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ABSTRACT

This paper draws on new data from four recent surveys, and outlines national and state indicators on three key questions concerning progress in science and mathematics education: (1) Are students receiving more instruction in science and mathematics now than 10 years ago? (2) Has the supply of qualified teachers in science and mathematics improved? and (2) Are students learning more science and mathematics? Data and findings from the national transcript studies of high school graduates conducted by the National Center for Education Statistics (NCES), the National Assessment of Education Progress (NAEP) assessments in science and mathematics, the Council of Chief State School Officers' State Indicators of Science and Mathematics Education, and the NCES Schools and Staffing Survey were used to address these questions. The analyses show that some improvements have been made in all three areas. High school course enrollments in science and mathematics have risen significantly. Scores on the NAEP science and mathematics assessments have increased since 1982, particularly for students at ages 9 and 17; however, the level of student proficiency is still too low. In mathematics, U.S. students score below the level of proficiency that is expected for their age and grade level. There is wide variation by state in course enrollments and student achievement. Most states have not experienced shortages of science and mathematics teachers but this general picture can mask shortages of teachers with strong preparation in science and mathematics as well as greater teacher shortages in school with more poor and minority students. (45 references) (KR)

Council of Chief State School Officers
State Education Assessment Center

Science and Mathematics Indicators Project

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HAS SCIENCE AND MATHEMATICS EDUCATION IMPROVED SINCE A NATION AT RISK?

Trends in Course Enrollments, Qualified Teachers, and Student Achievement

Rolf K. Blank and Pamela Engler

Improving student learning in mathematics and science is a high priority for our elementary and secondary schools. The national educational goals of the President and governors, set in 1990, state that science and mathematics achievement of American high school graduates will be first in the world by the year 2000. In September 1991, the National Education Goals Panel recommended measures to be used in tracking progress toward the goal and reported baseline data on several measures. The Panel set high expectations for improving the quality of science and mathematics. As policymakers and educators plan initiatives for working toward Goal 4 on science and mathematics achievement, it may be helpful to assess the progress that has been made over the past decade in response to the calls for education reform in the early 1980's.

National Commissions and State Policy Reforms

In the early 1980's many national and state reports made recommendations for reform of our education system (National Commission on Excellence in Education, 1983; National Science Board Commission on Precollege Mathematics, Science, and Technology Education, 1983; Task Force on Education for Economic Growth, 1983; Twentieth Century Fund, 1983). The report of the National Commission on Excellence in Education, A Nation at Risk: The Imperative for Education Reform, received the most attention and response. The Excellence Commission deplored a "rising tide of mediocrity" in our education system and identified specific problems in the areas of science and mathematics. The report noted the poor performance of American students on international assessments in science and mathematics, declining average scores on national achievement tests, and the relatively small amount of science and mathematics instruction received by the average American student. The Excellence Commission recommended that three mathematics and three science courses be required for high school graduation and that science be made a "new basic" in elementary school.

National commission reports also highlighted the problem of underqualified teachers in science and mathematics and impending teacher shortages (National Science Board, 1983; Carnegie Forum on Education and the Economy, 1986). In the early 1980's national experts saw a major problem in insufficient preparation of teachers in science and mathematics, particularly at the elementary and middle school levels (Johnston and Aldridge, 1984). Other data showed that many well-qualified science and mathematics teachers were leaving teaching, few new graduates in science and mathematics were going into teaching, and many science and mathematics teachers would be retiring in the 1990's (Aldrich, 1983; Darling-Hammond, 1984).

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States took the lead in responding to A Nation at Risk and other national commission reports (National Governors Association, 1986). States increased course credit requirements for graduation (particularly in mathematics and science), raised standards for teacher preparation, mandated teacher tests for certification, set higher levels for teacher pay, developed state curriculum guidelines and frameworks, and established new statewide student assessments (Blank and Espenshade, 1988; Goertz, 1988; CCSSO, 1989).

Studies of State Reforms. Debate has arisen concerning the effects of the state policy initiatives on education reform at the district, school, and classroom levels. One argument is that the state policy changes do not have substantial or lasting effects on how schools are organized, on the curriculum that is actually taught in classrooms, or on how teachers teach (Fuhrman et al, 1988; Firestone, et al. 1989; Smith and O'Day, 1991; David, et al, 1990). Another position is that state policy reforms did increase the amount of time spent on core academic subjects and improved student learning of basic skills, but that teaching and learning of higher order thinking skills were not advanced (Clune et al. 1989; ETS Policy Information Center, 1990). Some state policymakers argue that, while there is evidence that state reforms have produced improvements in science and mathematics education, more needs to be done. (Connecticut Department of Education, 1989; Honig, 1990; California Department of Education, 1991).

Much of the debate about effects of state policies is based on analyses of education reforms in one state or a small number of states. National and state-by-state data are now available for assessing state policy reforms. This paper summarizes some of the evidence concerning key indicators of change in science and mathematics education.

Three questions are addressed:

(1) Are students receiving more instruction in science and mathematics now than 10 years ago?
(2) Has the supply of qualified teachers in science and mathematics improved?
(3) Are students learning more science and mathematics?

Data and findings from four sources are used to address these questions: National transcript studies of high school graduates conducted by the National Center for Education Statistics (NCES), the National Assessment of Educational Progress (NAEP) assessments in science and mathematics, the Council of Chief State School Officers' State Indicators of Science and Mathematics Education, and the NCES Schools and Staffing Survey.

1. Are Students Receiving More Instruction in Science and Mathematics?

One of the common responses from state legislatures and state boards of education to calls for state education reforms was to raise course credit requirements in science and mathematics. From 1980 to 1987, 43 states increased mathematics course requirements for graduation and 40 states increased science requirements (Education Commission of the States, 1984; Blank and Espenshade, 1988). The number of states mandating or recommending a specific amount of time for science and mathematics instruction in elementary grades increased to 26 states by 1987 (Blank and Espenshade, 1988). One way of measuring the effect of this policy approach for improving science and mathematics is to determine the extent of change in student course taking in science and mathematics.

Rates of course enrollments by course level indicate the proportion of students advancing through the secondary science and mathematics curriculum. The rate of course taking in science and mathematics is also an important indicator because of the relationship between course-taking and student learning in these subjects. Research with large national surveys and international surveys (e.g., National Assessment of Education Progress, National Longitudinal Study, High School and Beyond, Second IEA Mathematics Assessment) demonstrates that there is a direct, positive relationship between the amount of elementary instructional time and secondary course taking in science and mathematics and the rate of student learning in these subjects (Jones, et al., 1986; Dossey, et al., 1988; Mullis, et al., 1988; Rock, et al., 1985; McKnight, et al., 1987; National Center for Education Statistics, 1991b). Walberg conducted a quantitative synthesis of 3,000 studies and identified instructional time as one of the nine "productive factors" in learning in schools (1984). Sebring found a positive relationship between science and mathematics course taking and College Board achievement test scores for students in California and New York (1987).

