DOCUMENT RESUME

ED 319 621 SE 051 434

TITLE	Preliminary Report--State Indicators of Science and Mathematics Education: Course Enrollments and Teachers.
INSTITUTION	Council of Chief State School Officers, Washington, DC. State Education Assessment Center.
SPONS AGENCY	National Science Foundation, Washington, D.C. Directorate for Science and Engineering Education.
PUB DATE	Apr 90
NOTE	76p.; Based on data collected by State Departments of Education on public schools in Fall 1988.
PUB TYPE	Statistical Data (110) -- Information Analyses (070)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Educational Improvement; *Educational Policy; Educational Trends; *Enrollment; Enrollment Trends; Mathematics Curriculum; Mathematics Education; Mathematics Teachers; Science Curriculum; Science Education; Science Teachers; Secondary Education; *Secondary School Mathematics; *Secondary School Science; *Teacher Characteristics; *Teacher Supply and Demand

ABSTRACT

Many of the educational policy initiatives of state legislatures and state boards of education in the 1980s were aimed at improving the quality of elementary and secondary education through upgrading state standards. Researchers are analyzing the effects of reforms on education and many states have expanded their systems for assessing, monitoring, and reporting on schools, teachers, and equity. The Council of Chief State School Officers established the State Education Assessment Center in 1985 to coordinate the development, analysis, and use of state-level data and charged the Center with implementing an education indicators model for reporting state-by-state data. This report is a preliminary analysis of state-by-state data from 1988-89. Chapter 1 addresses the use of state course enrollment as an indicator of curriculum in science and mathematics. Chapter 2 addresses the use of state data on teacher characteristics to analyze issues of teacher supply and demand. Analyses are provided on mathematics and science enrollments; science and mathematics teachers' age, sex, and race/ethnicity; and teacher certification. (CW)

SE

ED319621

Council of Chief State School Officers
State Education Assessment Center

SCIENCE & MATHEMATICS INDICATORS PROJECT

National Science Foundation

April 1990

PRELIMINARY REPORT
STATE INDICATORS OF SCIENCE AND MATHEMATICS EDUCATION: COURSE ENROLLMENTS AND TEACHERS

CCSSO STATE EDUCATION ASSESSMENT CENTER
400 North Capitol Street, N.W. Washington, D.C. 20001 (202) 624-7700

SE051434

Council of Chief State School Officers
State Science/Math Indicators Project

PRELIMINARY REPORT
STATE INDICATORS OF SCIENCE AND MATHEMATICS EDUCATION: COURSE ENROLLMENTS AND TEACHERS

April 1990

Based on data collected by State Departments of Education on public schools in Fall 1988.

The State Science/Math Indicators Project is supported by a grant from the National Science Foundation, Office of Studies and Program Assessment, Science and Engineering Education.

Rolf K. Blank, Project Director
Council of Chief State School Officers
State Education Assessment Center
400 N. Capitol Street
Washington, D.C. 20001
(202) 624-7700

TABLE OF CONTENTS

Summary of Findings 4

I. STATE-BY-STATE INDICATORS OF COURSE ENROLLMENT IN SCIENCE AND MATHEMATICS 5
State Policies and Curriculum in Mathematics and Science 5
Studies of State Reforms and Curriculum 7
Design for State-By-State Data on Course Enrollment 9
Uses of State Course Enrollments as Indicator of Curriculum 10
Summary 21
Tables 23

II. STATE-BY-STATE INDICATORS OF TEACHERS IN SCIENCE AND MATHEMATICS 33
Need for Improved Statistics on Teacher Demand and Supply 33
Design for State Indicators on Science and Math Teachers 35
Uses of State-By-State Indicators on Science/Math Teachers 38
Summary 54
Tables 56

REFERENCES 69

STATE INDICATORS OF SCIENCE AND MATHEMATICS EDUCATION: PRELIMINARY REPORT ON COURSE ENROLLMENTS AND TEACHERS

Many of the education policy initiatives of state legislatures and state boards of education in the 1980's were aimed at improving the quality of elementary and secondary education through upgrading state standards. The policy initiatives included increasing graduation requirements, revising state curriculum guidelines and frameworks, upgrading teacher certification requirements, and developing and revising student assessment tests. Now, at the end of the 1980's, and the beginning of the '90's, there are several kinds of responses to the state reforms. Researchers are analyzing the effects of the reforms on education in elementary and secondary schools. Many states have expanded their systems for assessing, monitoring, and reporting on schools, teachers, and students.

The Council of Chief State School Officers (CCSSO) established the State Education Assessment Center in 1985 to coordinate the development, analysis, and use of state-level data and charged the Center with implementing an education indicators model for reporting state-by-state data. The indicators model has three components: a) educational outcomes, b) state educational policies and practices, and c) state context. State indicators of student outcomes can be analyzed by indicators of state policies and educational practices, accounting for differences in state demographic and fiscal characteristics.

