studies. See appendix tables 1-15 and 1-16.

Science and Engineering Indicators 2006

Advanced Mathematics and Science Courses

Advanced courses as discussed in this section (and related data shown in figures and appendix tables 1-15 through 1-18) are courses that not all students complete. In other words, these courses, as a rule, are not 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" and "any calculus."

The "any advanced biology" category stands in contrast; it includes second- and third-year biology courses and those designated honors, accelerated, or Advanced Placement (AP)/International Baccalaureate (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. In addition, AP/IB courses are all advanced and designed 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 thus isolates the subset of courses that meet either of these programs' guidelines.

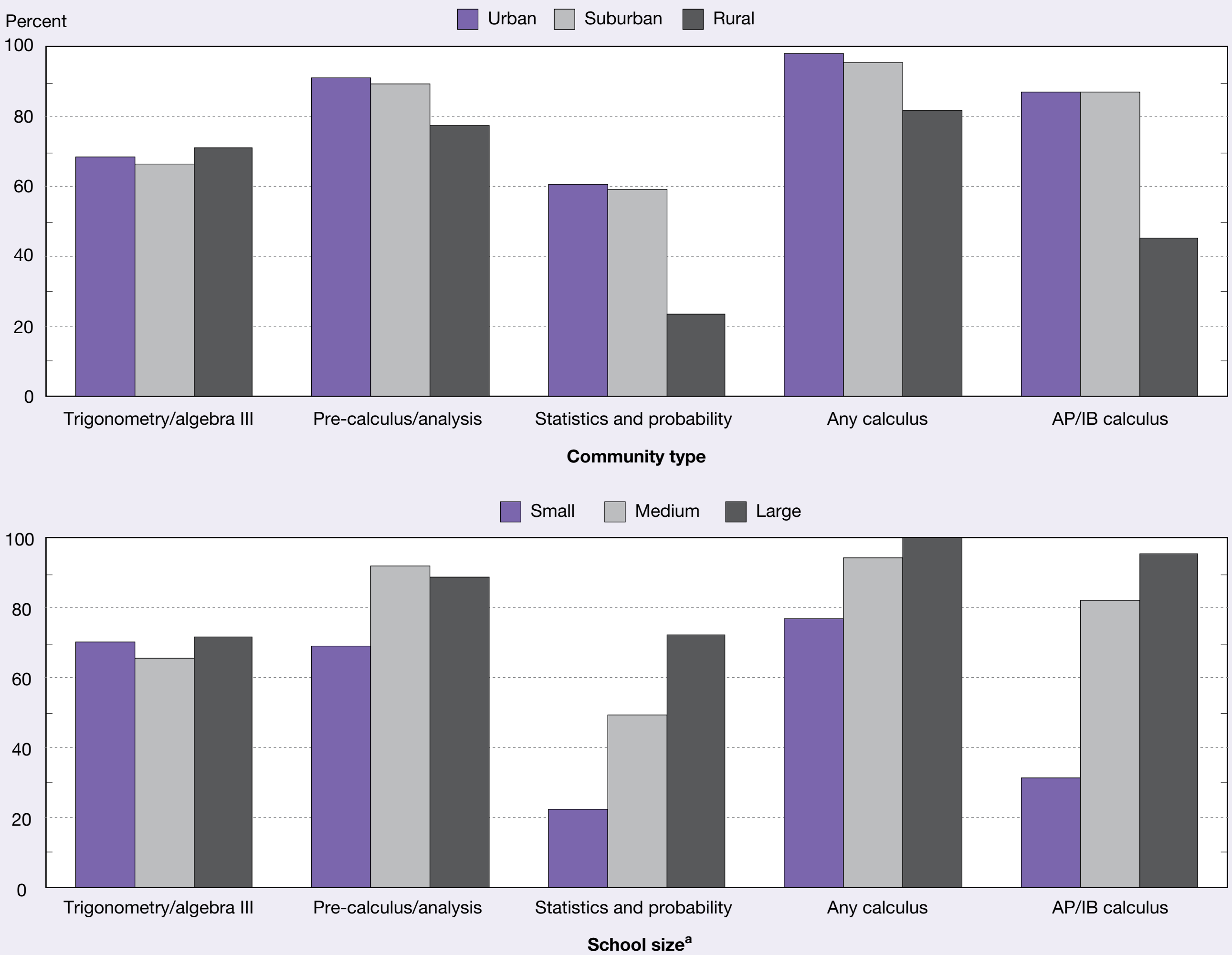
Access to Courses by School and Student Characteristics

Access to some mathematics classes differed by community type and school size. Students graduating in 2000 from urban or suburban schools, which tend to be relatively large, generally were more likely to have access to statistics/probability and calculus courses than those attending rural schools (figure 1-10). Urban and suburban schools were more than twice as likely as rural schools to offer statistics courses. Likewise, students attending small schools had less access to these mathematics courses than those attending medium or large schools, except for trigonometry and algebra III classes. Although most rural students were offered some kind of calculus (82%), an AP/IB course in calculus was far less common (45%).

No overall pattern of differential access to mathematics courses occurred by race/ethnicity (appendix table 1-15). White students, however, were less likely than their Asian/Pacific Islander counterparts to have a statistics or AP/IB calculus course offered by their school. In addition, 47% of Hispanic students had access to a statistics course in high school, compared with 68% of their Asian/Pacific Islander peers.

Chemistry, physics, and advanced biology courses were offered nearly universally by high schools; student access to these did not differ by community type (figure 1-11). However, for AP/IB courses in those three sciences, rural students were

Figure 1-10
High school graduates who attended schools offering advanced mathematics courses, by community type and school size: 2000



AP = Advanced Placement; IB = International Baccalaureate

[a]Small = <600 students, medium = 600–1,800 students, and large = >1,800 students.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2000 High School Transcript Study. See appendix table 1-15.

Science and Engineering Indicators 2006

at a disadvantage (appendix table 1-16). For chemistry and physics, rural students were less than half as likely as those in other types of communities to have access to AP/IB courses. Small schools exhibited the same patterns for AP/IB biology, chemistry, and physics, and medium-sized schools were less likely than large schools to offer these courses. White students were less likely than Asian/Pacific Islander students to attend schools that offered AP/IB chemistry or physics.

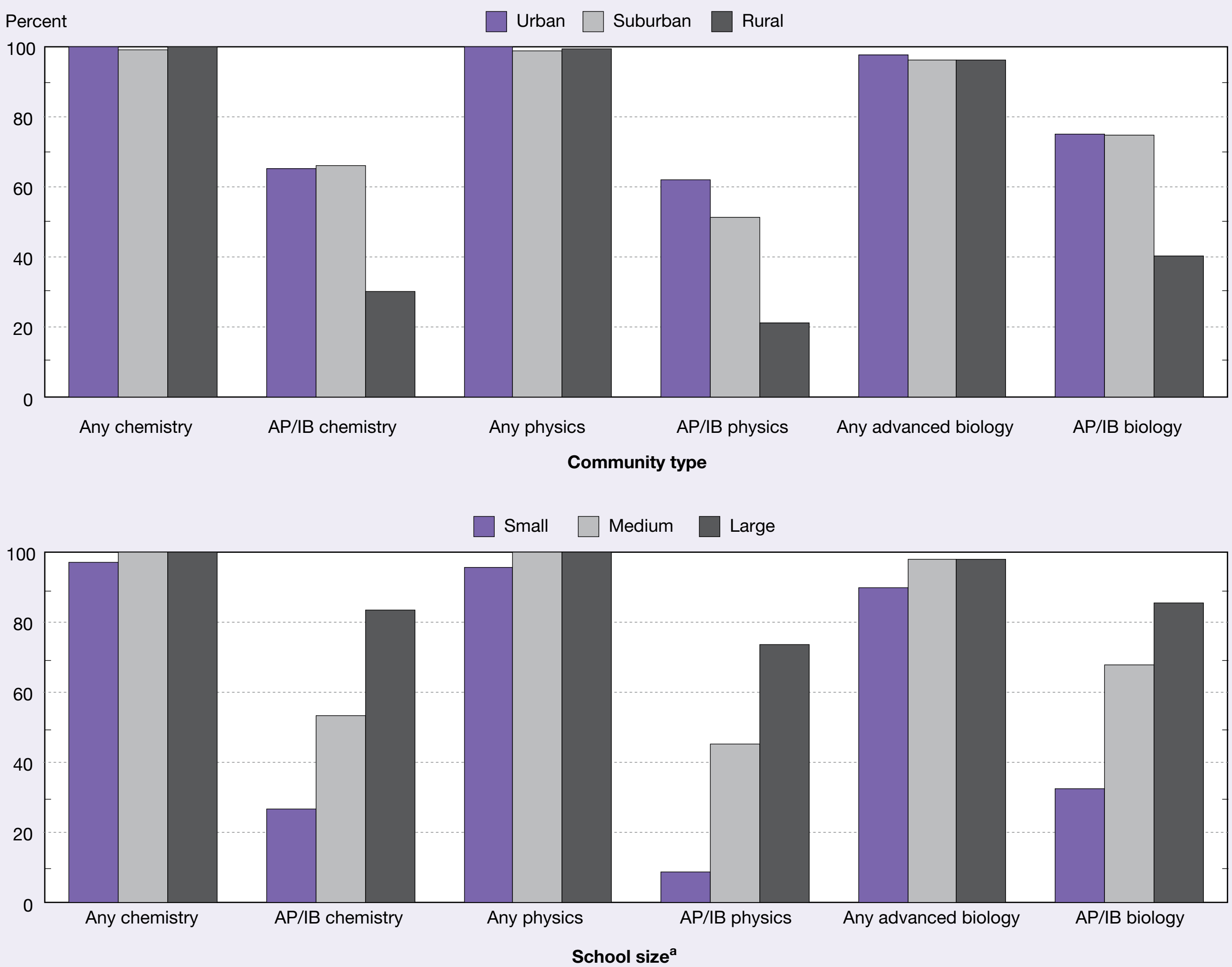
Courses Completed by High School Graduates

Trends in Coursetaking

High school students increased their course loads during the 1990s, both overall and in core academic courses (Perkins et al. 2004). In both mathematics and science, the highest level of coursework completed tended to correlate with students' NAEP scores in the respective subjects, which is consistent with earlier research demonstrating that most students gain proficiency by completing more high-level courses (Madigan 1997; Meyer 1998).

NAEP transcript data indicate increasing course completion in many advanced mathematics and science subjects during the 1990s[29] (figure 1-12). For example, students exhibited steady growth over the decade in studying precalculus, statistics or probability, and calculus (appendix table 1-17). In addition, 2000 graduates were more likely than graduates in 1998 to take an AP/IB calculus course. However, participation in trigonometry or algebra III showed no notable change. Despite gains during the 1990s, the proportions of students taking these mathematics courses remained relatively modest: thirteen percent of the 2000 graduates earned credits for

Figure 1-11
High school graduates who attended schools offering advanced science courses, by community type and school size: 2000



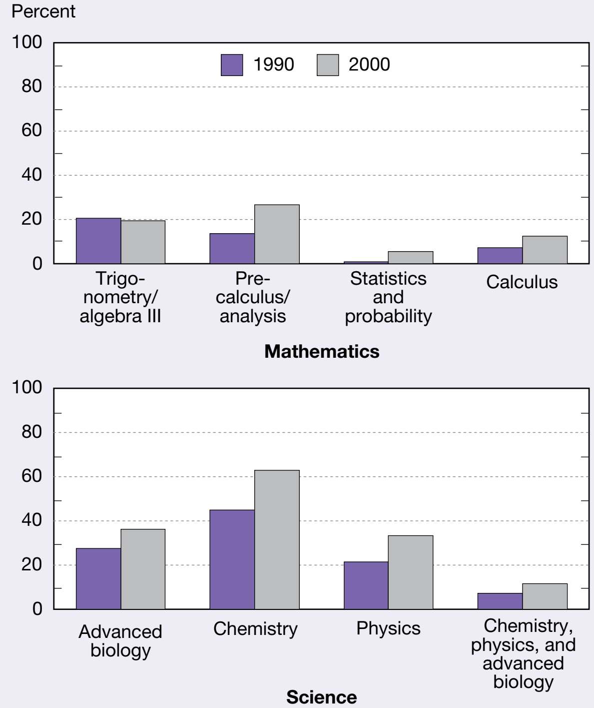
AP = Advanced Placement; IB = International Baccalaureate

[a]Small = <600 students, medium = 600–1,800 students, and large = >1,800 students.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2000 High School Transcript Study. See appendix table 1-16.

Science and Engineering Indicators 2006

Figure 1-12
High school graduates who completed advanced mathematics and science courses: 1990 and 2000



SOURCES: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 1990 and 2000 High School Transcript Studies. See appendix tables 1-17 and 1-18.

Science and Engineering Indicators 2006

calculus, 20% for trigonometry and algebra III, 27% for precalculus, and 6% for statistics and probability.

In science, the proportions of graduates completing chemistry and physics courses increased over the decade, from 45% to 63% for chemistry and from 21% to 33% for physics (figure 1-12). Study in advanced biology increased over part of the decade, then leveled off (appendix table 1-18). For the small proportion of students completing at least one course in each of three science subjects (chemistry, physics, and advanced biology), the trend climbed through 1998 to 12% and then leveled off. Few students took AP/IB courses in any of the three science subjects in either 1998 or 2000; there is insufficient evidence to conclude that their completion rates are increasing.

Coursetaking Differences by Student Characteristics

Students with different characteristics completed courses in advanced mathematics at different rates, reflecting in part their access to such courses.[30] For example, students who graduated from rural schools in 2000 were significantly less likely than others to have studied precalculus, statistics, any calculus, or AP/IB calculus. About 18% of rural graduates studied precalculus, compared with 29%–30% of urban and suburban graduates (appendix table 1-17). Similarly, students from small schools were about half as likely as those from medium or large schools to complete an AP/IB calculus course. Students at schools with very low poverty rates (those where 5% or less of students were eligible for the free or reduced-price lunch program) were generally more likely to complete courses in precalculus, calculus, and AP/IB calculus than students at other schools (figure 1-13). In part these differences are related to differing access; for example, very low school poverty rates were associated with a higher likelihood that students were offered AP/IB biology and chemistry courses.

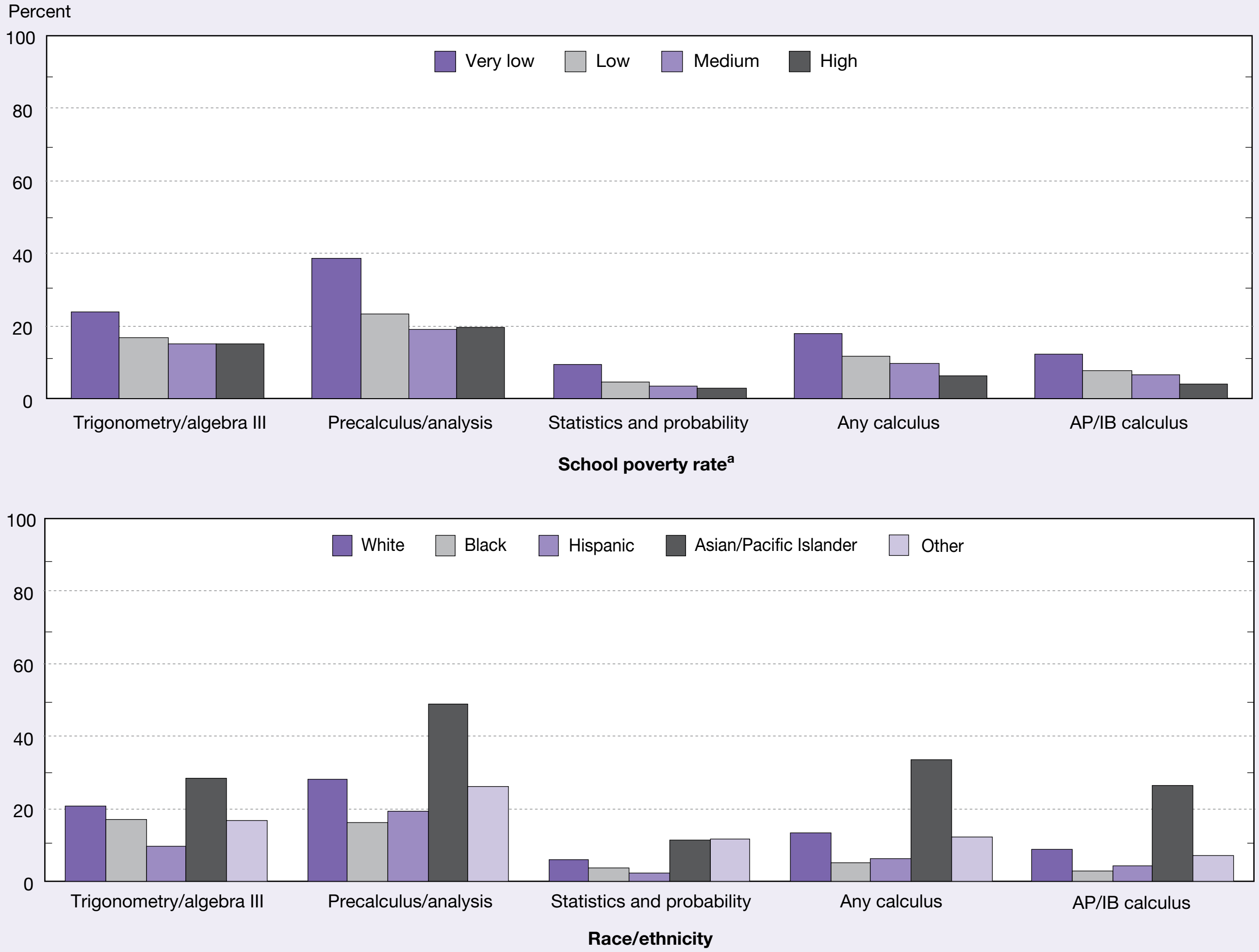
Generally, although black and Hispanic students were at least as likely as students from other groups to have advanced mathematics study offered at their school, they were less likely than others to complete these courses. Hispanic graduates were less likely than white or Asian/Pacific Islander graduates to complete any of the mathematics courses shown in figure 1-13, and Asian/Pacific Islander graduates were the most likely to complete each of these mathematics courses, except possibly for statistics and probability.[31] Black graduates were also less likely than their white or Asian/Pacific Islander peers to complete courses in precalculus and analysis, calculus, or AP/IB calculus, and less likely than Asian/Pacific Islanders to study statistics and probability. Except for trigonometry and algebra III, which black students studied at higher rates, black and Hispanic graduates did not differ from each other in their likelihood of taking these mathematics courses.