State-by-state course taking data were collected in 1989-90 and reported by the Council of Chief State School Officers (CCSSO) through a system of state indicators

(Blank and Dalkilic, 1990)[1]. National trends in high school course enrollments can be assessed by comparing the 1990 data with data from transcripts of nationally representative samples of high school seniors in 1982 (High School and Beyond Study) and 1987 (National Transcript Study) (Kolstad and Thorne, 1989).

o **Enrollments increased in science and mathematics "gatekeeper" courses from 1982 to 1990.** The percentage of students taking algebra 1 by the time they graduate increased from 65 percent in 1982 to 81 percent in 1990, the percentage taking algebra 2 went from 35 percent to 49 percent, and calculus enrollments increased from 5 percent to 9 percent. The percentage of students taking first year biology by the time they graduate increased from 75 percent in 1982 to 95 percent in 1990, the percentage taking chemistry went from 31 percent to 45 percent, and physics enrollments increased from 14 percent to 20 percent. Enrollments increased at all levels of high school science and mathematics during the 1980's. Rates increased more in lower level courses, such as algebra 1 and biology, than in upper level courses.

Trends in Course Taking in Science and Mathematics

	% Students Enrolled 1982	% Students Enrolled 1990
Algebra 1	65%	81%
Algebra 2	35	49
Calculus	5	9
Biology, 1st Year	75	95
Chemistry	31	45
Physics	14	20

High School and Beyond data for 1982, Kolstad and Thorne, 1989; State data for 1990, Blank and Dalkilic, 1990

o **Enrollments in science and mathematics vary widely by state.** An example of state-to-state differences in course taking is the variation in the proportion of students taking algebra 2. In Montana, 65 percent of students take algebra 2 while in Hawaii only 33 percent take mathematics at this level. As of 1989-90, 20 of 38 states reported more than 50 percent of students take algebra 2. The proportion of students taking chemistry by the time they graduate varies from 62 percent in Connecticut to 26 percent in Idaho. As of 1989-90, 11 of 38 states reported more than 50 percent of students taking chemistry (Blank and Dalkilic, 1990). Tables 1 and 2 (attached) provide state-by-state data on course enrollments for three levels of high school science and mathematics.

o **Gender differences in course taking are at advanced levels.** Sixteen states reported science and mathematics course enrollments by student gender in 1989-90. The data from these states show that rates of course taking are equivalent for male and female students from junior high courses up through trigonometry (in mathematics) and chemistry (in science). Differences occur in the advanced courses. On average, boys comprise 55 percent of enrollees in calculus and 60 percent of enrollees in physics; girls comprise 55 percent of enrollees in advanced/second year biology (Blank and Dalkilic, 1990). A comparison of the state figures to national statistics from 1982 (Kolstad and Thorne, 1989) shows that the rate at which girls take advanced mathematics and physics increased about three percent during the 1980's.

o **Participation in science and mathematics differs widely by student race/ethnicity.** Data from the national transcript study in 1987 show that science and mathematics enrollments are highest for Asian students and lowest for African-American and Hispanic students. For example, the percentage of students taking algebra 2 were: Asian--67 percent, white 52 percent, African-American--32 percent, and Hispanic--30 percent. The percentage of students taking chemistry were: Asian--70 percent, white--48 percent, African-American--30 percent, and Hispanic--29 percent (Kolstad and Thorne, 1989).

o **Science and mathematics enrollments as of 1990 are below recommendations of Excellence Commission.** Enrollments in science and mathematics increased in the 1980's but the rate did not reach the level recommended by the National Commission on Excellence in Education. The 49 percent rate for algebra 2 in 1990 indicates the proportion of graduates that take three years of high

1 In the 1989-90 school year, 38 states collected and reported data on enrollments in science and mathematics of public school students in grades 9-12. States reported the data to CCSSO using common reporting categories which provide the basis for valid state-to-state comparisons. CCSSO researchers used statistical analyses to calculate national estimates from the state data. The science and mathematics indicators were developed through support of the National Science Foundation, Office of Studies, Evaluation, and Dissemination.

school mathematics, since algebra 2 is typically the third course in the high school mathematics curriculum. The 45 percent rate for chemistry in 1990 indicates the proportion of students who take three years of high school science. Thus, by 1990 not quite half of American graduates met the standard for high school science and mathematics recommended by the Excellence Commission.[2]

o **Large high school enrollments in lower level mathematics courses.** In the fall of 1989, 84 percent of all students in grades 9-12 were taking a course in mathematics. Over one-fourth of the students (27%) were taking a course at a level prior to algebra 1, i.e., general mathematics, vocational/business mathematics, or pre-algebra (Blank and Dalkilic, 1990). Thus, to meet state graduation requirements, many students are taking mathematics courses which are generally not in the high school mathematics curriculum.

o **States with higher requirements have more overall course taking in science and mathematics and slightly more upper level course taking.** The data on course taking confirm that the amount of science and mathematics instruction did increase in the time period after states set higher graduation requirements. Were increases the result of changing state requirements? The 1990 CCSSO data show that states requiring 2.5 to 3 credits (13 states in mathematics, 6 states in science) had an average of 10 percent higher enrollments overall in mathematics and science than states requiring two credits (34 states mathematics, 38 states science). The high-requirement states have two to four percent more students taking upper level science and mathematics courses (e.g., chemistry, physics, geometry, algebra 2, trigonometry) (Blank and Dalkilic, 1990). Thus, the cross-sectional data from 1989-90 show that students take more courses in states with higher requirements. However, they do not necessarily take higher level courses. Data show there is a weak relationship between state requirements and enrollments in upper level science and mathematics courses. This issue will be studied further as state trend data are available through CCSSO.

In sum, course taking data indicate that American high school students are now taking more science and mathematics courses in high school at all levels, and the data suggest that state policies are related to the increased enrollments. However, the rates of increased course taking are smaller for more advanced courses such as chemistry, physics, trigonometry, and calculus.

2. Has the Supply of Qualified Teachers in Science and Mathematics Improved?

Central to policy reforms in the 1980's many states began initiatives aimed at improving the supply and quality of teachers. State policies increased incentives for entering and staying in teaching. For example, many states raised the minimum pay scale for teachers, and about half established alternative certification policies (CCSSO, 1989). States also developed loan and scholarship programs in critical teaching fields. At the same time, states raised standards for becoming a teacher. For example, by 1987 all states had specific state requirements for the amount of subject area preparation for certification of science and mathematics teachers (Blank and Espenshade, 1988). In addition, 36 states mandated written tests of teacher knowledge for certification (ETS Policy Information Center, 1990).

These policy initiatives responded to predictions that supply of qualified teachers was declining and existing teachers were insufficiently prepared, particularly in science and mathematics. Now, as we enter the 1990's, it is important to assess whether the condition of the teaching force in science and mathematics has improved and whether predictions of severe shortages in the 1990's are still likely. One of the major objectives under Goal 4 on science and mathematics is to "increase by 50% the number of teachers with a substantive background in science and mathematics" (National Governors Association, 1990). Two national panels have recently outlined the need for improved data on teacher supply, demand, and quality (National Research Council, 1990; NEGP, 1991). At present, some data are available from the NCES Schools and Staffing Survey and the CCSSO Science and Mathematics Indicators to assess key indicators of supply and shortages of qualified science and mathematics teachers.

Current Teacher Supply in Science and Mathematics

In 1989-90, there were approximately 111 thousand teachers of mathematics and 102 thousand teachers of science in public high schools in the 50 states and the District of Columbia (Blank and Dalkilic, 1990). This compares with 10.8 million students in grades 9-12 enrolled in public schools, (NCES, 1990), or an average

2 The average number of credits earned in mathematics increased from 2.4 in 1982 to 2.98 in 1987 (these statistics included lower level courses such as general mathematics and pre-algebra), and the average number of credits in science increased from 2.19 in 1982 to 2.63 in 1987, which is an increase of half a credit in each subject (Kolstad and Thorne, 1989).

of 107 students per mathematics teacher and 116 students per science teacher.[3]

Considering these overall numbers of students and teachers, what data are available to tell us if the supply of teachers for our schools has improved or declined? A first level of analysis is whether school districts are able to hire teachers to put in science and mathematics classrooms, i.e., the availability of new or continuing teachers, without considering teacher quality.

o **Low attrition rate of teachers.** The supply of teachers did not decline during the 1980's due to high attrition. The attrition rate of teachers is now relatively low--about 5 percent per year for science and mathematics teachers as well as for all public school teachers (Bobbitt, 1991). However, attrition rates are higher for teachers in the physical sciences, due to more professional opportunities outside of teaching that offer significantly higher pay (Murnane, et al, 1988).

o **Teachers reaching retirement age varies by state; rate of retirement will increase in mid 1990's.** Data on the ages of current teachers allow projections of potential shortages due to retirements. In 1989-90, state data showed that 19 percent of high school mathematics teachers and approximately 22 percent of science teachers were over age 50, while 21 percent of all high school teachers were over age 50. Thus, as a national average, science and mathematics teachers will not be retiring more rapidly than other teachers. However, the proportion of science and mathematics teachers over age 50 varies by state from 10 percent to over 30 percent. A shortage of science and mathematics teachers can be anticipated in a few states that have much higher percentages of their teaching force over 50 than other states. These states include Minnesota, Delaware, California, Michigan, and Illinois (Blank and Dalkilic, 1990). Projections by NCES show that attrition rates will rise to almost 10 percent after 1995 due to increasing retirement (NCES, 1989).

Percentage of Teachers Over Age 50

	Math	Biology	Chemistry	Physics
National Average	19%	20%	22%	23%
California	26%	21%	23%	22%
Connecticut	20	24	27	29
Delaware	28	23	41	29
Illinois	23	28	30	32
Michigan	24	26	33	29
Minnesota	29	30	45	43
Wisconsin	21	27	28	30

Blank and Dalkilic, 1990

o **More new hires from reserve pool and more college graduates in science and math education.** In 1987-88, about seven percent of all teachers were new hires (NCES, 1991a). This rate was constant during the 1980's (Kirby, et al, 1991). However, in the 1980's school districts depended less on new college graduates for new hires than in the past. NCES found that in 1988, only 26 percent of new hires were first-year teachers (Rollefson, 1991). In some districts, over half of new hires were from the "reserve pool" of teachers who left teaching and returned (NRC, 1990; Kirby, et al, 1991). Hiring from the reserve pool went up sharply in the 1980's. At the same time, efforts in the 1980's to encourage more science and mathematics teachers appear to have worked because the number of new certified college graduates in science and mathematics teaching increased (Lauritzen, 1990). The number of 1988 college graduates with majors in mathematics education was more than twice the number in 1982 (2,250 vs. 1,000), and the number of graduates with part-time majors in science education doubled in the same period (2,200 in 1988 vs. 950 in 1982) (NCES, 1985, 1990).

3 Students per teacher averages adjusted by the number of part-time teachers of science and mathematics.

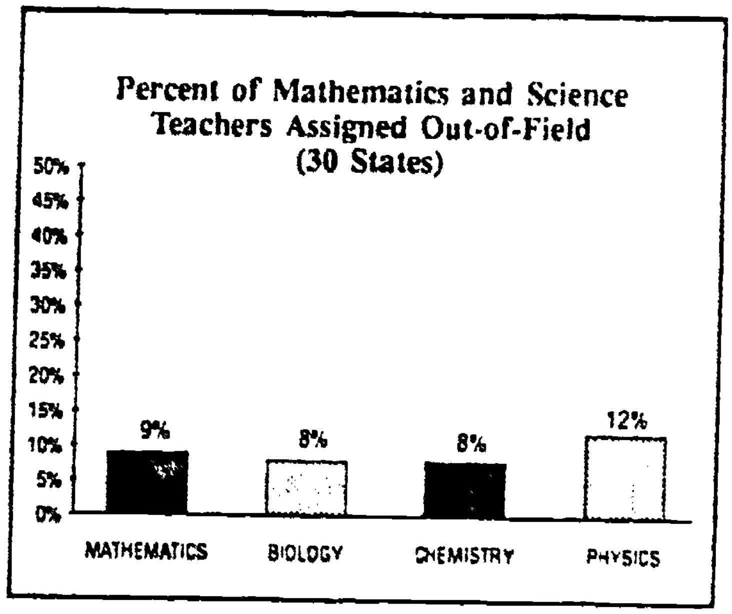
o **Shortage of chemistry and physics teachers.** National data for the 1987-88 school year show that only one percent of all teaching positions were unfilled (NCES, 1991a). However, school principals report that physics and chemistry teachers are harder to hire than teachers in any other field (Weiss, 1987). According to state data in 11 states, there are more high schools than the total number of assigned chemistry teachers, and in 28 states there are more high schools than the total number of assigned physics teachers. The number of assigned physics teachers is less than one-half the number of high schools in Illinois, Michigan, Mississippi, New Hampshire, Oklahoma, and Utah (Blank and Dalkilic, 1990).

Supply of Qualified Science and Mathematics Teachers

To address the question of whether there is an adequate teacher supply also requires application of a criterion of a "qualified" teacher in science and mathematics. For example, the criterion used by the National Education Goals Panel is the proportion of science and mathematics teachers in each state with a college major in their assigned field of teaching (NEGP, 1991). Another definition of qualified has been based on the standards established by the professional science and mathematics teacher associations (Weiss, 1989; National Science Board, 1989). A definition often used by states is whether a teacher is state-certified in the assigned teaching field (Blank and Dalkiiic, 1990). Data are available to examine the supply of qualified teachers using several different indicators.

o **1 of 11 science and mathematics teachers not certified in assigned field (assigned out-of-field).** CCSSO data from states show that nine percent of high school mathematics teachers are not certified in mathematics, and eight percent of biology teachers, eight percent of chemistry teachers, and 12 percent of physics teachers are not certified in these fields.[4] State-by-state analyses of teacher certification show that some states have 20 to 30 percent of mathematics and science teachers assigned "out-of-field" while a few states have no teachers assigned out-of-field. The state data show that states with more out-of-field teachers have many small, rural districts (e.g. South Dakota, Illinois, Mississippi) or states experiencing rapid population growth (e.g. California).