Males and females graduating in 2000 did not differ significantly in the percentage completing advanced mathematics courses (appendix table 1-17) but did differ in science coursetaking (see sidebar "Mathematics and Science Coursetaking: How Do the Sexes Differ?").

Coursetaking in science also differed by some school and student characteristics. Graduates who studied chemistry, physics, or all three science subjects (chemistry, physics, and advanced biology) were less common in rural than in urban high schools. About 52% of students at rural schools completed a chemistry course, compared with 68% at urban schools, for example. Students at schools with very low poverty rates were in general the most likely to complete courses in chemistry, physics, AP/IB chemistry, AP/IB physics, or the combination of all three science subjects; appendix table 1-18). However, advanced biology does not fit this pattern; 44% of students at schools with an intermediate poverty rate studied this subject, more than the 31−33% at schools with low or high poverty rates.

Except for advanced biology, chemistry, and AP/IB environmental science, Asian/Pacific Islander students were consistently more likely than their peers in each other group to complete science courses included in appendix table 1-18. Hispanic students were less likely than white students to study advanced biology, physics, AP/IB physics, or the array of three subjects. In none of these science categories did Hispanic and black students differ significantly in course completion rates.

Figure 1-13
High school graduates who completed advanced mathematics courses, by school poverty rate and race/ethnicity: 2000



AP = Advanced Placement; IB = International Baccalaureate

[a]Students eligible for national free/reduced-priced lunch program: very low = ≤5%, low = 6–25%, medium = 26–50%, and high = 51–100%.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 2000 High School Transcript Study. See appendix table 1-17.

Science and Engineering Indicators 2006

Participation in AP Testing

The AP program provides students with an opportunity to demonstrate a high level of proficiency in a subject by passing a rigorous AP Exam. About two-thirds of public high schools offer one or more AP courses, reflecting steady growth over the years. The number of students taking AP tests also has grown rapidly, both overall and in mathematics and science subjects. (The AP test-taking data discussed in this section are actual counts collected by the College Board; they should not be confused with AP/IB course data discussed in the previous section. The latter are data estimated in the NAEP study of high school students' transcripts.) Between 1990 and 2004, for example, the number of students taking the Calculus AB exam (see sidebar "Multiple AP Courses/Tests in One Subject") nearly tripled, and the number taking Calculus BC increased almost fourfold (table 1-9). The number of students taking AP science exams increased sharply as well, more than tripling for Physics C and Biology and increasing nearly fivefold for Physics B. To put this growth in perspective, the high school student population increased from 1990 to 2004 by about 24% (NCES 2004b).

Students earning a passing score on an AP Exam generally receive college credit for an introductory course in that subject, allowing them to begin at a higher level of college study, and in some cases, reducing the time needed to earn a bachelor's degree. Overall, a majority of students who take AP Exams receive a passing score, but passing rates vary by subject. The 2004 passing rates for AP mathematics and science tests ranged from 56% for chemistry to 80% for Calculus BC (table 1-9). Nationally, about 13% of students

Mathematics and Science Coursetaking: How Do the Sexes Differ?

Over the past three decades, females have made significant progress in many aspects of education (Freeman 2004). Large gaps favoring males that existed in the past have significantly decreased, disappeared, or even been reversed. For example, female students now have higher educational aspirations and earn more than half of bachelor's degrees (Peter and Horn 2005; NCES 2004a).

High school coursetaking trends in mathematics and science further illustrate recent educational advances by girls and women. Females have reached parity with males in advanced mathematics course completion and have surpassed males in some science subjects. Among 1990 high school graduates, males were more likely than females to take calculus in high school, but this gap had disappeared by 1994, and in subsequent years through 2000 the sexes completed calculus courses at about the same rates (table 1-8). The absence of a sex difference for other advanced mathematics coursetaking was consistent from 1990 through 2000.

In science, male and female graduates were about equally likely to take chemistry or advanced biology in 1990, but by 1994, females had surpassed males in these two subjects. Physics is the only advanced science subject in which males completed courses at consistently higher rates than females during the decade.* (Other advances by women in mathematics and science education are discussed in Chapter 2, Higher Education in Science and Engineering.)

* In 1994, the apparent sex difference in physics study favoring males was not statistically significant, but it was in each of the other years shown.

Table 1-8
High school graduates who completed advanced mathematics and science courses in high school, by sex and year of graduation: Selected years, 1990–2000
(Percent)

	1990		1994		1998		2000	
Subject	Male	Female	Male	Female	Male	Female	Male	Female
Mathematics								
Trigonometry/algebra III	20.6	20.9	23.0	24.9	19.4	22.5	17.9	21.1
Precalculus/analysis	14.4	13.0	16.3	18.4	23.1	22.9	25.4	27.9
Statistics and probability	1.2	0.8	2.0	2.1	3.4	4.0	5.8	5.6
Calculus	8.3	6.2	10.3	10.1	12.0	11.6	13.3	12.0
Science								
Advanced biology	25.7	29.2	31.5	37.8	33.8	40.8	31.5	40.5
Chemistry	43.8	46.1	47.5	53.3	53.3	59.2	58.1	66.8
Physics	24.9	18.3	26.7	22.5	31.0	26.6	35.6	31.5

SOURCES: U.S. Department of Education, National Center for Education Statistics, National Assessment of Educational Progress, 1990, 1994, 1998, and 2000 High School Transcript Studies.

Science and Engineering Indicators 2006

graduating from high school in 2004 had passed one or more AP tests, up from 10% in 2000 (The College Board 2005). Passing rates for 2004 increased for every state and the District of Columbia over 2003.

Although the number of students taking these AP tests has increased greatly since 1990, the percentages earning passing scores have declined slightly (table 1-9). For most subjects, the drop in the overall passing rate was relatively small, with the exceptions of Calculus AB and Chemistry.

Increases in the numbers of students taking AP tests from 1997 to 2004 occurred for both males and females and for all racial/ethnic groups. Gaps in the percentage of those passing the tests by sex and race/ethnicity were consistent across mathematics and sciences in 1997 and 2004: male test takers were more likely than females to pass the tests (with the single exception of Computer Science AB in 1997), as were whites and Asians/Pacific Islanders compared with blacks and Hispanics (appendix table 1-19). Although passing rates of white and Asian/Pacific Islander students were mostly far above 50%, those for blacks and Hispanics generally ranged from 23% to 48% in 2004. The single exception was Calculus BC; 58% of blacks and 62% of Hispanics passed in 2004.

Summary

The preceding discussion shows that high schools have increased their offerings of advanced mathematics and science courses since 1990. Students in smaller and rural schools were less likely than others to have certain courses taught at their school. High school students have responded to tighter high school graduation requirements by taking more academic courses overall; more students also completed courses in advanced mathematics and science subjects as the 1990s progressed. Nevertheless, relatively modest proportions complete any of these courses except for chemistry.

Table 1-9
Students who took mathematics and science Advanced Placement tests, and percent who had passing scores, by subject: 1990, 1997, and 2004

Subject	Students taking test (number) 1990	1997	2004	Students who passed (%) 1990	1997	2004
Mathematics						
Calculus AB	62,676	108,437	170,330	71.7	59.3	59.0
Calculus BC	13,096	22,349	49,332	81.9	78.9	79.5
Statistics	NA	7,551	65,063	NA	62.1	59.8
Science						
Biology	32,643	69,468	108,888	61.5	67.3	60.8
Chemistry	19,289	40,803	69,032	64.1	58.1	56.4
Computer science A	NA	6,992	13,872	NA	47.0	57.2
Computer science AB	NA	4,367	5,919	NA	71.7	63.3
Physics B	8,826	20,610	41,844	60.9	59.8	57.0
Physics C: electricity and magnetism	3,351	5,717	10,503	67.6	65.9	64.9
Physics C: mechanics	5,499	11,740	21,541	74.3	70.8	69.6

NA = not available

NOTE: Most U.S. colleges and universities grant college credit or advanced placement for scores of 3, 4, or 5 on Advanced Placement tests (on a scale of 1–5).

SOURCES: *Advanced Placement Program National Summary Reports, 1997 and 2004*. www.collegeboard.com.

Science and Engineering Indicators 2006

Multiple AP Courses/ Tests in One Subject

For some academic subjects, more than one Advanced Placement (AP) course and test are offered; they differ in the following ways.

Calculus AB and Calculus BC are both year-long courses and cover some of the same material in similar depth. However, Calculus BC extends to additional topics and aims to substitute for an additional college course beyond the course(s) Calculus AB replaces.

Computer Science A includes a subset of the topics addressed in Computer Science AB and covers some in less depth (for example, algorithms, data structures, design, and abstraction).

The two AP physics courses, Physics B and Physics C, differ primarily in depth and level of mathematics they require. Physics B rarely uses calculus but requires knowledge of algebra and trigonometry. It is equivalent to a 1-year terminal college course often taken by students majoring in fields such as life sciences, certain applied sciences, or premedicine. Physics C requires extensive use of calculus methods and is equivalent to college courses of up to 2 years' duration that are designed for students majoring in the physical sciences or engineering. Students take one Physics C exam, but components are scored separately for electricity and magnetism and for mechanics. For more detailed information, see http://www.apcentral.collegeboard.com/colleges/research/0,3060,154-181-0-2014,00.html.

Very small proportions of students complete advanced mathematics or science courses that provide college credit (such as AP/IB courses). The most popular category among these is AP/IB calculus; even there, only 8% of 2000 graduates completed such a course. More females than males completed courses in advanced biology, AP/IB biology, and any chemistry, although males had the edge in AP/IB physics. Participation in AP test taking has grown rapidly since 1990 in all mathematics and science subjects, whereas the percentage of test takers who earn passing scores has dropped slightly in most subjects. Males were more likely than females to earn passing scores, as were Asians/Pacific Islanders and whites compared with their black and Hispanic peers.

Mathematics and Science Teachers

Strengthening the quality of teachers and teaching has been central to efforts to improve American education in recent decades (NCTAF 1996 and 1997). Research findings consistently point to the critical role of teachers in helping students to learn and achieve (Darling-Hammond 2000; Goldhaber 2002; Wright, Horn, and Sanders 1997). Today's teachers are being called on to provide the nation's children with a high-quality education and to teach in new ways (Little 1993). Many believe that professional development is essential to improving teacher quality and that changes in teaching practices will occur if teachers have consistent and high-quality professional training (Desimone et al. 2002). Although professional development can help improve the quality of teachers and instruction, its effectiveness is diminished if schools cannot keep the most successful teachers in the profession. The issues of teacher salaries and working conditions have come under increasing scrutiny in recent years because cumulative evidence suggests that these are two key influences on teachers' persistence in the profession and professional satisfaction (Hanushek, Kain, and Rivkin 2004; NCTAF 2003; Odden and Kelley 2002). This section uses data from various sources to examine important issues related to teaching in mathematics and science, including teacher quality, participation in professional development, pay, and working conditions. Indicators in this section traditionally have relied heavily on the Schools and Staffing Survey (SASS) of the U.S. Department of Education. The SASS: 2003–04 data collections have been completed, but these new data were not available when this chapter was prepared.

Teacher Quality

The NCLB emphasizes the importance of teacher quality and requires all public school teachers of core academic subjects to meet specific criteria in preparation for teaching by academic year 2006.[32] In recent years, many states have developed new standards for teaching and implemented policies to improve the quality of teaching (Hirsch, Koppich, and Knapp 2001; Potts, Blank, and Williams 2002) (see sidebar "State Education Policies Related to Teachers and Teaching"). Although there is substantial agreement that teacher quality is one of the most important influences on student learning, disagreement remains about what specific knowledge and skills constitute "quality" (Goldhaber and Anthony 2004; Greenberg et al. 2004; McCaffrey et al. 2003; Wilson, Floden, and Ferrini-Mundy 2001). The following indicators of teacher quality focus on traditional measures identified in the literature on teaching effectiveness (Darling-Hammond 2000; Hanushek 1996): the academic background of college graduates entering the teaching force and congruence between teacher preparation and their assigned teaching fields.[33]

State Education Policies Related to Teachers and Teaching

Prompted by the publication of *A Nation At Risk* in the 1980s, many states have initiated a broad set of education policy reforms, including increased course credit requirements for graduation, higher standards for teacher preparation, teacher tests for certification, state curriculum guidelines and frameworks, and new statewide student assessments (CCSSO 2003). The No Child Left Behind Act of 2001 (NCLB) reaffirmed the key role of states by requiring all states to report on school and district performance using state assessments aligned to state standards in mathematics, science, and language arts. NCLB also requires states to ensure that all classrooms have highly qualified teachers in core academic subjects. Table 1-10 lists policies that states have developed and implemented to improve the quality of K–12 teachers and teaching. The trend data indicate increasing numbers of states involved in each activity.

Table 1-10
States with policies to improve teaching quality: Selected years, 1995–2002
(Count)

State policy	1995	1998	2000	2002
State content standards specifying goals for student learning				
Four core academic subjects (English/language arts, mathematics, science, social studies/history)	18	NA	NA	47
Mathematics	25	42	49	49
Science	23	41	46	47
State standards for teacher licensure	NA	34	42	47
State-mandated teacher assessments for new licensure, total	NA	37	NA	47
Assessment of basic skills	NA	NA	38	41
Assessment in field of teaching license	NA	NA	30	30
Assessment of professional knowledge of teaching	NA	NA	28	35
Performance assessment	NA	NA	23	22
Subject area preparation required for teacher license				
Major in content field	19	21	19	22
Major/minor in content field	9	10	13	12
Induction programs for new teachers	NA	NA	NA	23
Professional development requirements for teacher license renewal	42	44	47	48
State assessments of teacher education programs	NA	NA	NA	39
Policy linking professional development with content standards for student learning	NA	NA	NA	24

NA = not available

SOURCE: Council of Chief State School Officers, *Key State Education Policies on PK–12 Education: 2002* (2002).