4 These figures include teachers with a primary, secondary, or one period assignment.



Out-of-Field = Not state certified in assigned field
Blank and Dalkilic, 1990

o **One-half of science and mathematics teachers majored in their teaching field.** The NCES Schools and Staffing Survey provided data on the proportion of teachers in science and mathematics with a college major in their assigned teaching field. The data show that 42 percent of all high school teachers of mathematics have a mathematics major, and 54 percent of all teachers of science majored in a science field. The percent of teachers with majors in mathematics varies by state from 20 percent (Louisiana) to 62 percent (Kentucky), and in science from 31 percent (Louisiana) to 73 percent (Minnesota, Missouri) (Blank and Dalkilic, 1990; National Education Goals Panel, 1991). Table 3 (attached) provides state-by-state percentages of teachers that majored in mathematics, mathematics education, science, and science education.

Equity in the Teaching Force

Another consideration in analyzing the supply of science and mathematics teachers is equity, i.e., the extent to which gender and race/ethnicity of teachers matches the characteristics of students. Oakes (1990b) found that the rate of participation of female and minority students in science and mathematics courses is related to the presence of female and minority teachers.

7

o The proportion of female teachers in science and mathematics varies widely by state. The majority of high school science and mathematics teachers are male, but the gender distribution varies by field and by state. For example, 45 percent of mathematics teachers are female, while 22 percent of physics teachers are female. The percent of female teachers in mathematics varies by state from 21 percent (Minnesota) to 69 percent (South Carolina), and the percent of female teachers in physics varies by state from 10 percent (Michigan, Minnesota, Utah) to 49 percent (Alabama) (Blank and Dalkilic, 1990).

Gender of Mathematics and Science Teachers

	Percent Female	Percent Male
Mathematics	45%	55%
Biology	37	63
Chemistry	34	66
Physics	22	78
All Public High School Teachers	50	50

Blank and Dalkilic, 1990

o Shortage of minority teachers in all science and mathematics fields. State data on the race/ethnicity of high school science and mathematics teachers show that there is a wide disparity between the supply of minority science and mathematics teachers and the number of minority students in virtually all states. The proportion of minority teachers are: mathematics--11 percent, biology--10 percent, chemistry--7 percent, and physics--5 percent, while 11 percent of all high school teachers are from minority groups (Blank and Dalkilic, 1990). The student population in our public schools is 32 percent minority. Table 4 (attached) summarizes the state-by-state data on minority teachers and minority students. From 1982 to 1987 the percent of all public school teachers that are from minority groups increased two percent (from 8 to 10 percent), and the proportion of teachers who are African-American declined by one percent (NCES, 1990).

Minority and White Teachers in Mathematics and Science

	Percent Minority	Percent White
Mathematics	11%	89%
Biology	10	90
Chemistry	7	93
Physics	5	95
All Public High Schools	11	89

Blank and Dalkilic, 1990

o Fewer qualified teachers in schools with high percent of disadvantaged and minority students. Oakes (1990a) analyzed the qualifications of science and mathematics teachers by student and school characteristics and found that inner-city schools and schools with more disadvantaged and minority students have a significantly lower proportion of well-qualified teachers than other schools.

Other Factors in Analyzing Teachers. The data presented here on supply and shortages of science and mathematics teachers provide some indicators of the condition of science and mathematics teaching in our schools. To obtain a complete analysis, several other factors should be considered. For example, a key variable is the effects of increased demand in the future, such as from higher enrollments in high school and mathematics. The data have addressed teacher supply and shortages in high school science and mathematics, but shortages of qualified teachers may be more acute at the middle school/junior high level. Also, recent research has found that the average elementary classroom teacher has poor preparation in science and limited preparation in mathematics (Weiss, 1989). Finally, the indicators of "qualified teachers" do not measure actual teaching skills or practices, rather they measure the teacher's preparation for teaching in their subject. The National Education Goals Panel has recommended the collection and reporting of more detailed information on teaching skills and practices.

In sum, the current data on science and mathematics teachers lead to three general findings: first, some indicators of teacher shortages have improved since the early 1980's; second, teacher shortages vary by specialty within science and mathematics and by state; and, third, the criterion of a "qualified teacher" needs to be specified to determine shortages of science and mathematics teachers. We also know that shortages are greater in certain types of school districts and schools.

3. Are Students Learning More Science and Mathematics?

The National Assessment of Educational Progress (NAEP) has been monitoring the knowledge and skills of American students in science and mathematics since 1970. Nationally-representative samples of students at ages 9, 13, and 17 have been assessed every two to four years in science and mathematics. The use of common test items over time in NAEP provides a basis for measuring achievement trends. The recent NCES report Trends in Academic Progress provides details on the extent of improvement in science and mathematics learning of students since 1982 when state reforms began (NCES, 1991c).[5]

o **Average achievement in science and mathematics increased slightly from 1982 to 1990.** NAEP proficiency scores declined from 1973 to 1982 in both science and mathematics. From 1982 to 1990, NAEP scores showed significant improvement in science at ages 9 and 17 (from 221 to 229, 283 to 290) and in mathematics at ages 9 and 17 (219 to 230, 299 to 305). During the same period, NAEP scores showed less improvement in science and mathematics at age 13. Levels of achievement in science and mathematics are about the same as they were 20 years ago, and leading educators agree that much improvement is needed. However, the NAEP trends do show that progress has been made during the 1980's in increasing science and math learning.

Achievement Trends in NAEP

Average NAEP Proficiency Scores from 1982 to 1990					
Science	1982	1990	Mathematics	1982	1990
Age 17	283	290	Age 17	299	305
Age 13	250	255	Age 13	269	270
Age 9	221	229	Age 9	219	230

NCES, 1991 Trends in Academic Progress

Mathematics and science educators have pointed out that the NAEP achievement trends are based on information from multiple choice questions. Even though the trend results are valuable, multiple choice items largely assess students' factual knowledge rather than student learning and skills in problem solving and application. Some changes are being made in the NAEP design. Beginning with the 1990 mathematics assessment and the 1994 science assessment, the subsequent NAEP trend results will incorporate new open-ended items and other alternate methods of assessment.

o **Increased achievement of African-Americans in science and mathematics.**[6] Although the achievement levels of African-American students continue to average below the level of white students, the gap in achievement between African-Americans and whites has been reduced in both science and mathematics since 1982. As shown on page 9, the scores of African-Americans in science improved significantly at ages 9, 13, and 17 in the 1980s, with the largest gain at age 17 of 18 points. African-American students' scores in mathematics also increased significantly at all ages, with a 17 point increase at age 17 (NCES, 1991c). Smith and O'Day use the NAEP trend data to show that there has been considerable progress toward the goal of equality of educational outcomes since 1966, even though there is still much more progress needed (1991).

5 NAEP scores are reported on a proficiency scale that ranges from 0 to 500.

6 The NAEP trend data are also reported for Hispanic students. This population also showed improved achievement, although with a pattern by age, subject, and level that is somewhat different from African-American students.

Achievement Trends in NAEP for African-American Students

Average NAEP Proficiency Scores from 1982 to 1990					
Science	1982	1990	Mathematics	1982	1990
Age 17	235	253	Age 17	272	289
Age 13	217	226	Age 13	240	249
Age 9	187	196	Age 9	195	208

NCES, 1991 Trends in Academic Progress

o **Student proficiency in mathematics improving, but still low.** The National Education Goals Panel reported the 1990 NAEP mathematics scores in its first report in September 1991, and concluded that at grades 4, 8, and 12, less than 20 percent of students demonstrated "competency" in mathematics for their grade level (1991). NAEP trend data are reported by proficiency levels, and 1990 results indicate that the majority of students are proficient at a level of mathematics that is below what could be expected for their age and grade.[7] However, the trend data also show that mathematics proficiency has improved at all grade levels, with the most improvement at age 9. The trends by age and proficiency level are shown on page 10.

- o Among 17 year olds, only 7 percent scored at or above the mathematics level indicating proficiency with algebra and geometry and multi-step problem solving (i.e., prepared for advanced mathematics beyond high school). From 1982 to 1990 the percentage of students at this level increased only one percent. The percent of 17 year olds at or above the next lowest level--proficiency in fractions, decimals, percents and simple algebra and geometry--increased from 49 percent to 56 percent.

- o At age 9 (about 4th grade), 28 percent of students scored at or above the proficiency level of numerical operations with multiplication and division and beginning problem solving, which was a 9 percent increase since 1982. At the next lowest level--proficiency in additive numerical operations and problem solving with whole numbers--82 percent of the nine year olds were proficient, which was an 11 percent increase from 1982 (NCES, 1991c).

- o At age 13 (about 8th grade), 17 percent of students scored at or above the proficiency level of fractions,decimals, percents, and simple algebra and geometry, and this represented no change over 1982. In 1990, 75 percent of 13-year olds were proficient at the next lowest level--numerical operations with multiplication and division and beginning problem solving, and this percentage increased by 4 percent in the 1980's.

o **State-by-state mathematics results show wide variation in learning.** In 1990, NAEP conducted a Trial State Assessment of public school students in mathematics at grade 8. The results provide the first state-by-state comparisons on mathematics proficiency of U.S. eighth graders (NCES, 1991b).

The 1990 results showed wide variation in mathematics knowledge and skills within and between states. The percentages of students scoring at the proficiency level of reasoning and problem solving with fractions, decimals, percents, and simple algebra and geometry (300 scale level), varied by state from 24 percent of students in North Dakota to 2 percent of students in the District of Columbia. At the proficiency level of multiplication and division and two-step problem solving (250 scale level), state percentages varied from 88 percent of eighth graders in North Dakota and Montana to 43 percent in Louisiana (NCES, 1991b). As compared to previous NAEP assessments, the 1990 mathematics assessment had a substantially greater emphasis on problem solving in each mathematics content area and the 1990 assessment required use of calculators.[8]

7 Panels of teachers and mathematics educators reviewed and rated the mathematics content of NAEP questions that clearly differentiated student performance at each proficiency level (NCES, 1991b).

8 The assessment objectives for the 1990 mathematics assessment were developed through a new consensus process that was headed by the Council of Chief State School Officers (CCSSO, 1988). The process involved representatives from mathematics, mathematics education, administrators, policymakers, and the participating states. The assessment objectives relied heavily on the new Curriculum and Evaluation Standards for School Mathematics (1989) produced by the National Council of Teachers of Mathematics. The NAEP proficiency scores by state reflect student performance on the new questions for 1990 combined with performance on the questions used to report trends over time.

NAEP Trends in Mathematics by Proficiency Level

Percentages of Students at Four Levels from 1982 to 1990			
Proficiency Level	Age	1982 % of Students	1990 % of Students
Algebra, geometry, multistep problem solving (350)	17	6%	7%
Fractions, decimals, percents, simple algebra & geometry (300)	17 13	49 17	56 17
Multiplication, division, basic problem solving (250)	13 9	71 19	75 28
Additive numerical operations (200)	9	71	82

NCES, 1991 Trends in Academic Progress

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o **NAEP mathematics scores are related to course taking in mathematics.** The 8th and 12th grade students taking the 1990 NAEP mathematics assessment reported on their current and previous mathematics course taking. The data show that 39 percent of 12th grade students took four years of high school mathematics. The average achievement score for these students was 36 points higher than students who had taken less than three years of high school mathematics, or almost the equivalent of one level on the proficiency scale (NCES, 1991b). The 1990 results demonstrated a strong positive relationship between level of course taking in mathematics and mathematics achievement at both 8th and 12th grades.

Summary of Findings

States undertook many policy initiatives in the 1980's with the goal of stimulating improvements in the quality of education. Recently educators, scholars, and policymakers have questioned the effects of the state reforms on changing education in schools and classrooms. Students are taking more science and mathematics courses in high school at all levels, and the data suggest that state policies are related to the increased enrollments. However, the rates of increased course taking are smaller for more advanced courses such as chemistry, physics, trigonometry, and calculus. The data indicate that some states have made significantly more progress than others in encouraging more students to pursue study in science and mathematics. State graduation requirements have had limited success in increasing study of higher level science and mathematics, indicating that other reforms at state, district, or school levels are needed to accomplish this objective.

Trend analyses of NAEP assessments in science and mathematics show that proficiency scores have increased somewhat since 1982. The average achievement of 17-year-olds increased significantly in science and mathematics, and the achievement of 9-year-olds increased significantly in mathematics. The rate of improvement in NAEP proficiency scores has been greater for African-American students than for white students in science and mathematics, and the gap in achievement has been reduced. The NAEP achievement results showed a strong, positive relationship to the amount of coursework in science and mathematics.

Although some progress was made in the 1980's, NAEP results in mathematics indicate that much improvement still needs to be made. A majority of students' mathematics knowledge and skills in mathematics are lower than what mathematics educators expect for students at grades 4, 8, and 12. Much of the improvement in NAEP mathematics scores in the 1980's was at the proficiency levels involving numeral operations and beginning problem solving. As we move into the 1990's, mathematics educators are emphasizing that all students need to learn mathematics reasoning, higher level problem solving, and applications (NCTM, 1989). Mathematics educators and science educators are recommending that NAEP assessments move away from reliance on multiple choice items toward testing methods that give better information about students skills in problem solving and application of knowledge, such as open-ended items, hands-on exercises, and portfolios.

Many of the state policy initiatives were aimed at improving the supply and quality of teachers. Nationally, there are shortages of science and mathematics teachers but predictions of severe shortages have not materialized as of 1990. There are several reasons: the attrition rate of science and mathematics teachers is low and it has not increased during the 1980's; many experienced teachers have returned to the classroom; and, the number of new graduates in science and mathematics teaching has gone up.