Science and Engineering Indicators 2006

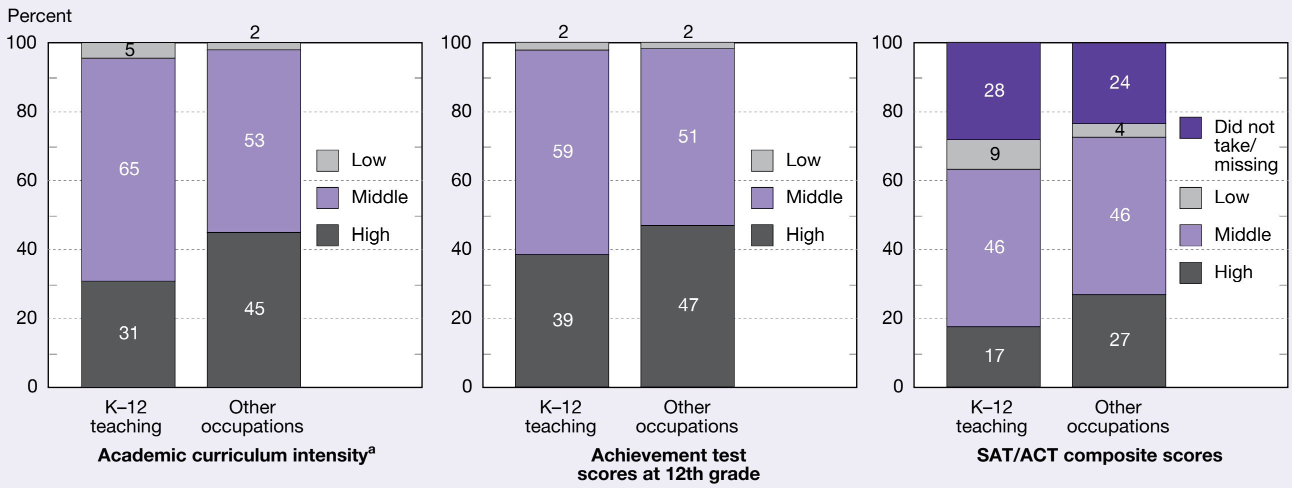
Academic Background of Entering Teachers

Early research on the sources of teacher effectiveness often examined their academic background and skills because these attributes predict teacher subject mastery and verbal ability, two elements believed to be critical to effective teaching (Darling-Hammond 2000; Vance and Schlechty 1982; Weaver 1983). Measures of academic competence commonly used over the past two decades are standardized test scores (Henke et al. 1996; Murnane et al. 1991; Vance and Schlechty 1982; Weaver 1983). Based on test scores, research shows that college graduates who became teachers had less rigorous academic preparation than those who did not go into teaching (Murnane et al. 1991; Vance and Schlechty 1982; Weaver 1983). These findings are further supported by transcript data from the National Education Longitudinal Study of 1988 (NELS:88), which tracks student progress from middle school through postsecondary education. Among 12th graders in the high school class of 1992 who had earned bachelor's degrees by 2000, those who entered K–12 teaching trailed graduates in nonteaching occupations on a number of academic measures in high school and college: they took fewer rigorous academic courses in high school, had lower achievement test scores at the 12th grade, and scored lower on college entrance examinations (figure 1-14). The differences were particularly salient when comparing teachers with those who entered the fields of engineering or architecture; research, science, or technology; computer science; and health care (appendix table 1-20). Teachers also were more likely to attend less-selective colleges and less likely to graduate from selective institutions, particularly when compared with those entering engineering, architecture, research, science, or technical fields and those working as editors, writers, reporters, or performers (appendix table 1-20).[34]

Congruence Between Teacher Preparation and Teaching Assignments

Although almost all U.S. teachers hold at least basic qualifications (e.g., a bachelor's degree and teaching certification) (Henke et al. 1997), many are teaching subjects for which they lack adequate academic training, certification, or both (Seastrom et al. 2002). This mismatch, commonly termed *out-of-field teaching,* has been a major policy concern, and its elimination has become a target of federal and state reform initiatives (Ingersoll 2002, 2003). The discussion below focuses on two important credentials required by NCLB for a teacher to meet the law's definition of *highly qualified:* certification and a college major or minor in the subjects taught.

Figure 1-14
Selected high school academic characteristics of 1992 12th graders who earned bachelor's degree by 2000, by current or most recent occupation: 2000



SAT = Scholastic Aptitude Test; ACT = American College Test

[a]Composite index constructed based on following high school curriculum components: highest level of mathematics, total mathematics credits, total Advanced Placement courses, total English credits, total foreign language credits, total science credits, total core laboratory science credits, total social science credits, total computer science credits. See more information in C. Adelman, *Answers in the Toolbox: Academic Intensity, Attendance Patterns, and Bachelor's Degree Attainment,* PLLI 1999–8021, U.S. Department of Education, Office of Educational Research and Improvement (1999); and C. Adelman, *Principal Indicators of Student Academic Histories in Postsecondary Education,* 1972–2000, U.S. Department of Education, Institute of Education Sciences (2004).

NOTE: Low level includes bottom 20% of all students with valid data, middle level includes middle 60%, and high level includes top 20%.

SOURCE: U.S. Department of Education, National Center for Education Statistics, National Education Longitudinal Study of 1988, NELS:88/2000, fourth follow-up, Postsecondary Education Transcript Study (PETS), 2000. See appendix table 1-20.

Science and Engineering Indicators 2006

Certification in the Assigned Teaching Field. Teaching certification is generally awarded by state 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 one or more exams (Kaye 2002). A teaching certificate in their assigned teaching field provides basic but essential documentation of teachers' academic preparation and teaching skills (Goldhaber and Brewer 2000) (see sidebar "National Board-Certified Teachers").

In 2002, 80% of public high school mathematics teachers had full certification in mathematics (table 1-11); one-fifth were either not fully certified or certified in a field other than mathematics.[35] The percentage of public high school science teachers with full certification in their teaching field ranged from a high of 83% for biology teachers to a low of 72% for earth science teachers. Certification rates for public middle-grade (seventh and eighth grade) mathematics and science teachers were lower: 60% and 58%, respectively.

Certification rates of mathematics and science teachers declined from 1990 to 2002. The percentage of public high school mathematics teachers with full certification in mathematics decreased from 90% in 1990 to 80% in 2002. Declines also occurred among biology, chemistry, physics, and earth science teachers. At the middle-grade level, the picture is somewhat different. The percentage of mathematics and science teachers with full certification increased in the late 1990s but declined subsequently.[36]

Certification rates varied greatly across states, reflecting, in part, different state policies and licensing requirements. In 1999–2000, the percentage of public school teachers who taught mathematics to 7th to 12th graders and who had full certification in mathematics ranged from 100% in Rhode Island and West Virginia to 65% in Hawaii (appendix table 1-21). Likewise, certification rates for public school 7th to 12th grade science teachers ranged from 100% in Idaho, Vermont, and Wyoming to 77% in Kentucky.

College Major or Minor in the Assigned Teaching Field. A growing body of research shows that teacher subject-matter knowledge is significantly associated with student learning (Greenberg et al. 2004; Hill, Rowan, and Ball 2004; Monk and King 1994), but what counts as "useful subject-matter knowledge" for teaching remains largely unspecified. One indicator used to gauge the breadth and depth of teacher subject-matter knowledge is whether they have a college major or minor in their teaching field (Ingersoll 2003). The assumption is that teachers acquire their subject-area expertise mostly in college, so a college minor in a subject is the minimum prerequisite for teaching that subject.

In 1999–2000, 71% of public school teachers who taught mathematics to 7th to 12th graders had a college major or minor in mathematics, and 77% of public school teachers who taught science in these same grades had a college major or minor in science (appendix table 1-22). In other words, 29% and 23%, respectively, of 7th to 12th grade mathematics and science teachers in public schools had neither a major nor a minor in the subject they taught.

As with certification, the distribution of mathematics and science teachers with a college major or minor in their field was uneven across states. In 1999–2000, only in Arkansas did 90% of 7th to 12th grade mathematics teachers have a college major or minor in mathematics, and only in Minnesota and New Jersey did more than 90% of 7th to 12th grade science teachers have a college major or minor in science (appendix table 1-22). More than 30% of teachers lacked even a college minor in their assigned teaching fields in 21 states for mathematics and 10 states for science.

National Board-Certified Teachers

The National Board for Professional Teaching Standards (NBPTS) has developed a voluntary assessment and certification process to identify highly effective teachers. To receive board certification, applicants undergo a rigorous and extensive performance-based assessment that focuses on classroom practices, content and pedagogical knowledge, and community and professional involvement. Although only fully licensed and experienced teachers may apply, participation in the NBPTS program has grown rapidly: the number of board-certified teachers increased from fewer than 100 in 1995 to 40,033 in 2004 (Editorial Projects in Education 2005; Goldhaber and Anthony 2004).

Does the presence of a high-quality board-certified teacher result in improved student academic outcomes? Goldhaber and Anthony analyzed achievement data for North Carolina students in grades 3, 4, and 5 and found that students of board-certified teachers had higher achievement gains in reading and mathematics than those of non-board-certified teachers; the differences were more pronounced for younger and low-income students. Positive effects of National Board certification were also reported in other studies that examined the effects of board certification on mathematics test scores of 9th and 10th graders in Miami-Dade County, Florida (Cavalluzzo 2004) and on the Stanford achievement tests in reading, mathematics, and language arts of students in grades 3 through 6 in Arizona (Vandevoort, Amrein-Beardsley, and Berliner 2004). Conflicting results exist, however. A study conducted by Stone (2003), for example, examined board-certified teachers of third to eighth graders in Tennessee and did not find these teachers to be more effective in improving student achievement than other teachers. Given the constraints on educational resources and the cost of the NBPTS program, research and debate continue on whether the NBPTS credential is a better indicator of teacher quality than other readily available measures, such as licensure status or academic degree.

Table 1-11
Public middle and high school mathematics and science teachers with full certification in assigned teaching field: Selected years, 1990–2002
(Percent)

	High school (grades 9–12)					Middle school (grades 7 and 8)	
Year	Mathematics	Biology	Chemistry	Physics	Earth science	Mathematics	Science
1990	90	92	92	88	NA	NA	NA
1994	88	90	92	86	81	54	63
1998	88	86	89	86	68	72	73
2000	86	88	88	85	82	66	68
2002	80	83	82	75	72	60	58

NA = not available

SOURCE: Council of Chief State School Officers, *State Indicators of Science and Mathematics Education: 2003* (2003).

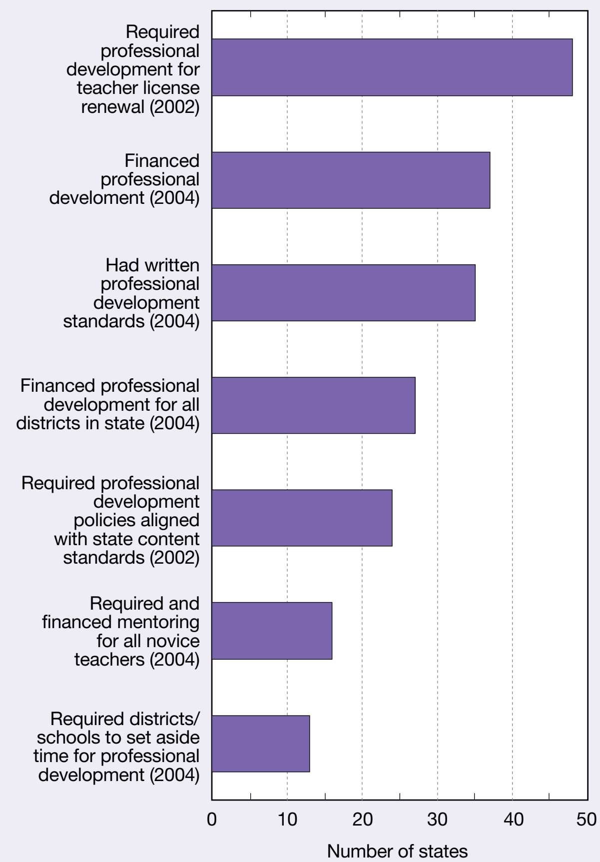
Science and Engineering Indicators 2006

Some recent studies suggest several reasons for the prevalence of out-of-field teaching. Demand for qualified teachers may exceed the supply, forcing school districts to hire less-qualified candidates to fill vacancies (Broughman and Rollefson 2000; Howard 2003). Also, schools may assign current staff members to out-of-field classes rather than expending administrator time and effort and school resources on finding and hiring new teachers in the field (Ingersoll 2003). Furthermore, the perception of precollegiate teaching as a female-dominated and easy-to-enter occupation not requiring a great deal of expertise, skill, and training may foster the belief that teaching credentials do not matter very much, thus out-of-field teaching is considered a tolerable practice (Wang et al. 2003).

Teacher Professional Development

Ongoing efforts to raise academic standards in mathematics and science require teachers to have knowledge and skills that many did not acquire during their initial preparation for teaching (NCTM 2000; NRC 1996). The changing and expanding demands of teaching jobs have prompted increased attention to the importance of professional development in providing teachers with opportunities to acquire new knowledge and keep abreast of advances in their field (Elmore 2002; Little 1993). For two decades, the U.S. government has made teacher professional development a component of its reform efforts (Porter et al. 2000). Many states also have developed and implemented policies designed to promote participation in professional development and to improve its quality (CPRE 1997; Hirsch, Koppich, and Knapp 1999, 2001). By 2002, 48 states had required professional development for teacher license renewal, and 24 had adopted professional development policies aligned with state content standards (figure 1-15). As of 2004, 37 states financed some professional development programs, 35 had standards in place for professional development, 27

Figure 1-15
States with various professional development policies for teachers: 2002 or 2004



SOURCES: Editorial Projects in Education, State of the States, *Education Week, Quality Counts 2005* 24(17):94 (2005); and A. Potts, R.K. Blank, and A. Williams, *Key State Education Policies on PK–12 Education: 2002,* Council of Chief State School Officers (2002).

Science and Engineering Indicators 2006

provided professional development funds for all districts in the state, 16 required and financed mentoring programs for all novice teachers, and 13 required districts or schools to set aside teacher time for professional development (Editorial Projects in Education 2005; Potts, Blank, and Williams 2002) (see sidebar "New Models and Current Practices in Professional Development").

Effects of Professional Development

Research literature contains a mix of large- and small-scale studies, including intensive case studies of classroom teaching (e.g., WestEd 2000), evaluations of programs designed to improve teaching and learning (e.g., Banilower 2002; Weiss, Banilower, and Shimkus 2004), and surveys of teachers about professional development experiences (e.g., Choy and Chen 1998; Parsad, Lewis, and Farris 2001). Thus far, strong evidence of the positive effects of professional development is limited to teaching practices. Relatively few rigorous studies have directly linked teacher professional development to improved student outcomes (Elmore 2002; Guskey 2003). More research is needed following the advent of mathematics and science testing under NCLB. Several recent studies on the effects of professional development are summarized below.

- In their longitudinal study tracking the experiences of mathematics and science teachers participating in various professional development activities, Desimone et al. (2002) found that professional development focusing on specific teaching strategies (e.g., use of technology, higher-order instruction, use of alternative assessments) increased teachers' use of these strategies in the classroom. Also, the effects on teachers' instruction were stronger when professional development included collective participation of teachers from the same school, department, or grade; active learning opportunities such as reviewing student work or obtaining feedback on teaching; and coherence such as linking to other activities or building on teachers' previous knowledge. The Consortium of Chicago School Research also found that "high-quality" professional development programs (those characterized by sustained and coherent training, collaborative learning, and followup support) had a significant effect on teachers' instructional practices (Smylie et al. 2001).
- Studies conducted by NCES based on national data found that a majority of teachers who had participated in professional development programs on various topics relating to teaching and instruction reported that these programs were useful and improved their classroom teaching practices (Choy and Chen 1998; Parsad, Lewis, and Farris 2001; Smith and Desimone 2003).

New Models and Current Practices in Professional Development

For many years, teacher professional development has consisted of district- or school-sponsored workshops or conferences in which an outside consultant or curriculum expert offers teachers a one-time seminar on a pedagogic or subject-matter topic on a staff development day (Choy and Chen 1998; Parsad, Lewis, and Farris 2001). This approach has been widely criticized in the professional literature for lack of focus, continuity, and coherence (Corcoran 1995; Little 1993; Miller 1995; Sprinthall, Reiman, and Thies-Sprinthall 1996). Recognizing the limitations of this traditional model, the education research community began to look for new models for professional development (Corcoran 1995; Guskey 2003; Loucks-Horsley et al. 2003; Miller 1995). A consensus has emerged that professional development yields the best results when it covers both content and pedagogy, addresses teachers' needs and involves them in planning, fosters collaboration among teachers and between teachers and principals, incorporates evaluation of its effects on teaching practice and student outcomes, is part of an overall reform plan, and is continuous and ongoing with followup support for further learning (Garet et al. 2001; Hawley and Valli 1999; Loucks-Horsley et al. 2003). Both qualitative and quantitative research studies now point to a consensus on several important qualities of effective professional development such as extended duration, collective participation of teachers in a school, active learning opportunities, focus on content, and coherence with other activities at the school (Cohen and Hill 2000; Desimone et al. 2002; Garet et al. 2001; Loucks-Horsley et al. 2003; Porter et al. 2003).

However, these new models of professional development require substantially more resources, time, and effort than traditional workshops. States and districts have been struggling to find ways to provide effective and ongoing professional development, to encourage teachers to participate, and to reward them for completing such programs (Hirsch, Koppich, and Knapp 2001). Studies have found that the typical professional development experience is not of high quality (Desimone et al 2002; Porter et al. 2000). Although more teachers have been participating in professional development overall, especially in content-focused programs (Smith and Desimone 2003), professional development in many school districts in the late 1990s still consisted primarily of one-time workshops with little followup (Choy and Chen 1998; Parsad, Lewis, and Farris 2001). As of 1999–2000, almost all public school teachers (99%) participated in professional development, but the dominant forms were still traditional workshops and conferences (95%) (Choy, Chen, and Bugarin forthcoming). Furthermore, many teachers attend professional development programs for 8 or fewer hours over the course of a school year.