There are shortages of qualified high school science and mathematics teachers, as measured by the number of teachers assigned out of their field of certification and by the proportion of teachers with majors in their assigned fields. Shortages of qualified teachers vary widely from state to state, and shortages are much higher in districts with more poor and minority students. Some states with more older teachers are likely to experience shortages of science and mathematics teachers in the 1990's. In addition, a number of states currently have shortages of qualified chemistry and physics teachers. State or local efforts to increase study of upper level science and mathematics could produce further shortages. However, the capacity of school districts to hire new teachers and offer new courses may be restrained by the present budgetary problems in many states.

Table 1

ESTIMATED PROPORTION OF PUBLIC SCHOOL STUDENTS TAKING SELECTED MATHEMATICS COURSES BY GRADUATION

STATE	ALGEBRA 1 (Formal Math Level 1)	ALGEBRA 2 (Formal Math Level 3)	CALCULUS (Formal Math Level 5)
ALABAMA	70%	46%	6%
ALASKA	—	—	—
ARIZONA	—	—	—
ARKANSAS	88	48	5
CALIFORNIA	92	44	9
COLORADO	—	—	—
CONNECTICUT	74	61	14
DELAWARE	73	43	17
DC	65	39	3
FLORIDA	78	42	9
GEORGIA	—	—	—
HAWAII	52	33	4
IDAHO	95+	64	6
ILLINOIS	77	39	9
INDIANA	60	45	8
IOWA	92	50	9
KANSAS	66	47	9
KENTUCKY	81	54	6
LOUISIANA	95+	64	4
MAINE	84	64	—
MARYLAND	94	51	13
MASSACHUSETTS	—	—	—
MICHIGAN	—	—	—
MINNESOTA	90	55	12
MISSISSIPPI	85	58	3
MISSOURI	95	58	8
MONTANA	94	65	6
NEBRASKA	75	54	6
NEVADA	90	32	5
NEW HAMPSHIRE	—	—	—
NEW JERSEY	—	—	—
NEW MEXICO	95+	47	8
NEW YORK	69	46	12
NORTH CAROLINA	67	51	8
NORTH DAKOTA	95	64	3
OHIO	80	47	8
OKLAHOMA	95+	60	8
OREGON	—	—	—
PENNSYLVANIA	88	57	16
RHODE ISLAND	—	—	—
SOUTH CAROLINA	69	55	7
SOUTH DAKOTA	—	—	—
TENNESSEE	79	54	4
TEXAS	82	54	5
UTAH	82	63	13
VERMONT	—	—	—
VIRGINIA	81	55	11
WASHINGTON	—	—	—
WEST VIRGINIA	73	42	2
WISCONSIN	79	36	9
WYOMING	73	29	8
U.S. TOTAL	81%	49%	9%

Note: Each state proportion is a statistical estimate of course taking of high school students by the time they graduate based on the total course enrollment in grades 9-12 in Fall 1989 (See Appendix Table A-5) divided by the estimated number of students in a grade cohort during four years of high school. The statistical estimating method is imprecise above 95 percent course taking rate. (see Appendix C for further explanation)
Algebra 1 percentages include grade 8.
—Data not available
U.S. Total=Proportion of all high school students estimated to take each course, including imputation for non-reporting states.
Source: State Departments of Education, Data on Public Schools, Fall 1989; N. Carolina and Wisconsin, Fall 1988
Council of Chief State School Officers, State Education Assessment Center, Washington, DC, 1990

Table 2
ESTIMATED PROPORTION OF PUBLIC HIGH SCHOOL STUDENTS TAKING SELECTED SCIENCE COURSES BY GRADUATION

STATE	BIOLOGY 1st Year	CHEMISTRY 1st Year	PHYSICS 1st Year
ALABAMA	95+%	38%	21%
ALASKA	—	—	—
ARIZONA	—	—	—
ARKANSAS	95+	33	13
CALIFORNIA	91	33	16
COLORADO	—	—	—
CONNECTICUT	95+	62	36
DELAWARE	95+	48	19
DC	75	46	13
FLORIDA	95+	44	19
GEORGIA	—	—	—
HAWAII	88	40	21
IDAHO	80	26	15
ILLINOIS	78	40	20
INDIANA	95+	42	19
IOWA	95+	57	27
KANSAS	95+	45	17
KENTUCKY	95+	45	14
LOUISIANA	90	50	21
MAINE	94	58	—
MARYLAND	95+	61	27
MASSACHUSETTS	—	—	—
MICHIGAN	—	—	—
MINNESOTA	95+	44	23
MISSISSIPPI	95+	55	17
MISSOURI	86	41	16
MONTANA	95+	48	24
NEBRASKA	95+	46	21
NEVADA	65	33	13
NEW HAMPSHIRE	—	—	—
NEW JERSEY	—	—	—
NEW MEXICO	95+	33	15
NEW YORK	95+	56	28
NORTH CAROLINA	95+	47	15
NORTH DAKOTA	95+	54	24
OHIO	95+	49	20
OKLAHOMA	93	37	10
OREGON	—	—	—
PENNSYLVANIA	95+	56	29
RHODE ISLAND	—	—	—
SOUTH CAROLINA	95+	51	16
SOUTH DAKOTA	—	—	—
TENNESSEE	88	42	11
TEXAS	95+	40	12
UTAH	80	37	20
VERMONT	—	—	—
VIRGINIA	95+	57	23
WASHINGTON	—	—	—
WEST VIRGINIA	95+	40	11
WISCONSIN	95+	51	25
WYOMING	86	36	16
U.S. TOTAL	95+%	45%	20%

Note: Each state proportion is a statistical estimate of course taking of high school students by the time they graduate based on the total course enrollment in grades 9–12 in Fall 1989 (See Appendix Table A-6) divided by the estimated number of students in a grade cohort during four years of high school. The statistical estimating method is imprecise above 95 percent course taking rate. (see Appendix C for further explanation)

—Data not available

U.S. Total=Proportion of all high school students estimated to take each course, including imputation for non-reporting states.