- Studies show that teacher participation in professional development affects teaching practice, which in turn affects student performance. For example, the National Staff Development Council examined the features of award-winning professional development programs at eight public schools that had made measurable gains in student achievement (WestEd 2000). The researchers observed that, in each school, the nature of professional development had shifted from isolated learning and occasional workshops to focused, ongoing organizational learning built on collaborative reflection and joint action. Wenglinsky (2002) found that higher student test scores in mathematics and science were linked with teachers' professional development training in higher-order thinking skills.
- Based on an extensive review of studies on the effects of professional development on student achievement, Clewell et al. (2004) concluded that the content of professional development linked to subject-matter knowledge was more important than its format in terms of improving student achievement. Clewell and her colleagues cited the work of Kennedy (1998) and Cohen and Hill (2000) to support their conclusion. Based on 12 studies of professional development programs that reported effects on student achievement, Kennedy (1998) found that the programs showing the greatest effects were those that focused on subject-matter knowledge and on student learning in a particular subject. Cohen and Hill (2000) also reported that students of California elementary school teachers who attended curriculum-focused workshops and learned about the state assessment system had higher achievement scores on the assessment.
- Numerous studies indicate that sustained and intensive professional development is an important factor in influencing change in teachers' attitudes and teaching behaviors (Clewell et al. 2004). For example, the amount of time teachers spent on professional development activities was positively related to their perceptions of these activities' usefulness (Parsad, Lewis, and Farris 2001). The more time teachers spent on professional development in using computers for instruction, the more likely they were to have their students use computers during class (Choy, Chen, and Bugarin forthcoming).
- Based on data from the NSF-funded Local Systemic Change (LSC) project,[37] researchers found that participation in LSC professional development positively changed teachers' attitudes and teaching behaviors (Banilower 2002; Boyd et al. 2003; Weiss, Banilower, and Shimkus 2004). Changes were most evident among those who participated intensively (e.g., more than 60 hours or even more than 80 hours) in LSC professional development (Boyd et al. 2003; Weiss, Banilower, and Shimkus 2004). Other research also suggests that teachers typically need at least 80 hours of intensive professional development before they change their classroom behaviors and practices significantly (Supovitz and Turner 2000).

Teacher Salaries

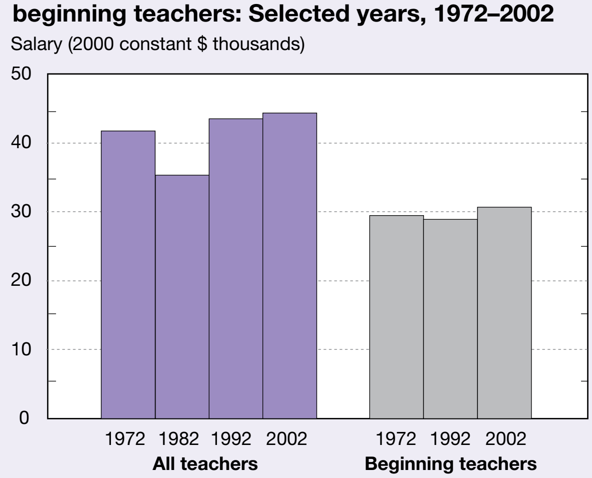
Teacher salaries are the largest single cost in education, making compensation a critical consideration for policymakers seeking to increase the quality of the teaching force. For many years, schools have tried to attract highly qualified and skilled people to teaching and to keep the most able ones from leaving the profession (Hanushek, Kain, and Rivkin 2004; Macdonald 1999). Evidence suggests that teacher salaries play an important role in determining both the supply of new teachers and retention of current teachers (Odden and Kelley 2002; Shen 1997). The indicators below review changes in U.S. teacher salaries and compare their salaries with those of teachers in other nations.

Trends in U.S. Teacher Salaries

The average salaries (in constant 2002 dollars) of all U.S. public school K−12 teachers decreased from 1972 to 1982, increased from 1982 to 1992, and remained about the same between 1992 and 2002 (figure 1-16; appendix table 1-23). The net effect was that the average inflation-adjusted salary of all public school K−12 teachers was $44,367 in 2002, just about $2,598 above what it was in 1972. The average salary for beginning teachers followed a similar trend.

Teacher salaries are often lower compared with the salaries of other white-collar occupations (Allegretto, Corcoran, and Mishel 2004; Horn and Zahn 2001), but comparing teachers' annual salaries to those of other workers is complicated by some unique features of the teaching profession, such as a shorter work year. To control for differences in time worked, a recent study focused on the weekly wages of teachers from 1996 to 2003.[38] The results showed that teachers' weekly wages consistently and considerably lagged

Figure 1-16
Average salaries of U.S. public school K–12 and beginning teachers: Selected years, 1972–2002



NOTE: Beginning teachers' salary in 1982 not available.

SOURCE: F.H. Nelson and R. Drown, *Survey and Analysis of Teacher Salary Trends 2002,* American Federation of Teachers (2003). See appendix table 1-23.

Science and Engineering Indicators 2006

behind those of other workers with similar education and experience and that this gap had enlarged over time (Allegretto, Corcoran, and Mishel 2004).

International Comparisons of Teacher Salaries

After adjusting for the cost of living, U.S. teachers earn more than teachers in many other countries (OECD 2004). In 2002, the beginning, midcareer (after 15 years of teaching), and top-of-the-scale statutory salaries for U.S. public primary and secondary school teachers were all higher than the corresponding OECD averages (figure 1-17).[39] However, regardless of experience, teachers in Germany and Switzerland earned significantly more than U.S. teachers and the gaps seemed to increase with the level of schooling. Teachers with 15 years of experience in Japan and South Korea also earned more than their U.S. counterparts (appendix table 1-24).

Statutory salaries may not capture all differences in salaries because teaching time varies considerably across countries. To control for this variation, an alternative measure of teacher pay is the ratio of annual salary to the number of hours per year the teacher is required to spend teaching students in class (referred to as *salary per instructional hour).* When instructional time was taken into account, U.S. teachers did not fare well compared with teachers in other nations (appendix table 1-24). The salary per instructional hour of U.S. teachers with 15 years of experience was lower than the OECD average at both the lower and upper secondary levels and was the same at the primary level.

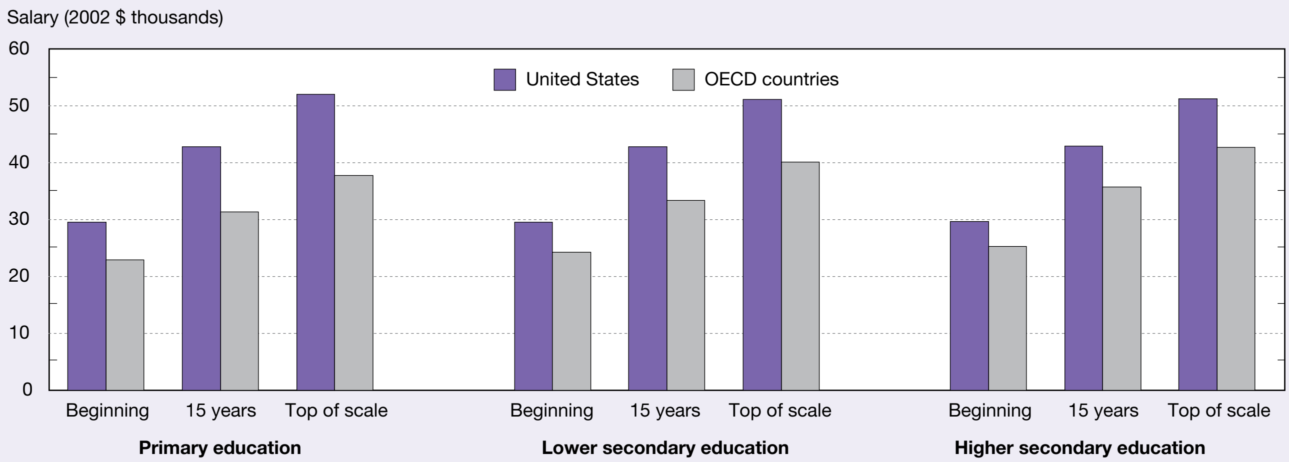
Another way to compare teacher salaries across countries is to compute the ratio of salaries to the per capita gross domestic product (GDP). The resulting ratio compares teacher salaries with a country's overall wealth and may indicate a nation's financial investment in teaching as a profession. Appendix table 1-24 shows the ratio of teacher salaries after 15 years experience to per capita GDP. U.S. ratios were below the average for OECD countries for all three levels of education.

Attrition and Mobility of Mathematics and Science Teachers

In addition to salary, working conditions affect the career decisions of potential and current teachers and their professional satisfaction with teaching (Bogler 2002; Hanushek, Kain, and Rivkin 2004; Hardy 1999; Luekens, Lyter, and Fox 2004; Ma and Macmillan 1999; Shen 1997). Research shows that teacher effectiveness can be enhanced in environments that support and value their work and can be diminished by poor working conditions, lack of professional support, widespread student problems, and inadequate facilities and resources (Macdonald 1999; NCTAF 2003; Scott, Stone, and Dinham 2001). The following indicators examine the attrition and mobility of mathematics and science teachers, discuss their reasons for moving or leaving the profession, and examine their views on school working conditions.

Various studies, commissions, and national reports on teacher supply and demand have concluded that teacher shortages in mathematics and science are considerable (AAEE 2003; NCTAF 2003). Teacher attrition (teachers leaving the teaching profession) is a general contributing factor, whereas teacher mobility (teachers moving from one school to another) also creates staffing problems in individual schools. Between

Figure 1-17
Annual statutory salaries of public school teachers at beginning, after 15 years of experience, and at top of scale for United States and OECD country average, by school level: 2002



OECD = Organisation for Economic Co-operation and Development

NOTES: Statutory salaries refer to salaries set by official pay scales. Converted to equivalent 2002 U.S. dollars using OECD purchasing power parities. OECD countries are Australia, Austria, Belgium, Belgium (Flemish community), Czech Republic, Denmark, England, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Scotland, Slovak Republic, South Korea, Spain, Sweden, Switzerland, Turkey, and United States.

SOURCE: OECD, *Education at a Glance: OECD Indicators 2004* (2004). See appendix table 1-24.

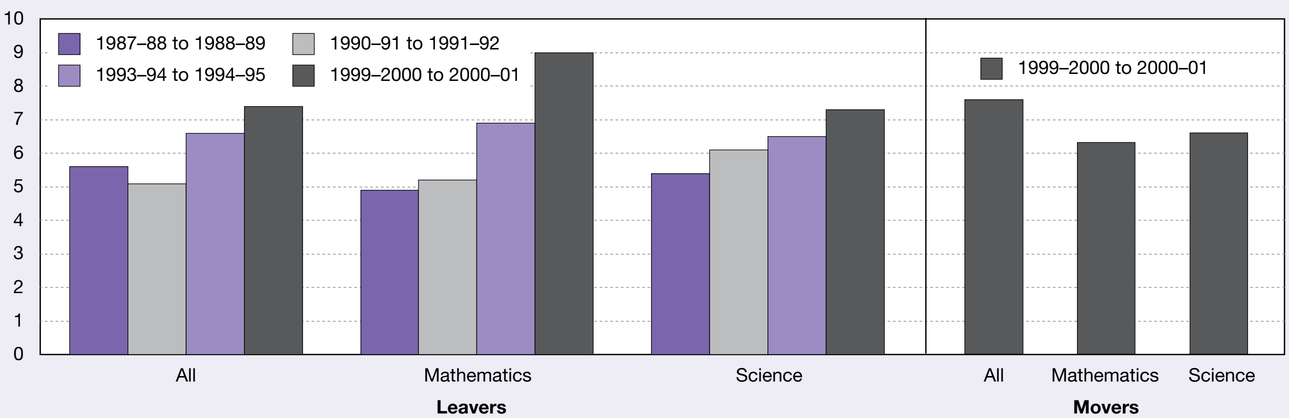
Science and Engineering Indicators 2006

the 1999–2000 and 2000–01 school years, 7% to 9% of public school mathematics and science teachers left the teaching profession and 6% to 7% moved to a different school (figure 1-18). The attrition of mathematics and science teachers appears to be increasing over time: only about 5% of public school mathematics and science teachers left the profession between the 1987–88 and 1988–89 school years.

Reasons for Leaving or Moving

In 2000–01, both mathematics and science teachers and other teachers rated the following reasons as very or extremely important in their decision to leave teaching: pursuing another career, obtaining a better salary or benefits, and retiring (table 1-12). However, mathematics and science teachers were more likely than other teachers to cite pursuing another career as a very or extremely important reason for leaving, whereas others were more likely to give retirement as a very or extremely

Figure 1-18
Public school teachers who left teaching or moved to a different school: Selected school years



SOURCES: U.S. Department of Education, National Center for Education Statistics (NCES), 1999–2000 School and Staffing Survey; 2000–01 Teacher Follow-up Survey; and S.D. Whitener, K.J. Gruber, H. Lynch, K. Tingos, M. Perona, and S. Fondelier, *Characteristics of Stayers, Movers, and Leavers: Results From the Teacher Follow-up Survey: 1994–95,* NCES 97-450 (1997).

Science and Engineering Indicators 2006

Table 1-12
Public school teacher leavers who rated various reasons as very or extremely important in their decision to leave profession: 2000–01
(Percent)

Reason for leaving	Mathematics/ science teachers	Other teachers
Pursue another career	25.8*	19.7
Better salary or benefits	22.5	18.4
Retirement	21.8*	30.4
Changed my residence	20.4*	9.3
Health	17.8	9.3
Take courses to improve career opportunities outside education	12.1	9.1
Take sabbatical or other break from teaching	11.3	11.3
Feel unprepared to implement or disagree with new reform measures	9.2	8.4
Pregnancy or child rearing	9.1*	17.7
Dissatisfied with job description or responsibilities	7.1*	14.1
School received little support from community	5.9	6.5
Dissatisfied with changes in job description or responsibilities	4.8*	12.0
Take courses to improve career opportunities within education	4.5	7.6
Laid off or involuntarily transferred	3.7	3.1
Lack of certification	1.7	2.1

*p = .05, statistically significant difference between mathematics/science teachers and other teachers.

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01Teacher Follow-up Survey.

Science and Engineering Indicators 2006

important reason for leaving. These results suggest that retaining mathematics and science teachers can be particularly difficult because they may find more lucrative career opportunities elsewhere (see sidebar "Occupations of Former Teachers").

Teachers who moved to another school seem to have different motives from those who left the profession. Among the top reasons given by mathematics and science teachers who moved to a new school were dissatisfaction with support from school administrators (40% for mathematics and science teachers and 38% for other teachers) and dissatisfaction with workplace conditions (37% for mathematics and science teachers and 32% for other teachers) (table 1-13). Mathematics and science teachers who moved were more likely to report changing schools to obtain a better salary or benefits (29% and 18%) but less likely to move for a better teaching assignment (26% and 42%).

Perceptions of Working Conditions by Teachers Who Moved, Left, or Stayed

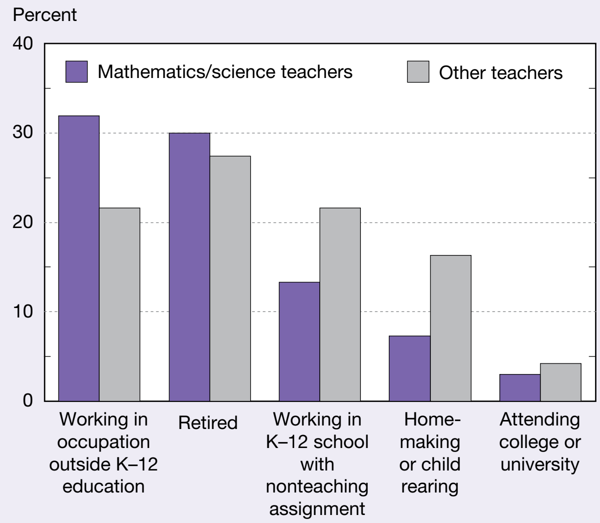
In general, teachers who left or moved expressed less satisfaction with their schools' conditions than did those who stayed (appendix table 1-25). Among public school mathematics and science teachers, those who left the profession were less likely than those who stayed to report satisfaction with the amount of autonomy and control they had over their classrooms, with teaching in their current or last year's schools and teaching overall, with the availability of computers and other technology for their classrooms, and with opportunities for professional development.[40] Mathematics and science teachers who left for nonteaching jobs appeared to be more satisfied with their new jobs (see sidebar "Former Teachers' Satisfaction With New Jobs Compared With Teaching").

Those who moved to a different school also appeared to be more critical of experiences and conditions in their former

Occupations of Former Teachers

Where do teachers go when they leave teaching? Among public school mathematics and science teachers who left teaching between 1999–2000 and 2000–01, 32% worked outside education, 30% retired, 13% stayed in education but not in teaching, 7% became homemakers or at-home parents, and 3% attended a college or university. Mathematics and science teachers were more likely to choose an occupation outside education (figure 1-19).

Figure 1-19
Main occupational status of public school teachers who left teaching profession: 2000–01



SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01 Teacher Follow-up Survey.

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Table 1-13
Public school teacher movers who rated various reasons as very or extremely important in their decision to move to different school: 2000–01
(Percent)

Reason for moving	Mathematics/ science teachers	Other teachers
Dissatisfied with support from administrators at previous school	40.0	38.0
Dissatisfied with workplace conditions at previous school	37.1	31.5
Better salary or benefits	28.9*	17.8
Opportunity for better teaching assignment	26.2*	41.5
Changed my residence	21.3	23.0
Higher job security	14.1	16.4
Dissatisfied with opportunities for professional development at previous school	10.3	15.2
Dissatisfied with changes in job description or responsibilities	10.1*	19.8
Feel unprepared to implement or disagree with new reform measures	9.3	8.8
Laid off or involuntarily transferred	5.0*	11.1
Did not have enough autonomy over classroom at previous school	4.8	8.6

*p = .05, statistically significant difference between mathematics/science teachers and other teachers.