Source: State Departments of Education, Data on Public Schools, Fall 1989; N. Carolina and Wisconsin, Fall 1988

Council of Chief State School Officers, State Education Assessment Center, Washington, DC, 1990

Table 3
PERCENTAGE OF MATHEMATICS AND SCIENCE TEACHERS WITH COLLEGE MAJOR IN FIELD

	Teachers of Math % with Math Major	Teachers of Science % with Science Major	Teachers of Math % with Major in Math or Math Education	Teachers of Science % with Major in Science or Science Education
ALABAMA	39 %	52 %	69 %	63 %
ALASKA	25	48	32	55
ARIZONA	-	43	-	51
ARKANSAS	37	41	63	54
CALIFORNIA	33	52	37	54
COLORADO	30	66	55	75
CONNECTICUT	43	65	57	67
DELAWARE	-	-	-	-
DIST OF COLUMBIA	-	-	-	-
FLORIDA	26	56	60	67
GEORGIA	54	54	76	62
HAWAII	-	-	-	-
IDAHO	33	47	60	52
ILLINOIS	51	56	67	63
INDIANA	37	50	59	65
IOWA	45	55	64	68
KANSAS	44	41	74	44
KENTUCKY	62	57	73	67
LOUISIANA	20	31	55	44
MAINE	22	48	49	57
MARYLAND	58	-	90	-
MASSACHUSETTS	51	59	61	62
MICHIGAN	47	56	71	68
MINNESOTA	54	73	75	82
MISSISSIPPI	49	46	77	72
MISSOURI	40	73	71	76
MONTANA	-	54	62	68
NEBRASKA	32	47	67	55
NEVADA	-	-	-	-
NEW HAMPSHIRE	-	-	-	-
NEW JERSEY	53	71	73	82
NEW MEXICO	54	47	57	54
NEW YORK	49	58	67	69
NORTH CAROLINA	26	49	60	64
NORTH DAKOTA	28	61	65	74
OHIO	44	61	68	71
OKLAHOMA	24	41	52	56
OREGON	31	58	42	66
PENNSYLVANIA	41	55	83	81
RHODE ISLAND	-	-	-	-
SOUTH CAROLINA	47	58	68	78
SOUTH DAKOTA	40	38	65	44
TENNESSEE	46	33	57	44
TEXAS	42	51	60	57
UTAH	24	32	40	37
VERMONT	-	-	-	-
VIRGINIA	57	74	71	77
WASHINGTON	27	36	43	43
WEST VIRGINIA	44	47	74	58
WISCONSIN	49	66	76	77
WYOMING	31	39	55	49
U.S. TOTAL	42 %	54 %	63 %	64 %

- Too few cases for a reliable estimate.
Source: Schools and Staffing Survey, Public School Teachers, National Center for Education Statistics, Spring 1988
Council of Chief State School Officers, State Education Assessment Center, Washington, DC, 1990

Table 4
MINORITY TEACHERS IN MATHEMATICS AND SCIENCE BY MINORITY STUDENTS IN STATE

STATE	Percent Minority Students (K-12)	Percent Minority Teachers (9-12)			
		Math	Biology	Chemistry	All High Schools
MAINE	2 %	.2 %	0 %	0 %	.3 %
IOWA	6	.4	0	1	1
IDAHO	7 *	2	1	0	2
MONTANA	7 *	1	1	0	2
UTAH	7	2	2	1	3
NORTH DAKOTA	8	.2	1	1	2
KENTUCKY	10	2	3	1	4
INDIANA	14	3	3	2	4
KANSAS	15	3	2	3	4
RHODE ISLAND	16	2	2	5	6
WISCONSIN	14	2	2	1	2
OHIO	16	3	5	2	6
PENNSYLVANIA	17	3	3	1	3
MICHIGAN	22	7	3	1	8
NEVADA	24	9	7	3	10
COLORADO	24	5	6	–	7
CONNECTICUT	24	3	3	2	5
ARKANSAS	25	10	10	6	10
OKLAHOMA	25	5	5	4	6
VIRGINIA	27 *	13	14	10	15
DELAWARE	31	8	4	0	11
NORTH CAROLINA	33	14	16	11	16
NEW JERSEY	34	10	7	5	10
ARIZONA	36	6	5	–	10
ILLINOIS	34	11	12	7	12
ALABAMA	37	18	19	17	21
MARYLAND	38	17	16	–	–
SOUTH CAROLINA	42	22	21	17	20
TEXAS	50	18	17	11	19
MISSISSIPPI	51	26	30	27	31
CALIFORNIA	53	18	16	12	18
NEW MEXICO	58	20	19	19	25
HAWAII	77	71	61	67	78
U.S. TOTAL	32 %	11 %	10 %	7 %	11 %

Percent minority teachers = sum of four non-white categories of public school teachers.
Minority teachers reported under Biology for Colorado, Arizona, Maryland = All science fields.
Sources: (teachers) State Departments of Education, Fall 1989; (students) NCES Common Core of Data, Public School Universe, Fall 1989; (*) USDE Office for Civil Rights, State Summaries of Projected Data. 1986.
Council of Chief State School Officers, State Education Assessment Center, Washington, DC, 1990

REFERENCES

Aldrich, H. (1983) "Teacher Shortage: Likely to Get Worse Before It Gets Better." Education Week, Vol. 2, Number 39, July 27.

Blank, R. & Dalkilic, M. (1990) State Indicators of Science and Mathematics Education. Washington, DC: CCSSO, State Education Assessment Center.

Blank, R. & Espenshade, P. (1988) "50-State Analysis of Education Policies on Science and Mathematics." Educational Evaluation and Policy Analysis, Vol. 10, Number 4.

Bobbitt, S.A. (1991) Characteristics of Stayers, Movers, and Leavers, E.D. TAB report from SASS, Washington, DC: U.S. Department of Education, National Center for Education Statistics.

California Department of Education (1991) California's National Education Goals Report. Sacramento, CA: California Department of Education.

Carnegie Forum on Education and the Economy (1986) A Nation Prepared: Teachers for the 21st Century. The Report of the Task Force on Teaching as a Profession, Washington, DC: Carnegie Forum on Education and the Economy.

Clune, W.H., White, P., Patterson, J. (1989) The Implementation and Effects of High School Graduation Requirements: First Steps Toward Curriculum Reform. New Brunswick, NJ: Rutgers University, Center for Policy Research in Education.

Connecticut Department of Education (1989) Meeting the Challenge. Hartford, CT: Connecticut Department of Education.

Council of Chief State School Officers (1988) "Assessing Mathematics in 1990 by the National Assessment of Education Progress," Washington, DC: CCSSC, State Education Assessment Center.

Council of Chief State School Officers (1989) State Education Indicators: 1989. Washington, DC: CCSSO, State Education Assessment Center.

Darling-Hammond, L. (1984) Beyond the Commission Reports: The Coming Crisis in Teaching. Santa Monica, CA: The RAND Corporation.

David, J., Cohen, M., Honetschlager, D. and Traiman, S. (1990) State Actions to Restructure Schools: First Steps. Washington, DC: National Governors' Association.

Dossey, J.A., Mullis, I.V.S., Lindquist, M.M., and Chambers, D.L. (1988) The Mathematics Report Card: Are We Measuring Up? Princeton, NJ: Educational Testing Service.

Education Commission of the States. (1984) "Minimum High School Graduation Requirements in the States." Clearinghouse Notes. Denver, CO: Author.

Educational Testing Service (1990) The Education Reform Decade. Princeton, NJ: ETS, Policy Infomation Center.

Firestone, W.A., Fuhrman, S.H. and Kirst, M.W. (1989) The Progress of Reform: An Appraisal of State Education Initiatives. New Brunswick, NJ: Rutgers University, Center for Policy Research in Education.

Fuhrman, S.H., Clune, W.H. and Elmore, R.F. (1988) "Research on education reform: lessons on the implementation of policy," Teachers College Record, 90(2).

Goertz, M.E. (1988) State Educational Standards in the 50 States: an Update. Princeton, NJ: Educational Testing Service.