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01Teacher Follow-up Survey.

Science and Engineering Indicators 2006

Former Teachers' Satisfaction With New Jobs Compared With Teaching

Mathematics and science teachers who left for a job outside education were more satisfied with their new jobs than with teaching. In an evaluation of 17 occupational characteristics, such as salary, general working conditions, and intellectual challenge, they rated 15 characteristics better in their current job than in teaching, with the exceptions being benefits and a safe working environment. Differences in the ratings for some characteristics were large, including manageability of workload, general work conditions, opportunities for professional advancement, professional prestige, intellectual challenge, opportunities for professional development, opportunities for learning from colleagues, recognition and support from administrators, and autonomy or control over one's own work (table 1-14).

Table 1-14
Former public school mathematics and science teachers who rated various aspects of their current occupation as worse than teaching, better than teaching, or about the same: 2000–01
(Percent distribution)

Aspect of occupation	Worse than teaching	Better than teaching	About same
Salary	22.2	55.9*	21.9
Benefits	50.2	40.1*	9.7
Job security	20.1	46.1*	33.8
Intellectual challenge	15.0	59.0*	26.0
Opportunities for professional development	13.9	58.1*	28.0
Professional prestige	9.0	63.4*	27.6
General work conditions	3.4	64.3*	32.3
Safety of environment	20.4	25.3	54.3
Manageability of workload	15.1	76.9*	8.1
Procedures for professional evaluation	15.1	50.6*	34.3
Autonomy or control over own work	18.7	57.6*	23.7
Influence over workplace policies and practices	12.8	41.9*	45.3
Availability of resources and materials/equipment for doing job	33.5	55.9*	10.7
Recognition and support from administrators/managers	12.1	51.7*	36.2
Professional caliber of colleagues	17.2	43.6*	39.2
Opportunities for learning from colleagues	12.9	57.1*	30.0
Opportunities for professional advancement	7.2	63.6*	29.2

*p = .05, statistically significant difference between worse than teaching and better than teaching.

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01 Teacher Follow-up Survey.

Science and Engineering Indicators 2006

schools than those who stayed: they were less likely to report satisfaction with the subject they were assigned to teach, with the amount of autonomy and control, with feeling safe inside or outside the school, with job security, with the high caliber of professionalism, with school emphasis on academic success, with supportive administrators, and with uninterrupted class time (appendix table 1-25).

Summary

Indicators in this section reveal both progress and ongoing challenges in strengthening the U.S. teaching force. Based on a number of measures, ranging from the rigor of high school coursetaking and achievement test scores at the 12th grade to college entrance examination scores and the selectivity of the institutions from which teachers enrolled and graduated, teaching appears to attract a higher share of college graduates with weak academic backgrounds. Although almost all public middle-grade or high school mathematics and science teachers held a bachelor's degree and teaching certification, many were teaching subjects for which they did not have certification or a college major or minor in the field. The distribution of out-of-field teaching in mathematics and science was uneven across states.

During the past decade, many states have developed and implemented professional development policies and increasing proportions of teachers participated in professional development programs. Although the characteristics of high-quality professional development have been identified, most teachers' professional development experiences were not of high quality. The dominant form of professional development in the late 1990s were still one-time workshops with little followup and most teachers attended programs for only a few hours over the course of the school year, far below the minimum of 60 to 80 hours some studies show as needed to bring about meaningful change in teaching behaviors.

Between the 1999 and 2000 academic years, 7%–9% of public school mathematics and science teachers left the teaching profession, and another 6%–7% changed schools.

Those who left often reported they planned to pursue another career. Those who moved cited various aspects of poor working conditions as reasons for changing schools. One-third of leavers found a job outside the field of education and many reported more satisfaction with their new job than with teaching.

Information Technology in Education

The United States has made great progress in introducing and upgrading information technology (IT) in classrooms, school libraries, and computer labs over the past decade. Federal, state, and district agencies have provided funds and incentives to increase students' access to hardware and software resources. Initiatives (including the E-rate program) have targeted funding toward high-poverty and rural or urban public schools, and recent legislation has supported effective teacher training for integrating IT with curriculum and instruction. In addition, as families have obtained home computers and Internet connections, children and adolescents have increased their IT use at home, often for school work.

National survey data have focused on measures such as student access to IT and frequency of use, and other research has examined important questions about how teachers and students use IT resources and how integration of IT with instruction may influence student learning. One goal of providing computers in schools is to develop students' computer literacy, which is needed for college and for many jobs. A second goal, using IT as an instructional tool to enhance learning in other subjects, is more difficult to reach, partly because of the many ways the tools can be deployed. A substantial body of research indicates that tutorials and other computer-based instruction in basic skills can improve students' achievement on standardized tests in math and science (e.g., Becker 1994; Kulik 2003; Van Dusen and Worthen 1994). The preponderance of these studies shows that well-designed tutorials can supplement teacher guidance, providing more immediate responses to students' efforts and allowing them to work at their own pace. However, two recent studies found that student use of computers at school is not necessarily beneficial and may be associated with lower mathematics achievement (Angrist and Lavy 2002; Fuchs and Woessman 2004).

Less evidence exists for IT effectiveness in applications other than tutorials, such as simulations and computer-based labs in science (Kulik 2003). Experts have noted IT's promise for supporting inquiry-based instruction: for example, helping students learn how to locate, evaluate, organize, and synthesize information to solve complex problems (Ringstaff and Kelley 2002; Sandholtz, Ringstaff, and Dwyer 1997). High-capacity multimedia computers and high-speed Internet connections can enhance students' research and collaboration activities, increasing their access to up-to-date materials and allowing rapid communication with experts outside the school, for example. However, the research base is sparse on any effects of technology used for such learning methods, and results tend to rely on subjective measures.

The indicators in this section present more detail on students' increasing access to IT, including trends in the "digital divides" related to family income, race/ethnicity, and geographic location. In addition, data describe how students use computers and the Internet for a variety of activities at home and in school. The section concludes with a discussion of third grade teachers' ratings of their preparation for integrating technology into their teaching and their technical support at school.

Trends in IT Access at School

School systems have invested heavily in IT during and since the 1990s to expand opportunities for learning and to overcome gaps in home access for students (Donnelly, Dove, and Tiffany-Morales 2002). Supported by government funds and sometimes corporate and community contributions, these efforts have been largely successful. First, IT resources have become much more widely available in schools, and second, schools have helped equalize access for disadvantaged students (DeBell and Chapman 2003; NTIA 2002).

The number of students per public school computer has decreased sharply, and schools have made dramatic progress in providing Internet access: the 3% of instructional rooms with an online connection in 1994 rose to 93% in 2003 (Parsad and Jones 2005). Urban public school classrooms were slightly less likely than those in towns or rural areas to have online connections in 2002, however. In public schools with Internet access, 95% had broadband connections, which indicates rapid change since 1996 when 74% used dial-up. In addition, the ratio of public school students to online computers improved from about 12:1 in 1998 to 4:1 in 2003 (Parsad and Jones 2005).

Gaps by school poverty concentration narrowed over these 5 years, as high-poverty schools greatly increased their supply of Internet-connected machines. However, students in high-poverty public schools remained at a disadvantage in 2003, with 5.1 students per online computer compared with 4.2 students in low-poverty schools.

Trends in IT Access at Home

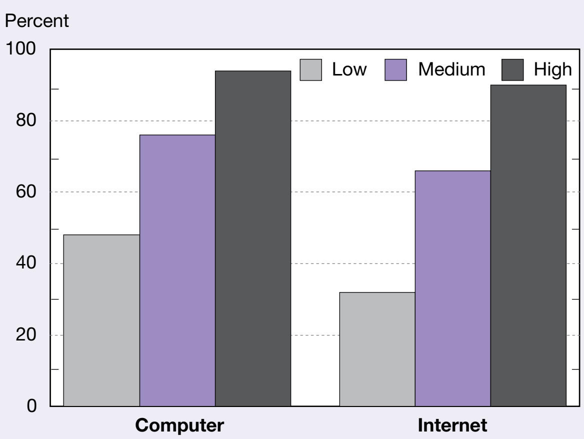
Home computer ownership and Internet access grew rapidly during the 1990s among all population groups. From 1984 to 2001, the inequality of home computer ownership by family income decreased, particularly over the last few years of the period (NTIA 2002). Computer ownership rates increased for all groups over these 17 years but grew more rapidly for lower-income families. Regarding home Internet access, the digital divides related to income and householders' education also narrowed from 1998 to 2001 (NTIA 2002). Rural residents were less likely to use the Internet than metropolitan-area residents through 1998, but this gap had closed by 2001 (NTIA 2002). Gaps among demographic groups have diminished as computer ownership and online connectivity costs have declined.

Access to home computers and Internet connections continued to grow from 2001 to 2003, and the most rapid change occurred in the proportion of households with broadband Internet connections, which more than doubled from 9% to 20% over these 2 years (NTIA 2004). People with broadband access tend to use the Internet more frequently and for a wider range of activities, including educational purposes. The greater speed and continuous connection that broadband provides increase the feasibility and efficiency of doing Internet research and taking online courses.

In 2003, 77% of students in grades K–12 lived in a household with a computer and 67% had Internet access at home (appendix table 1-26). The access gaps noted above remained. Students from high-income families, for example, were nearly three times more likely than those from low-income families to have home Internet access, 90% versus 32% (figure 1-20). Similarly, although 94% of high-income students had a computer at home, only 48% of low-income students had such access. The likelihood of having these resources at home also increased sharply with level of parental education (appendix table 1-26).

White and Asian/Pacific Islander students were far more likely in 2003 to have a computer in their homes (86% and 87%, respectively) than were black and Hispanic students (55% and 57%); similar gaps were evident in rates of home Internet access (figure 1-21). In addition, students attending public schools were less likely than their peers in private schools to have either computer or Internet access at home. However, students' use of IT resources at school differed little by sector (appendix table 1-26).

Figure 1-20
K–12 students who had computer and Internet access at home, by family income: 2003

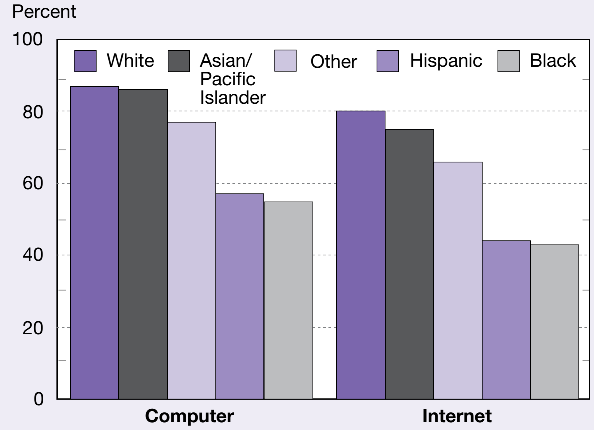


NOTE: Low income includes families in lowest 20% of income distribution, middle income includes middle 60%, and high income includes highest 20%.

SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-26.

Science and Engineering Indicators 2006

Figure 1-21
K–12 students who had computer and Internet access at home, by race/ethnicity: 2003



SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-26.

Science and Engineering Indicators 2006

IT Use at School and at Home

Student Use of IT at School

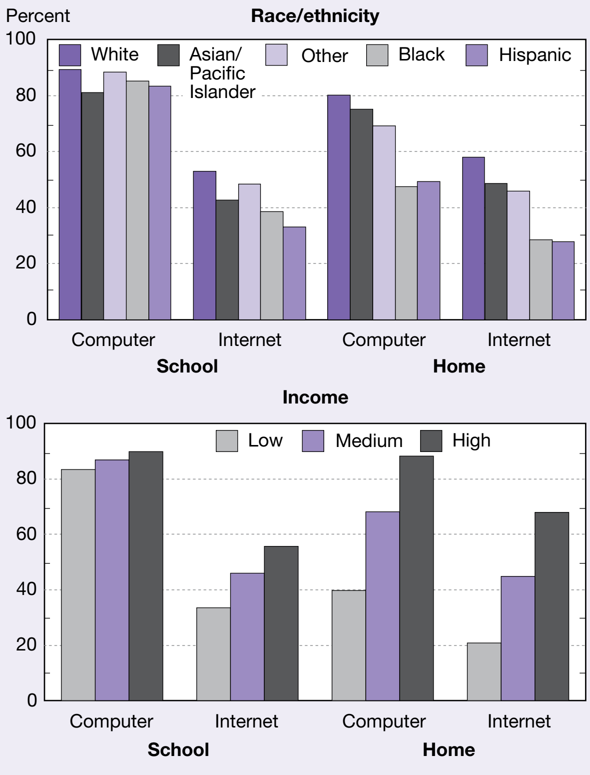
Computers can be used for instructional activities ranging from tutorials (used in mathematics and other classes) to simulations and specialized laboratories (used in some science classes). Internet access facilitates certain student-directed learning activities, such as conducting research on the Web, contributing to data collection and analysis projects based outside the school, and communicating with experts and other students for projects. IT's potential for expanding students' understanding and interest in learning has generated public support for bringing these resources into schools and encouraging their effective integration into lessons.

However, IT is not necessarily more effective than other educational tools. Results largely depend on how computers are used and whether they effectively support teachers' instructional goals. A recent study of 15-year-olds in the United States and 29 other nations that participated in PISA found that using computers and the Internet at school may support learning up to a point, but more frequent use was associated with lower achievement (Fuchs and Woessman 2004). This analysis controlled for school resources, which were related to socioeconomic and other characteristics of students' families. However, these data present a one-time snapshot and cannot show causality. Another recent study found that the introduction of computer-aided instruction in elementary and middle grades in Israel was consistently linked to lower mathematics test scores for fourth and eighth graders, although there was less clear evidence of a link with the latter (Angrist and Lavy 2002).

In addition to extending access, schools also serve to equalize students' use of IT resources. Not only are overall use rates higher at school than at home, but this difference is more pronounced for less-advantaged students. Low-income students, for example, were more than twice as likely to use a computer at school than at home in 2003, 84% compared with 40% (figure 1-22). Even middle-income students were more likely to use computers at school than at home. Furthermore, the demographic differences in school computer use were small compared with those for home use; the percentage of students who used computers at school ranged from 84%–90% by family income and from 81%–89% across racial/ethnic groups.

Although nearly all schools had an Internet connection, just under half (47%) of students accessed the Internet at school in 2003 (appendix table 1-26). As with school computer use, school Internet use was related to race/ethnicity, family income, and parental education. Students in secondary grades were far more likely to use the Internet at school, perhaps because the Internet is often used for research tasks more suited to older students. Male and female students did not differ substantially in their likelihood of using either computers or the Internet at school.

Figure 1-22
K–12 students who used computers and Internet at school and home, by race/ethnicity and family income: 2003



NOTE: Low income includes families in lowest 20% of income distribution, middle income includes middle 60%, and high income includes highest 20%.

SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-26.

Science and Engineering Indicators 2006

Computer Use in Third Grade Classrooms

In 2002, teachers of third grade students reported how often they required their students to access the Internet and to use a computer for some other purpose such as games or tutorials.[41] Computer use for purposes other than Internet access was much more common for third graders: 56% of students were given computer work at least three times weekly, whereas only 22% were assigned Internet use that often (appendix table 1-27). These computer uses were more frequent in public school classrooms; for example, 24% of public school students used the Internet that often in class compared with 9% of private school students.

In the past, teaching experience and teacher age were inversely related to frequency of IT use in the classroom, partly because veteran teachers were less likely to have gained computer skills through informal exposure in their preservice years (Smerdon et al. 2000). However, in 2002, more experienced third grade teachers were more likely than those with less experience to give students computer tasks at least three times a week (appendix table 1-27). These results suggest that at least in the early elementary grades, professional development and generally increased levels of computer literacy may be compensating for the variance in IT skills that teachers bring to their jobs.

Uses for Home Computers and the Internet

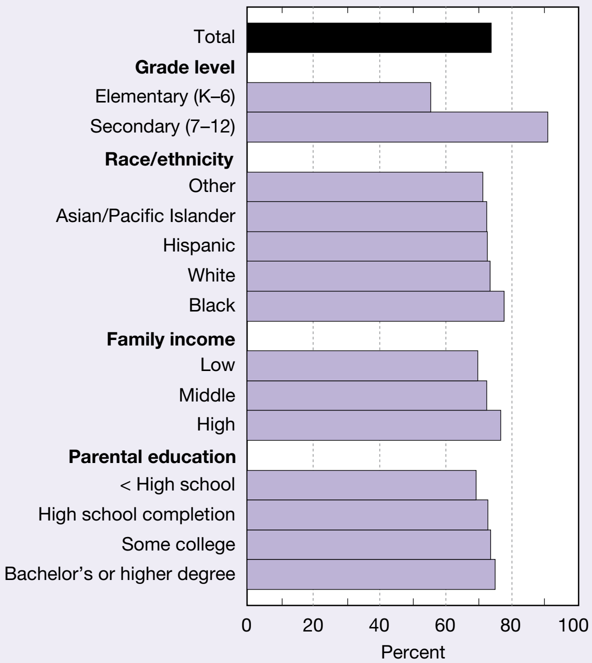
Students use IT resources at home for a variety of purposes, some of which may be educational.[42] Using educational software, e-mail, and accessing Web pages at home have been linked to higher achievement in mathematics after controlling for family background characteristics (including parental education) (Fuchs and Woessman 2004). Overall, about three in four students with access to a computer at home used it for school work in 2003 (appendix table 1-28), which was less common than for playing games (83%) but more common than for e-mail (49%).

Groups more likely to use a home computer for school work were students in secondary grades and those who were female or black, who came from higher-income families, or who had more highly educated parents. For example, secondary students with access were far more likely than elementary students to use home computers for school work, 91% versus 55% (figure 1-23).

E-mail was also a more common pursuit for older students, at 70% compared with 27% for those in elementary grades (appendix table 1-28). In 2003, younger students were somewhat more likely than older ones to play computer games: 87% compared with 78% (figure 1-24). (Some games may be educational, either by teaching specific skills and knowledge by design or by incidentally developing skills like planning or problem solving.)

Students in the elementary and secondary grades also tend to use the Internet differently. Overall, secondary students who had access used the Internet quite frequently: 53% used it at least once a day, 36% less often but at least weekly, and only 11% less than weekly (appendix table 1-28).

Figure 1-23
Among K–12 students with access, percentage who used home computers for schoolwork, by student characteristics: 2003



NOTE: Low income includes families in lowest 20% of income distribution, middle income includes middle 60%, and high income includes highest 20%.

SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-28.

Science and Engineering Indicators 2006

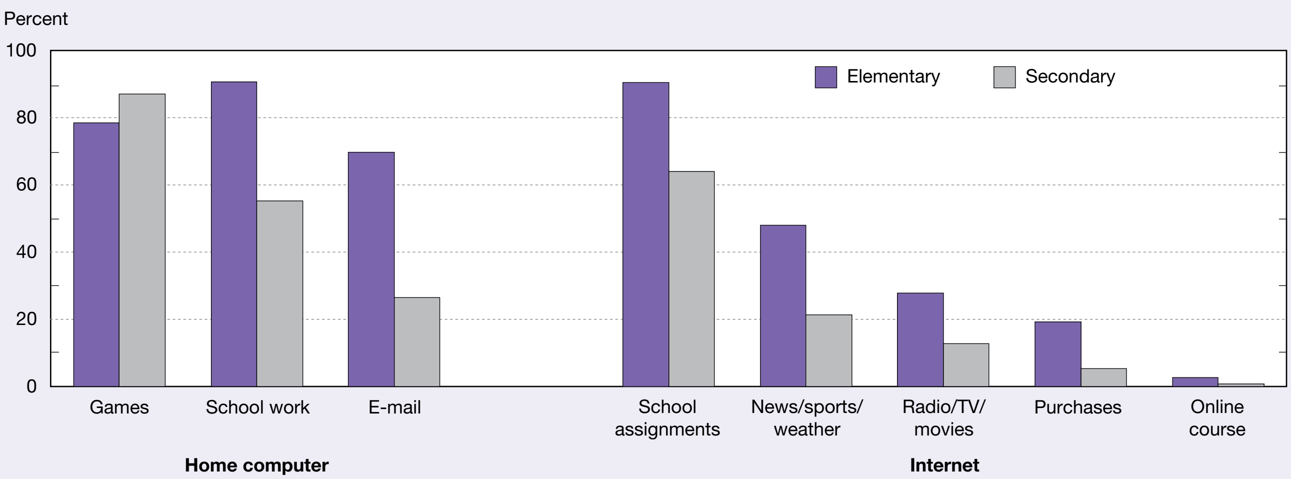
Elementary school students were less frequent Internet users, with only 27% using it at least once a day. In the secondary grades, almost all students (91%) with access used the Internet for school assignments (figure 1-23). Less common uses for the Internet were seeking news or sports information (48%), enjoying movies or television or radio programs (28%), purchasing goods or services (19%), and taking an online course (3%). In the elementary grades, a majority of students (64%) used the Internet for school assignments.

Teacher Preparation for Using IT and Technical Support

In 2003, 38 states had teacher qualification standards that included a technology component (Editorial Projects in Education 2004). In addition, certification requirements in 15 states included preservice training in using IT for teaching, and 9 states required prospective teachers to pass a test demonstrating technology skills and knowledge. For recertification, 10 states required teachers to demonstrate their knowledge about IT use, either through professional development or by passing a test. Twelve states had incentive policies to encourage teachers to use IT in their classrooms.

Research supporting such policies indicates that thorough IT training not only encourages teachers to use computers more extensively in classrooms but also can improve their teaching (Coley, Cradler, and Engel 1997; Sivin-Kachala and Bialo 2000). Most teachers lack extensive training in integrating computers with instruction and in making the most of IT potential, however (Ringstaff and Kelley 2002; Silverstein, Frechtling, and Miyoaka 2000). Preservice training has focused more on developing computer literacy than on

Figure 1-24
K–12 students with access who used home computers or Internet (from any location) for specific tasks, by grade level: 2003



SOURCE: U.S. Census Bureau, Current Population Survey 2003 (October), School Enrollment and Computer Use Supplement File. See appendix table 1-28.

Science and Engineering Indicators 2006

effectively integrating computers into instruction (Moursund and Bielefeldt 1999; Sandholtz 2001; Willis and Mehlinger 1996), at least until recent years.

Teacher Professional Development in IT Use

Types of Training. Professional development in IT may be shifting away from basic skills and toward developing advanced skills and using computers to support instructional goals. In 1999, public school teachers were very likely to be offered professional development in basic computer and Internet skills and software applications (87%–96%); integrating IT into instruction and advanced training were offered somewhat less frequently (79% and 67%, respectively) (Smerdon et al. 2000). In fall 2002, teachers in 87% of public schools had been offered training in integrating the Internet into curriculum in the preceding year (Kleiner and Lewis 2003).

In 2000–01, 63% of public school teachers reported participating in some professional development on using computers for instruction during the previous year. Roughly half said they had trained on one or more of three topics: the mechanics of using IT, integrating computers into instructional activities, and using the Internet (appendix table 1-29). However, only about half of the teachers who trained said each topic was central to the training; for the other half, the topic was merely mentioned. For example, about 29% of public school teachers had received recent professional development for which the central topic was integrating computers into instructional activities; for 25%, integration was mentioned in the training. Math and science teachers differed little or not at all from elementary or other teachers on these measures[43] (figure 1-25).

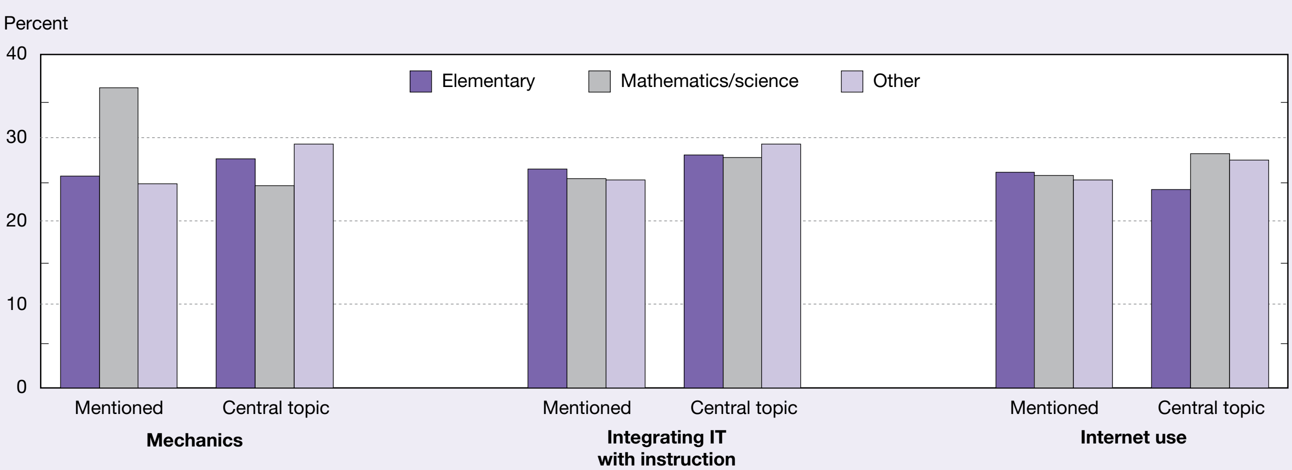
Few 2000–01 public school teachers had extensive recent training in IT use. About 37% had no such training, 33% had 8 hours or less, and only 8% had more than 32 hours of computer-related training in the last year. These data are consistent with findings described in the previous section, "Teachers of Mathematics and Science," on the relatively short amounts of time most teachers spend on professional development.

Adequacy of Training. Many public school teachers surveyed in 1999 indicated that their preparation for using IT in instruction was inadequate; 53% said they felt only somewhat prepared, and 13% said they felt not at all prepared (Smerdon et al. 2000). For the most part, these teachers had participated in little recent IT training: about half had 1 day or less in the past 3 years and only 12% had more than 4 days. The study noted that teachers who felt better prepared were far more likely to use IT resources for a range of activities, including creating instructional materials, obtaining model lesson plans and researching effective practices, and communicating with colleagues and parents. Middle and secondary school mathematics and science teachers in 1999–2000 often rated further training in IT use as a high priority (NSB 2004).

Third Grade Teacher Confidence in IT Skills and Technical Support

In contrast to these earlier findings, 62% of 2002 third grade students had teachers who indicated they felt prepared to use computers for instruction (figure 1-26); that is, their teachers either agreed (45%) or strongly agreed (17%) with the statement, "I am adequately prepared to use computers for instruction in my class." Only 20% indicated that they lacked adequate preparation for using computers to teach. The apparent improvement in preparation may be explained

Figure 1-25
Public school teachers with IT training that mentioned or focused on computer mechanics, integrating information technology with instruction, and Internet use, by main teaching field: 2000–01

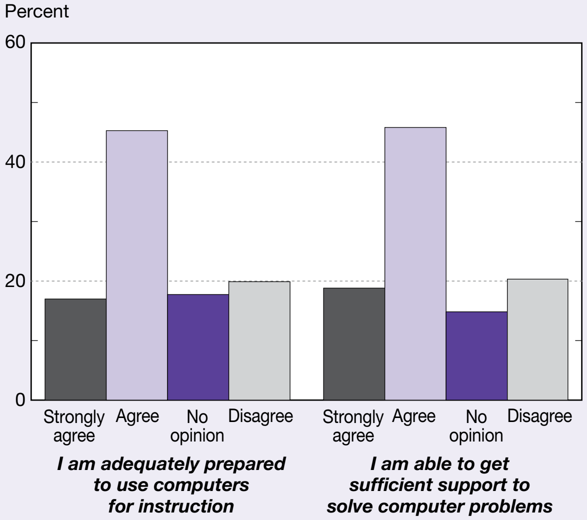


IT = information technology

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01 Teacher Follow-up Survey. See appendix table 1-29.

Science and Engineering Indicators 2006

Figure 1-26
Third grade teachers' agreement with statements about their own preparation to use computers and about their school's technical support: 2002



SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Fall 1998 Kindergartners in Spring 2002. See appendix table 1-30.

Science and Engineering Indicators 2006

partly by differences in grade levels; the earlier data apply to all teachers, whereas in 2002 they apply only to third grade teachers. Integrating IT with instruction is more likely in elementary grades, where teachers focus on basic skills development (Hedges, Konstantopoulos, and Thoreson 2003; Sutton 1991).

Another survey provides some complementary data. Most 2000–01 elementary and secondary teachers reported being fairly comfortable using computers: 75% in all agreed, and 35% said they strongly agreed, with the statement, "I am reasonably familiar and comfortable with using computers" (appendix table 1-29). (The statement is broad rather than focused on the educational uses of computers, however.) Mathematics or science teachers were far more likely than others to express strong agreement, and teachers with at least 10 years of experience were somewhat less likely than those with less seniority to feel very comfortable using computers.

The proportions of third grade teachers who had a positive assessment of their school's technical support were similar to the proportions who had confidence in their own IT skills. About 65% of students had teachers who agreed or strongly agreed with the statement, "In this school, I am able to get sufficient support to solve any computer problems I have," with 19% expressing strong agreement (figure 1-26). No substantial differences separated teachers at urban, suburban, or rural schools or at schools with different concentrations of minority students for either IT preparation or technical support (appendix table 1-30). Earlier gaps between advantaged and disadvantaged schools, and among schools in different community types, in teacher preparation for using IT may be narrowing as training becomes more widespread (Smerdon et al. 2000; Wenglinsky 1998). Teachers with different amounts of teaching experience differed little in their confidence about using computers, as 16%–19% strongly agreed that they were prepared. These findings suggest that at least basic training for using IT has reached many early elementary school teachers at different kinds of schools.

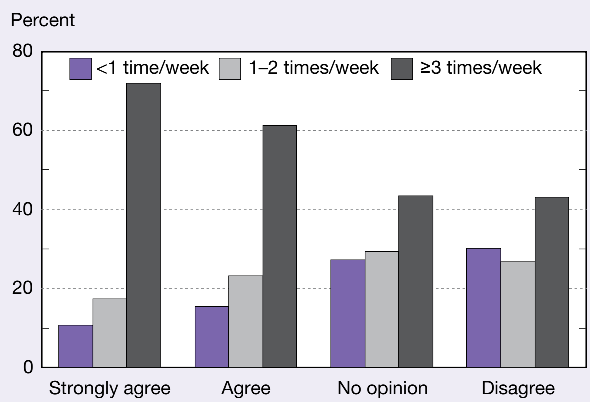
Third grade teachers' evaluation of their IT preparation was closely related to having their students use computers and access the Internet frequently (figure 1-27). About 72% of students whose teachers had strong IT confidence used computers for non-Internet tasks at least three times weekly, compared with only 43% of those whose teachers felt lacking in preparation.[44]

Similarly, when teachers thought they had better technical support, their students were more likely to use IT resources in class at least three times a week (appendix table 1-27). Along with extensive teacher training in computer use, strong technical support has also been associated with teachers' effective use of IT (Becker 1994; Cuban 1999; Hruskocy et al. 2000).

Summary

Access to IT resources, particularly in schools, has increased in the past two decades, generally leveling the playing field for disadvantaged students. Virtually all public schools were connected to the Internet in 2003, and nearly all had broadband connections. Gaps by family income and race/ethnicity in student use of computers and the Internet at school have decreased greatly. However, despite diminishing for years, substantial gaps in home access persisted in

Figure 1-27
Frequency of assigning non-Internet computer work to third grade students, by teachers' confidence in their preparation to use computers for instruction: 2002



NOTE: Third grade teachers' agreement with the statement: *I am adequately prepared to use computers for instruction.*

SOURCE: U.S. Department of Education, National Center for Education Statistics, Early Childhood Longitudinal Study, Fall 1998 Kindergartners in Spring 2002. See appendix table 1-27.

Science and Engineering Indicators 2006

2003. At a particular disadvantage are students from low-income families, who were about one-third as likely as those from affluent families to have home Internet access in 2003. Nearly all students used a computer at school, whereas just under half of them accessed the Internet there. Computer use for non-Internet purposes was quite common for third graders; 56% of them reportedly did computer work at least three times a week in 2002.

Among students with access at home, the most common computer use was playing games, followed by schoolwork, with e-mail a distant third. Most likely to work on home computers for school work were students in secondary grades, female or black students, those from affluent families, and those with highly educated parents. About 80% of students used the Internet (from any location) for school assignments.

Teachers' professional development in IT may be shifting toward using computers to more effectively support instructional goals and away from computer literacy skills. Roughly half of 2000–01 public school teachers had trained in the last year on one or more of three topics: the mechanics of using IT, integrating computers into instructional activities in their subject, and/or using the Internet. However, such training tended to be brief rather than sustained. Third grade teachers with different characteristics and at different kinds of schools differed little or not at all in their confidence about using computers for instruction, whereas in the past, veteran teachers more often assessed their computer knowledge as lacking compared with that of their junior colleagues. The more confident third grade teachers assigned their students computer and Internet more often than did other teachers.