Honig, B. (1990) "'Comprehensive Stategy' Can Improve Schools," Education Week.

Johnston, K.L., & Aldridge, B.G. (1984) "The Crisis in Science Education: What Is It? How Can We Respond?" Journal of College Science Teaching, 14(1), 20-28.

Jones, L.V., Davenport, E.C., Bryson, A., Bekhuis, T., and Zwick, R. (1986) "Mathematics and Science Test Scores as Related to Courses Taken in High School and Other Factors." Journal of Educational Measurement, 23(3), 197-208.

Kirby, S.N. et al; (1991) "Sources of Teacher Supply: Some New Evidence From Indiana." Educational Evaluation and Policy Analysis, Vol. 10, Number 3.

Kolstad, A., and Thorne, J. (1989) "Changes in High School Course Work from 1982 to 1987: evidence from two national surveys." Paper at annual meeting of American Educational Research Association.

Lauritzen, P. (1990) Wisconsin Teacher Supply and Demand: An Examination of Data Trends. Whitewater, WI: The University of Wisconsin, Whitewater.

McKnight, C.C. et al, (1987) The Underachieving Curriculum. Assessing U.S. School Mathematics from an International Perspective. Champaign, IL: Stipes Publishing.

Mullis, I.V.S., and Jenkins, L.B. (1988) The Science Report Card: Elements of Risk and Recovery. Princeton, NJ: Educational Testing Service.

Murnane, R. J., Singer, J. D., & Willett, J. B. (1991) Who Will Teach? Policies That Matter. Cambridge, MA: Harvard University Press.

National Center for Education Statistics (1985) Digest of Education Statistics. Washington, DC: U.S. Department of Education.

National Center for Education Statistics (1989) Projections of Education Statistics to 2000. Washington, DC: U.S. Department of Education.

National Center for Education Statistics (1990) Digest of Education Statistics. Washington, DC: U.S. Department of Education.

National Center for Education Statistics (1991a) Aspects of Teacher Supply and Demand in Public School Districts and Private Schools: 1987-88. Washington, DC: U.S. Department of Education.

National Center for Education Statistics (1991b) The STATE of Mathematics Achievement. Washington, DC: U.S. Department of Education.

National Center for Education Statistics (1991c) Trends in Academic Progress. Washington, DC: U.S. Department of Education.

National Council of Teachers of Mathematics (1989) Curriculum and Evaluation Standards for School Mathematics. Reston, VA: Author.

National Education Goals Panel (1991) The National Education Goals Report. Building a Nation of Learners. Washington, DC: National Education Goals Panel.

National Governors' Association (1986) Time for Results: The Governors' 1991 Report on Education. Washington, DC: National Governors' Association, Center for Policy Research and Analysis.

National Governors' Association (1990) "National Education Goals." Washington, DC: National Governors' Association, Center for Policy Research and Analysis.

National Research Council, Committee on National Statistics (1990) Precollege Science and Mathematics Teachers: Monitoring Supply, Demand, and Quality. Washington, DC: National Academy Press.

National Science Board Commission on Precollege Education in Mathematics, Science and Technology (1983) Educating Americans for the 21st Century. Washington, DC: National Science Foundation.

National Science Board (1989) Science and Engineering Indicators - 1989. Washington, DC: National Science Foundation.

Oakes, J. (1990a) Multiplying Inequalities: The Effects of Race, Social Class, and Tracking on Opportunities to Learn Mathematics and Science. Santa Monica, CA: The RAND Corporation.

Oakes, J. (1990b) Lost Talent: The Underparticipation of Women, Minorities, and Disabled Students in Science. Santa Monica, CA: The RAND Corporation.

Rock, D., Braun, H.I., and Rosenbaum, P.R. (1985) Excellence in High School Education: Cross-sectional Study, 1980-1982. Final Report. Princeton, NJ: Educational Testing Service.

Rollefson, M. (1990) "Supply Sources of Newly Hired Teachers: Where Do They Come From?" Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Sebring, P.A. (1987) "Consequences of Differential Amounts of High School Coursework: Will the New Graduation Requirements Help?" Education Evaluation and Policy Analysis, Vol. 9, Number 3.

Smith, M.S. and O'Day, J. (1991) "Systemic School Reform," The Politics of Curriculum and Testing. Philadelphia, PA: The Falmer Press.

Smith, M.S. and O'Day, J. (1991) "Educational Equality: 1966 and Now." The 1990 American Education Finance Association Yearbook: Spheres of Justice in Education. Washington, DC: American Education Finance Association.

Walberg, H.J. (1984) "Improving the Productivity of American Schools." Educational Leadership, 41(8).

Weiss, I.R. (1987) Report of the 1985-86 National Survey of Science and Mathematics Education. Research Triangle Park, NC: Research Triangle Institute.

Weiss, I.R. (1989) Science and Mathematics Education Briefing Book. Chapel Hill, NC: Horizon Research, Inc.

REPORTS AVAILABLE THROUGH CCSSO

Blank, R. (1986) "Science and Mathematics Indicators: Conceptual Framework for a State-Based Network." Washington, DC: CCSSO, State Education Assessment Center.

Blank, R. and Espenshade, P. (1988) "Survey of States on Availability of Data on Science and Mathematics Education." Washington, DC: CCSSO, State Education Assessment Center.

Blank, R. and Selden, R. (1989) "Alternative Methods for Assessing Science: Report to the States." Washington, DC: CCSSO, State Education Assessment Center.

Blank, R. and Schilder, D. (1990) "State Policies and State Role in Curriculum." Chapter in *Politics of Curriculum and Testing*. 1990 Yearbook of AERA Politics and Education Association. London: Taylor & Francis.

Blank, R. and Dalkilic, M. (1990) *State Indicators of Science and Mathematics Education.* Washington, DC: CCSSO, State Education Assessment Center.

Council of Chief State School Officers, *State Education Indicators.* (Annual Reports 1987-90) Washington, DC: CCSSO, State Education Assessment Center.

Council of Chief State School Officers (1988) "On Reporting Student Achievement at the State Level by the National Assessment of Educational Progress." Washington, DC: CCSSO, State Education Assessment Center.

Council of Chief State School Officers (1988) "Assessing Mathematics in 1990 by the National Assessment of Educational Progress." Washington, DC: CCSSO, State Education Assessment Center.

Council of Chief State School Officers (1989) "State Education Policies Related to Science and Mathematics." Washington, DC: CCSSO, State Education Assessment Center.

Council of Chief State School Officers (1991) "Final Report: 1994 National Assessment of Educational Progress Science Consensus Framework." Washington, DC: CCSSO, State Education Assessment Center.

Council of Chief State School Officers (1991) "Instructions and Reporting Forms for Data on Science and Mathematics Education in (each state)." Washington, DC: CCSSO, State Education Assessment Center.

Weiss, I.R. (1988) "Indicators of Science and Mathematics Education: Providing Tools for State Policymakers." Washington, DC: CCSSO, State Education Assessment Center.