Transition to Higher Education

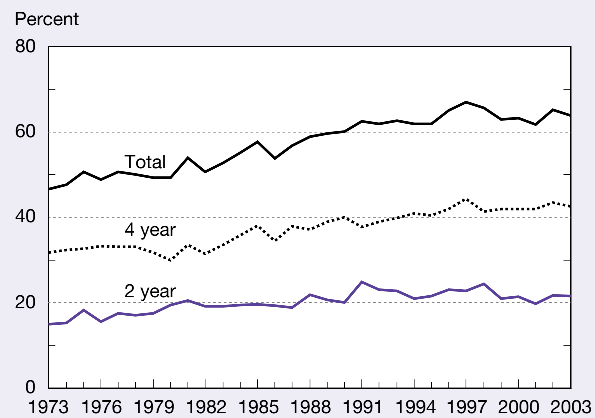
Student progress in completing high school and entering postsecondary education provides measures of the effectiveness of education at the secondary level. Today, a vast majority of students expect to continue their education after high school and many anticipate earning a bachelor's or higher degree. (In 2002, 80% of 10th graders expected to attain a bachelor's or higher degree and another 11% expected some postsecondary education [NCES 2004a].) In fact, increasing numbers of students are entering college directly from high school (NCES 2005). This bright picture, however, is clouded by the ongoing challenge of the dropout problem. In 2002, 10% of 16–24-year-olds (about 3.7 million) had left school without earning a high school credential (NCES 2005).[45] Although dropouts may return to earn a diploma, many do not go on to postsecondary education (Hurst, Kelly, and Princiotta 2004). Further, the increasing rates of immediate college enrollment belie the large numbers of entering freshmen who are poorly prepared for college work and need remedial help. This section presents indicators related to students' transition to college: long-term trends in the immediate college enrollment rates of U.S. high school graduates, first-time entry rates into postsecondary education in the United States and other countries, and remedial coursetaking among U.S. college freshmen. Together, these indicators provide an overview of the accessibility of higher education to high school students and their academic preparation for college-level work.

Immediate Enrollment in Postsecondary Education

The proportion of students choosing to continue their education directly after high school is on the increase (NCES 2005). One indicator of this trend is the percentage of students who enter college immediately following their high school graduation (referred to as the *immediate college enrollment rate*).[46] The immediate college enrollment rate was about 50% between 1973 and 1980, increased to 67% in 1997, and has since leveled off (figure 1-28). In 2003, 64% of high school graduates entered college directly after high school. Enrollment rates increased at both 4- and 2-year institutions: in 1973, 32% of students entered 4-year institutions immediately after completing high school, and 15% entered 2-year institutions. By 2003, the percentages had increased to 43% and 22%, respectively.

Immediate college enrollment rates increased for both males and females during this period, but the rates for females increased faster (figure 1-29). In fact, between 1973 and 2003, the rate of female enrollment in 4-year institutions increased faster than that of males at 4-year institutions and of both males and females at 2-year institutions. White high school graduates had persistently higher immediate enrollment rates than their black and Hispanic counterparts

Figure 1-28
High school graduates enrolled in college in October after completing high school, by institution type: 1973–2003



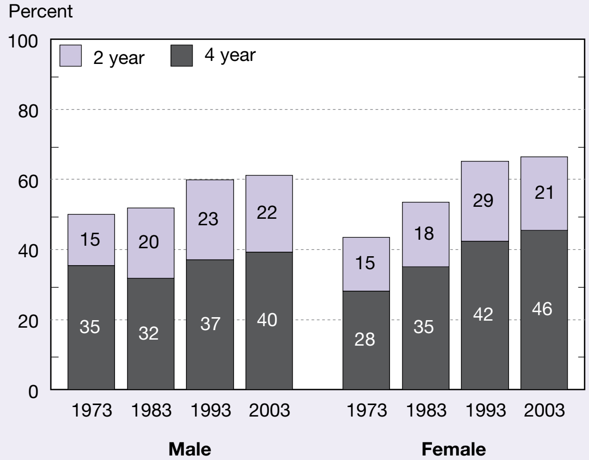
NOTE: Includes students 16–24 years old completing high school in survey year.

SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005,* NCES 2005-094 (2005). See appendix table 1-31.

Science and Engineering Indicators 2006

(appendix table 1-31). Likewise, differences in immediate enrollment rates by family income have persisted. In each year between 1975 and 2003, students from high-income families were more likely to enter college than their counterparts from low-income families (figure 1-30).

Figure 1-29
High school graduates enrolled in college in October after completing high school, by sex and institution type: Selected years, 1973–2003

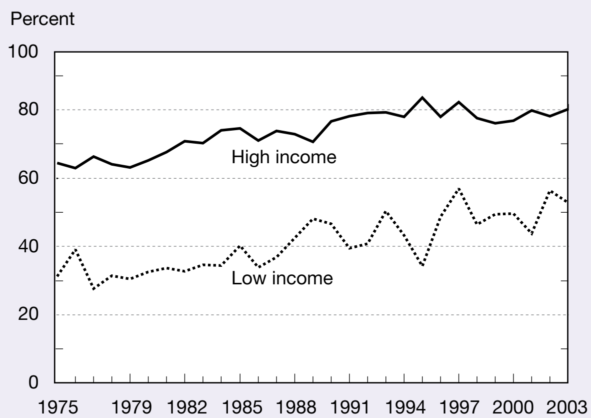


NOTE: Includes students 16–24 years old completing high school in survey year.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005*, NCES 2005-094 (2005).

Science and Engineering Indicators 2006

Figure 1-30
High school graduates enrolled in college in October after completing high school, by family income: 1975–2003



NOTES: Includes students 16–24 years old completing high school in survey year. Low income includes bottom 20% of all family incomes, high income includes top 20% of all family incomes.

SOURCE: U.S. Department of Education, National Center for Education Statistics, *The Condition of Education 2005,* NCES 2005-094 (2005). See appendix table 1-31.

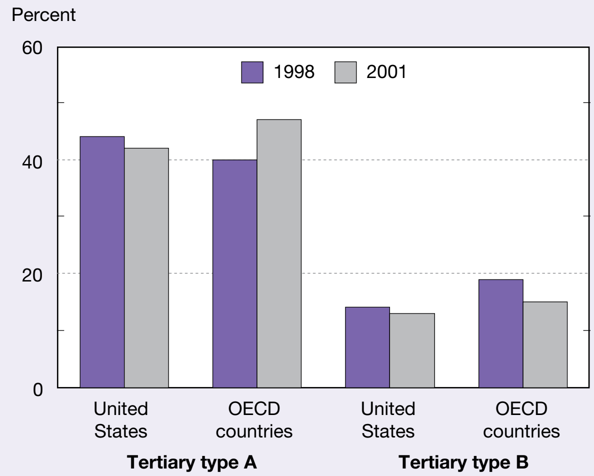
Science and Engineering Indicators 2006

International Comparisons

Participation in education beyond secondary schooling has been rising in many countries in recent years (OECD 2000 and 2003a). One measure of such participation is the OECD-developed first-time entry rate into postsecondary programs. OECD distinguishes between postsecondary programs that are largely theory oriented and designed to prepare students for advanced research programs and high-skills professions (tertiary type A) and those that focus on occupationally specific skills for direct entry into the labor market (tertiary type B).[47] In the United States, tertiary type A programs are mostly offered at 4-year institutions and lead to bachelor's degrees, and tertiary type B programs are often offered at community colleges and lead to associate's degrees.[48]

In 2001, the average first-time entry rate into tertiary type A programs was 47% for the 26 OECD countries with available data (figure 1-31). The United States had an entry rate

Figure 1-31
First-time entry rates into postsecondary (tertiary) education, United States and OECD country average, by program type: 1998 and 2001



OECD = Organisation for Economic Co-operation and Development

NOTES: Tertiary type A programs provide education that is largely theoretical and is intended to provide sufficient qualifications for gaining entry into advanced research programs and professions with high-skill requirements. Entry into these programs normally requires successful completion of upper secondary education (i.e., high school); admission is competitive in most cases. Minimum cumulative theoretical duration at this level is 3 years of full-time enrollment. Tertiary type B programs are typically shorter than tertiary type A programs and focus on practical, technical, or occupational skills for direct entry into labor market, although they may cover some theoretical foundations in respective programs. They have minimum duration of 2 years of full-time enrollment at tertiary level. OECD calculates entry rates by dividing number of first-time entrants of specific age in each type of tertiary program by total population in corresponding age group and then adding results for each single year of age. Entry rates for tertiary type A and B programs cannot be combined to obtain total tertiary-level entry rate because entrants into both types of programs would be counted twice.

SOURCES: OECD, *Education at a Glance: OECD Indicators 2000* (2000); and *Education at a Glance: OECD Indicators 2003* (2003). See appendix table 1-32.

Science and Engineering Indicators 2006

of 42%, slightly lower than the overall average.[49] Australia, Finland, Iceland, New Zealand, Norway, Poland, and Sweden all had entry rates of more than 60% (appendix table 1-32). Between 1998 and 2001, first-time entry rates into tertiary type A programs increased in 19 of the 22 OECD countries with data, except for the United States and United Kingdom, where rates declined, and Turkey, where rates remained the same.

Entry rates into tertiary type B programs were generally lower and more variable in many countries. In 2001, the average first-time entry rate into tertiary type B programs was 15% for the 23 OECD countries with available data. The rate for the United States was 13%. From 1998 to 2001, the OECD average entry rate into type B programs declined from 19% to 15%, whereas U.S. rates remained virtually unchanged (14% to 13%).

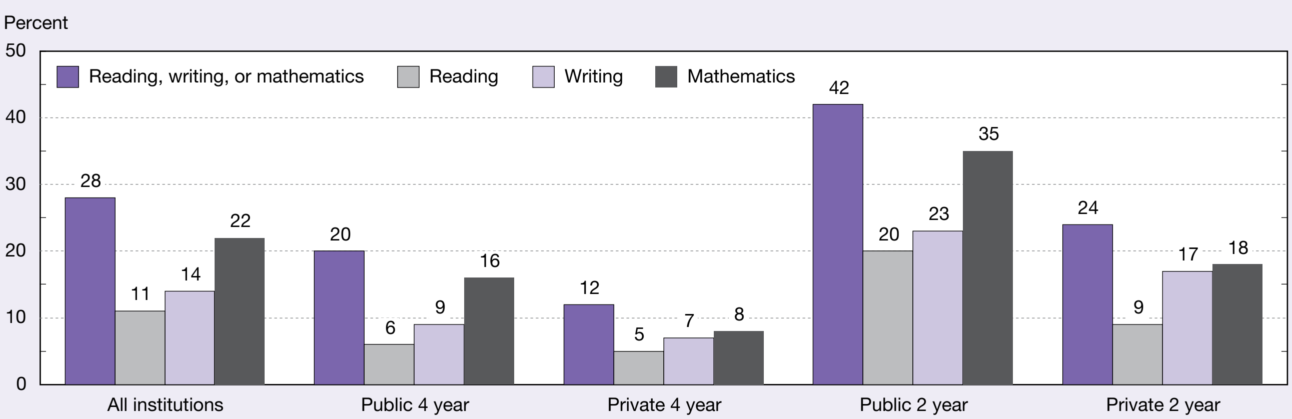
Remedial Education for Entering College Freshmen

Academic preparation in high school plays a critical role in students' ability to enroll and succeed in postsecondary education. For example, high school students who completed rigorous curricula were more likely to enroll in a 4-year college, persist through postsecondary education, and earn a bachelor's degree (Adelman 1999 and 2004; Horn and Kojaku 2001). Despite the increasing numbers of U.S. students completing advanced high school courses and even earning college credits by passing AP Exams, many others are poorly prepared for college academic work and need remediation before they are ready to enroll in standard college-level courses. Postsecondary remedial education has been the subject of an ongoing debate among educators, policymakers, and the public (Parsad and Lewis 2003). Although providing remedial courses at 2-year institutions may be necessary and appropriate given the type of students who attend, there is considerable debate about offering remedial courses at 4-year institutions. Proponents argue that remedial education is necessary because it expands educational opportunities for underprepared students; critics counter that college-level remediation should be discouraged because offering courses covering content and skills that should have been learned in high school is both inefficient and costly to the higher education system (Hoyt and Sorenson 2001). A study by Adelman (2004) shows that students who took remedial courses graduated from college at significantly lower rates; no "cause-and-effect" conclusions, however, can be drawn from the study.

In fall 2000, 76% of all degree-granting 2- and 4-year institutions offered at least one remedial reading, writing, or mathematics course (Parsad and Lewis 2003).[50] At these institutions, 28% of freshmen enrolled in at least one remedial reading, writing, or mathematics course (figure 1-32). Freshmen appeared to need more remediation in mathematics than in the other two subjects: 22% undertook remediation in mathematics, compared with 14% in writing and 11% in reading. Freshmen at public 2-year institutions that offered remedial courses were especially likely to receive remedial help: 42% of freshmen at these institutions, compared with 12%–24% of their peers at other types of institutions, enrolled in a remedial course in fall 2000.

Most freshmen took remedial courses for less than a year. However, time spent in remediation was much longer at public 2-year institutions than at other types of institutions. In fall 2000, 63% of public 2-year institutions offering remedial courses reported that the average time a student spent in remediation was 1 year or more, compared with 38% and 17%, respectively, of public and private 4-year institutions offering remedial courses (figure 1-33). The average length of time spent in remediation also increased over time. Between 1995

Figure 1-32
Freshmen enrolled in remedial courses, by subject area and institution type: Fall 2000

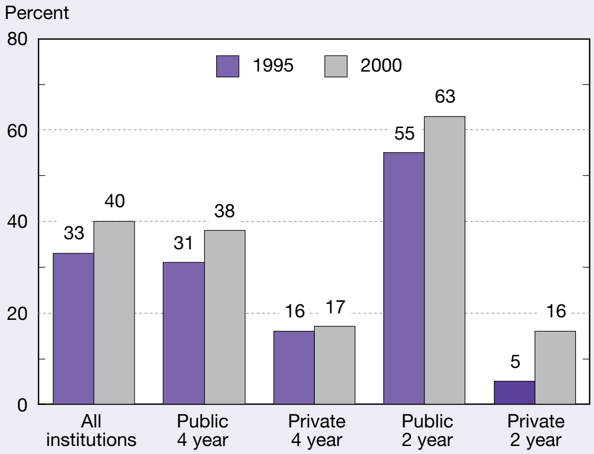


NOTE: Includes only postsecondary institutions that offered remedial courses.

SOURCE: B. Parsad and L. Lewis, *Remedial Education at Degree-Granting Postsecondary Institutions in Fall 2000,* NCES 2004-010, U.S. Department of Education, National Center for Education Statistics (2004).

Science and Engineering Indicators 2006

Figure 1-33
Institutions reporting average time freshmen took remedial courses was 1 year or more, by institution type: Fall 1995 and 2000



NOTE: Includes only postsecondary institutions that offered remedial courses.

SOURCE: B. Parsad and L. Lewis, *Remedial Education at Degree-Granting Postsecondary Institutions in Fall 2000,* NCES 2004-010, U.S. Department of Education, National Center for Education Statistics (2004).

Science and Engineering Indicators 2006

and 2000, the proportion of institutions reporting that the average time spent in remediation was a year or more increased from 33% to 40%. This increase occurred in all types of institutions, except for private 4-year institutions.

Conclusions

Raising academic achievement levels for all students is a top priority for education reform at all levels across the United States. In mathematics and science, improvements in the performance of U.S. elementary and secondary students have been uneven. In mathematics, achievement on NAEP rose from 1990 to 2003 among 4th and 8th graders and from 1990 to 2000 for 12th graders. The mathematics gains occurred in many demographic subgroups. In science, between 1996 and 2000, the average scores changed little at the 4th and 8th grade levels and declined at the 12th grade level.

The proportion of students reaching the proficient achievement level (which is based on judgments of what students should know and be able to do at each grade level) raises additional concerns. In both mathematics and science, most 4th, 8th, and 12th graders did not demonstrate proficiency in the knowledge and skills taught at their grade level. Students from disadvantaged backgrounds lagged behind their more advantaged peers with these disparities starting as early as kindergarten, persisting across grades, and, for some kinds of skills, widening over time.

International assessments also yielded both encouraging and discouraging results. Although U.S. students performed above the international average on the TIMSS tests (which evaluate mastery of curriculum-based knowledge and skills), they performed below the international average on the PISA tests (which assess their ability to apply mathematics and science). However, the number and type of participating countries differed between the two assessments. Furthermore, despite showing some improvement in mathematics and science performance in recent years, U.S. students continued to lag behind their peers in many other developed countries.

Many factors influence student performance, either directly or indirectly. Access to challenging courses, qualified and experienced teachers, school environments that support learning and teaching, and opportunities for using computers and the Internet are all important factors. Educational policies on curriculum standards, testing and accountability, and instructional materials also help define the broad learning context, and their practical effects on curriculum, teaching methods, and learning materials all shape the experiences of teachers and students. Looking at these and other factors affecting education provides a context for the student achievement results reported here.

- **Course offerings.** Access to advanced mathematics courses has increased since 1990, and access to advanced science courses remained nearly universal. In 2000, most high school students had access to advanced mathematics courses, such as trigonometry or algebra III, precalculus, and calculus, and virtually all students had access to advanced science courses such as chemistry, physics, and advanced biology. For most students, however, a significant gap separates current high school graduation requirements from the skill levels needed to succeed in college and to prepare for family-sustaining jobs. Also, despite overall availability of advanced course offerings, access varied by school characteristics. Students attending urban or suburban schools, large schools, or low-poverty schools were generally more likely to be offered advanced mathematics and science courses than those attending rural schools, smaller schools, or high-poverty schools.
- **Coursetaking.** High school students increased their advanced coursetaking in mathematics and science throughout the 1990s, but despite this increase, overall participation in advanced courses remained relatively modest. In 2000, the proportion of high school graduates completing various advanced mathematics courses was 27% or lower, and the proportion completing advanced science courses ranged from 33% for physics and 36% for advanced biology to 63% for chemistry. Even such moderate levels may overstate participation in advanced coursetaking because the definition of advanced used in this report sets a minimal bar: courses that not all students complete and are not widely required for graduation. Some courses included in certain categories may not meet other definitions of advanced that are based on the content and skills they require.

- **Advanced coursetaking differed by school and student characteristics.** Students from rural, smaller, or high-poverty schools were less likely to take advanced mathematics and science courses. Although males and females were equally likely to take advanced mathematics courses, females were more likely to take chemistry and advanced biology courses and males more likely to take physics courses. Asians/Pacific Islanders were generally more likely than other racial/ethnic groups to take advanced mathematics and science courses.
- **Participation in AP programs.** The number of students taking AP tests has grown rapidly since 1990, both overall and specifically in mathematics and science subjects. Female AP test takers were less likely than their male counterparts to earn passing scores, which allow students to earn college credits. Blacks and Hispanics were also less likely than their Asian/Pacific Islander and white peers to earn passing scores.
- **Teacher quality.** College graduates entering the teaching profession tended to have somewhat lower academic skills, as evidenced by their lower rates of participation in rigorous academic courses in high school, lower scores on high school senior achievement tests and college entrance examinations, and lower rates of attending and graduating from selective colleges. Although virtually all mathematics and science teachers held a bachelor's degree and teaching certification, many, particularly those in the high-school grades, were teaching subjects for which they had little academic preparation. This so-called *out-of-field teaching,* measured as teachers lacking either a certificate or a college major or minor in their assigned teaching field, was prevalent in many states and appeared to be increasing over time.
- **Teacher attrition and working conditions.** About 7%–9% of public school mathematics and science teachers left the teaching profession between the 1999 and 2000 academic years. Among those who left, one-third did so for a job outside the field of education, and many of those found more satisfaction with their new job than with teaching. Although some mathematics and science teachers left to pursue more lucrative career opportunities outside education, others left because of poor working conditions in their schools. Data indicate that compared with those who stayed, mathematics and science leavers were less satisfied with teaching in their former schools and expressed less positive views about various aspects of working conditions. These findings suggest that the school environment may play a role in teachers' decisions to leave the profession.
- **Access to and use of IT.** Access to computers and the Internet has become more widespread both at school and at home. Home computer ownership and Internet access continue to differ by family income, parental education, and race/ethnicity, although these gaps are narrowing over the long term. The rapid growth in access to computers and the Internet at school have helped equalize access for disadvantaged students. Most students, especially at the secondary level, used home computers and the Internet for schoolwork, although playing games was also a common activity. About 62% of third grade teachers indicated in 2002 that they felt adequately prepared to use computers for instruction. Third grade teachers' confidence in their IT skills was related to how frequently they assigned their students to use computers and access the Internet.
- **Participation in postsecondary education.** Increasing proportions of students continue their education immediately after high school, but gaps persist among student subpopulations. The gender gap was relatively small and favored females starting in the late 1980s, but gaps by race/ethnicity and family income continued to be large, with lower rates for black and Hispanic students and those from low-income families.
- **Remediation in college.** Despite the rising participation in AP programs and advanced coursetaking, many college freshmen were not ready for college-level work and needed remedial assistance (particularly in mathematics) after their transition to college. Among freshmen taking remedial courses, most spent less than a year in remediation, but trends indicate increases in the average length of time spent. It is possible that the rising immediate college enrollment rate is partially responsible for the increased need for remediation among college freshmen.

The indicators presented in this chapter provide an overview of the conditions of U.S. mathematics and science education. The results show both improvement and weaknesses in its various aspects. The tasks of encouraging students to take more rigorous academic courses, improving the overall quality of the teaching force, and creating better working environments for both students and teachers will remain a critical challenge as the nation seeks to improve the achievement of all students.

Notes

1. A series of reports based on data from the ECLS-K study and released by the National Center for Education Statistics (NCES) can be found at: http://nces.ed.gov/ecls.

2. The ECLS-K assessment measures students' overall mathematics achievement through both scale scores and their specific mathematics skills and knowledge as measured through a set of proficiency scores. The scale scores place students on a continuous ability scale based on their overall performance on the assessment, whereas the proficiency scores are based on clusters of items assessing particular skills and report whether students mastered those skills. When describing gains over the kindergarten year, this review focuses on proficiency in specific areas. When reporting on growth in achievement from kindergarten to third grade, scale scores are discussed. For more information on the ECLS assessment battery and scoring, including the Item

Response Theory (IRT) methodology used, see Rathbun and West (2004) and West, Denton, and Reaney (2000).

3. The studies reviewed in this chapter report combined results for Asians and Pacific Islanders. It is important to note that this category combines groups that have very different cultural and historical backgrounds, and whose achievement varies widely.

4. In later years of the ECLS-K study, family income below the federal poverty level was substituted for the welfare assistance risk factor. Students were classified as having no family risk factors, one risk factor, or two or more risk factors.

5. About 10% of the cohort was in second grade, and another 1% was in another grade. For the sake of simplicity, the students in the 2002 followup are referred to as third graders.

6. Trends in mathematics and science performance by gender are not easily summarized, with girls outperforming boys in some age groups and boys outperforming girls in other cases. See *Science and Engineering Indicators – 2004*, page 1-7, for more details on long-term trends in mathematics and science performance of males and females. See sidebar in this issue "Long-Term Trends in Student Mathematics Achievement."

7. Students were identified as attending private schools continuously, attending public schools continuously, or attending a combination of private and public schools between the beginning of kindergarten and the end of third grade. There were no statistically significant differences in gains in average mathematics scores across these three groups.

8. Because students have been assessed in science only once in the ECLS, the study has thus far produced less information on science learning. As of yet, only science scale scores have been reported. As the study continues to follow these students, future reports will likely provide more detail on science achievement.

9. 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.

10. These recent trends are based on data from the national NAEP program. The current national mathematics assessment was first administered in 1990 and was given again in 1992, 1996, 2000, and 2003. In 2003, only fourth and eighth grade students were assessed. The current national science assessment was first administered in 1996 and was given again in 2000 and 2005. The 2005 results were not available in time for inclusion.

11. The 2002 and 2004 volumes reviewed trends in science from 1969 to 1999 and in mathematics from 1973 to 1999. The long-term trend assessment in mathematics was administered again in 2004, but those data were not released in time to be included in the text of this chapter (see sidebar "Long-Term Trends in Student Mathematics Achievement"). The long-term trend assessment in science has not been given since 1999.

12. NAEP is in the process of changing the way it includes students with disabilities and limited English proficiency in assessments. Before 1996, these students were not allowed to use testing accommodations (e.g., extended time, one-on-one testing, bilingual dictionary); as a result, many did not participate. In 1996 and 2000, the assessment was administered to split samples of "accommodations not permitted" and "accommodations permitted." In 2003, the NAEP mathematics assessment completed the transition to an "accommodations permitted" test.

13. Using eligibility for the free or reduced-price lunch program as a proxy for family poverty is not as reliable in the higher grades because older students may attach stigma to receiving a school lunch subsidy.

14. Sample size was insufficient to permit reliable mathematics estimates for American Indian/Alaska Natives prior to 1996 for grades 4 and 12 and prior to 2000 for grade 8.

15. NCES did not publish 2000 science scores for fourth grade Asian/Pacific Islander students because of accuracy and precision concerns; therefore, those scores are not included.

16. In science, the apparent difference at grade 12 in average scale scores by gender was not statistically significant. However, a greater proportion of 12th grade boys reached the proficient level in science than did girls.

17. For detailed racial/ethnic group comparisons see NCES (2003, 2001a, 2001b).

18. The primary grade assessed in each country was "the upper of the two adjacent grades with the most 9-year-olds" (Mullis et al. 2005). In the United States, and most other countries, this was the fourth grade. The middle grade assessed was defined as the "upper of the two adjacent grades with the most 13-year-olds." In the United States and most countries, this was the eighth grade. Students in their final year of secondary school (12th grade in the United States) were assessed with TIMSS in 1995. For a review of those results, see page 1-14 in *Science and Engineering Indicators – 2004* or Takahira et al. (1998). Subsequent TIMSS administrations have focused on the middle grades.

19. To be assessed in TIMSS, the specific content domains and topics had to be included in the curricula of "a significant number of participating countries" (Mullis et al. 2005). It is important to note that whereas the TIMSS program identified common mathematics and science curriculum across participating countries, there are many differences in the way countries delivered that curriculum and in their breadth of coverage (Sherman, Honegeger, and McGivern 2003).

20. More information about TIMSS and PISA assessments can be found at http://nces.ed.gov/TIMSS/ and http://nces.ed.gov/Surveys/PISA/.

21. Of the 14 other countries that participated in both the 1995 and 2003 grade 4 TIMSS mathematics assessments, the United States was outperformed by four countries in 1995 and by seven countries in 2003. Of the 21 other countries that participated in both the 1995 and 2003 grade 8 mathematics assessments, 12 had average scores higher than the U.S. average score in 1995 and 7 had higher scores in 2003.

22. Of the 14 other countries that participated in both the 1995 and 2003 grade 4 TIMSS mathematics assessments, only 1 had a higher average score than the United States in 1995, but 2 did in 2003. At grade 8, of the 21 countries that participated in both years, 9 had higher average scores than the United States in 1995, whereas 5 did in 2003.

23. Forty-one countries participated in the 2003 PISA assessment—30 OECD member countries and 11 non-OECD countries. This section summarizes a report released by NCES (2004c) that presents PISA results from a U.S. perspective. That report omitted data from the United Kingdom because of low response rates and from Brazil because these data were not yet available. That report and this section compare U.S. averages first to OECD averages (i.e., average of national averages from the 29 OECD countries for which data were available, including the United States) and, second, to individual country averages (both OECD and non-OECD countries).

24. Data for both 2000 and 2003 are available for 26 OECD countries, including the United States. Of these countries, nine improved their science scores and five registered declines.

25. Comparing change in mathematics performance is complicated by the fact that the 2003 PISA assessment was more extensive than the 2000 assessment. In 2000, two content areas were assessed: *space and shape* and *change and relationship.* In 2003, those two areas, along with two additional content areas (*quantity* and *uncertainty*) were tested. Thus, change in mathematics performance can be examined only for the two content areas assessed in both years. The average scores for U.S. students did not change from 2000 to 2003 on either the *space and shape* or the *change and relationship* content areas. Of the 25 other countries that participated in both assessment years, 18 outperformed the United States in the *space and shape* area in 2003 compared with 19 in 2000. In the *change and relationship* area, 17 countries outperformed the United States in 2003, and 14 did in 2000.

26. Even in these three states, students and parents may choose a less rigorous program, but these requirements are the default. These requirements were in effect in Texas for the class of 2008 and were scheduled to begin in the near future in Arkansas and Indiana.

27. The data on courses offered and completed are from the NAEP High School Transcript Study from 1990 to 2000. A caveat: courses are classified based on titles and content descriptions. However, material studied, methods used, and overall difficulty can differ widely across schools for courses with similar titles or in the same category.

28. It may seem odd that the calculus courses percentage is larger than the precalculus percentage. However, although most students would be required to study precalculus or similar content to prepare for calculus, in some schools such material may be taught in a course such as trigonometry or algebra III, or even, in rare cases, in a course not included in the categories shown in the table.

29. Coursetaking and course completion are used interchangeably in this section. The NAEP data show credits for specific courses; students earn credits by completing a course and earning a passing grade.

30. Percentages taking courses are percentages of all graduates who had complete transcripts rather than of the subset who had access to each type of course.

31. A single exception qualifies this statement: Asian/Pacific Islander graduates did not differ from graduates in the group classified as "other" in the likelihood of completing a statistics course.

32. 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.

33. Teaching experience is another indicator of teacher quality and was examined in the 2004 edition of *Science and Engineering Indicators*. Because of a lack of national data, that indicator cannot be examined in this edition. Other factors may also play important roles in teacher quality, including 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.

34. Other research has found that teachers tend to have higher undergraduate GPAs than other graduates (Frankel and Stowe 1990; Gray et al. 1993; Henke et al. 1996). However, grades are not standardized among or within institutions, which makes it difficult to compare teachers' academic performance with that of other graduates.

35. Full certification refers to a state's regular, standard, advanced, or probationary certificate. It does not include

temporary, alternative, provisional, or emergency certificates granted to those who have not fulfilled requirements for licensing. These teachers are referred to as "not fully certified."

36. Researchers often cited teacher shortages as a major reason for this decline, claiming that increasing student enrollment, reduction of class sizes, high rates of teacher turnover, and lack of qualified candidates have created teacher shortages, which in turn have forced schools and districts to hire less-qualified candidates to fill vacancies (Boe and Gilford 1992; Howard 2003). This explanation, however, has not been empirically demonstrated.

37. The purpose of the LSC project is to improve the teaching of science, mathematics, and technology by focusing on the professional development of teachers within whole schools or districts. Each participating teacher is required to have a minimum of 130 hours of professional development over the course of the project. The training focuses on preparing teachers to implement designated exemplary mathematics and science instructional materials in their classrooms (Weiss, Banilower, and Shimkus 2004).

38. Data on weekly pay of teachers come from the Bureau of Labor Statistics' Current Population Survey (CPS). Weekly earnings were either reported directly by respondents or estimated using the number of weeks worked and annual, monthly, or biweekly earnings.

39. *Statutory salaries* refers to salaries set by official pay scales. These figures should be distinguished from the actual salaries teachers receive. The 2002 U.S. salaries were estimated from average scheduled salaries from the 1999–2000 SASS. The 1999–2000 figures were adjusted for inflation by 3.8% for 2000–01 and an additional 2.9% for 2001–02 (OECD 2004).

40. Differences in other items also appear large, but are not statistically significant, because of large standard errors associated with mathematics and science teacher leavers.

41. About 90% of students in the sample were in third grade at the time of the followup survey; most of the remaining 10% were in second grade.

42. Data on computer tasks apply to students' use of home computers only, whereas the Internet tasks and frequency of use apply to Internet use at any location. The percentages in appendix table 1-28 discussed in this section are based only on students who had access to computers at home and access to the Internet anywhere, whereas in appendix table 1-26 and the text on access, the base for percentages is all students in K–12.

43. Teachers in the Teacher Followup Survey for 2000–01 were divided into three groups based on their main assignment field: elementary if it was kindergarten, general elementary, or early childhood special education; mathematics or science if the subject was in those fields; and other for all other fields. The latter two categories consist primarily of secondary grade teachers.

44. Causality may not flow in only one direction, however. For example, teachers who are required to use IT resources may seek out more training, and school leaders who emphasize teaching with technology may strongly encourage teachers both to participate in IT training and to use computers frequently.

45. There are different ways to estimate dropout rates. This rate, typically called the "status dropout rate," represents the percentage of an age group not enrolled in school and not holding a high school credential (i.e., diploma or equivalent, such as a General Educational Development [GED] certificate).

46. The base for immediate enrollment rates is the population of high school graduates. The rates would be lower if all high school students, including dropouts, were considered.

47. OECD calculates the first-time entry rates for its member countries by dividing the number of first-time entrants of a specific age in each type of tertiary education by the total population in the corresponding age group and then adding the results for each single year of age (OECD 2003a). The purpose is to make the rates comparable across countries with different college entry ages. First-time entry rates for tertiary-type A and B programs cannot be added together to obtain the total tertiary-level entry rate because entrants into both types of programs would be counted twice.

48. This distinction is fairly general. Some U.S. community colleges offer strong transition programs and make their courses equivalent to the lower-division courses of 4-year institutions, and therefore resemble 4-year institutions. On the other hand, vocationally oriented courses are not offered exclusively in community colleges; many 4-year institutions also offer such courses. In addition, the U.S higher education system and those of other countries are different, so simple comparisons may lead to inaccurate conclusions.

49. First-time entry rates cannot be directly compared with immediate college enrollment rates because of the different population bases and calculation methods for the two measures. In computing immediate college enrollment rates, the base is all high school graduates. In calculating first-time entry rates, the base is a country's population.

50. Depending on institutional requirements, courses considered "remedial" may vary across postsecondary institutions.

Glossary

Advanced Placement: An opportunity to study college-level material while in high school and to demonstrate advanced proficiency in a subject by passing a rigorous exam.

Digital divide: The gap between those with access to new technologies and those without; this division tends to fall along socioeconomic and racial/ethnic lines.

International Baccalaureate: An internationally recognized preuniversity course of study designed for secondary school students.

Out-of-field teaching: A mismatch between the subjects a teacher teaches and that teacher's academic training and/or certification.

Time-based course requirements: Requirements based on the number of years a student should take a particular subject; this type of requirement is losing popularity to those that set standards for the skills and content students need to learn.

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