Since 1986 CCSSO has received support from the National Science Foundation to develop and report on indicators of science and mathematics education. There are two major goals for the "State Science/Math Indicators Project": 1) to improve the quality and usefulness of data on science and mathematics education to assist state policymakers and program managers in making more informed decisions, and 2) to develop a system of indicators that provides the capacity for state-to-state comparisons of science and mathematics education as well as a national database to assess the condition of education in these subjects.

The state science/math indicators were selected and developed with states through a planning process. Three major steps were included in the process: a) development of a conceptual framework paper (Blank, 1986), which reviewed recommendations on needed indicators of science and mathematics education (e.g., National Science Board, 1983; Raizen and Jones, 1985; Shavelson, et al, 1987; Murnane and Raizen, 1988; Oakes, 1986) and outlined "ideal indicators" for science and math at the state level; b) a survey of state departments of education to determine the availability of data on science/math education and to identify state interests in indicators (Blank and Espenshade, 1988b), and c) an advisory panel reviewed the available data and the ideal indicators and recommended a set of "priority indicators" upon which the CCSSO Project should focus its efforts. The indicators were selected in six categories (Student Outcomes, Instructional Time/Enrollment, etc.). For each recommended indicator, the best source of state-by-state data was identified, e.g., "NAEP" or "STATE DATA."

SCIENCE/MATH INDICATOR	DATA SOURCE
Student Outcomes	
STUDENT ACHIEVEMENT	NAEP
STUDENT ATTITUDES/INTENTIONS	NAEP
Instructional Time/Enrollment	
GRADES 7-12 COURSE ENROLLMENT	STATE DATA (CCSSO)
ELEMENTARY MINUTES PER WEEK	Schools/Staffing Survey (NCES)
Curriculum Content	
STUDENTS' "OPPORTUNITY-TO-LEARN"	NAEP

School Conditions

CLASS SIZE by Subject/Course NO. of COURSE PREPARATIONS PER TEACHER COURSE OFFERINGS PER SCHOOL	Schools/Staffing Survey or State Data (Available in some states)

Teachers

COURSES/CREDITS IN SCIENCE/MATH	Schools/Staffing Survey
TEACHING ASSIGNMENTS BY FIELD/SUBJECT By Age, Gender, Race/Ethnicity	STATE DATA (CCSSO)
TEACHING ASSIGNMENTS BY CERTIFICATION FIELD/SUBJECT (Number of Teachers Out-of-Field/Uncertified)	STATE DATA (CCSSO)

Equity

GENDER AND RACE/ETHNICITY by Student or Teacher Indicator	STATE DATA (CCSSO) (where available)

During the 1988-89 school year, states reported data to CCSSO on several indicators of science and mathematics education, including secondary course enrollments and teacher characteristics. The data were collected by state departments of education using regular state-designed systems for collecting information on teachers and student enrollments. States aggregated data for all secondary students and reported state totals to CCSSO using common definitions and reporting categories that were determined by a task force of state education representatives and project staff. CCSSO plans to implement biannual reporting by states on the science/math indicators. With data from succeeding cycles there will be an opportunity for analyses of trends in science/math indicators for individual states and for state-to-state and state-to-nation comparisons.

This report is a preliminary analysis of state-by-state data from 1988-89. During the 1989-90 school year, the states are reporting data on the same indicators, and a report will be produced in fall 1990. The present report has two chapters: Chapter 1 addresses the use of state course enrollment as an indicator of curriculum in science and math, and Chapter 2 addresses the use of state data on teacher characteristics to analyze issues of teacher supply and demand.

Summary of Findings

- Mathematics Enrollments: Among the reporting states, an average (state median) of 79% of students take Algebra I over four years of high school, an average of 55% take Geometry, and an average of 7% take Calculus. In 1988-89, in the average state, 82% of high school students were taking a math course, and almost one-third of the enrollment was in General Math or Pre-Algebra courses.

- Science Enrollments: Among the reporting states, an average (state median) of 43% of students take Chemistry over four years of high school, 19% take Physics, and 14% take an advanced Biology course. In 1988-89, in the average state 71% of high school students took a science course, and one-third of the total were taking first-year Biology and one-third either Earth, Physical, or General Science.

- The report describes ranges among the states in enrollment rates for specific types of science and math courses in grades 9-12, enrollments by student gender. and analysis of general vs. applied science courses.

- Science/Math Teachers' Age, Sex, Race/Ethnicity: Demographic data on teachers show that the median state percentage of Math teachers under age 30 is 14% and the median percentage over age 50 is 16%; for Biology teachers, the median percentage under 30 is 11% and the median percentage over 50 is 17%.

- The number of male and female science/math teachers differs widely--for example, the percentage of female Math teachers varies from 20% in Minnesota to 76% in Texas, and the percentage of female Chemistry teachers ranges from 6% in Hawaii to 79% in Texas.

- All states have a significantly lower proportion of minority science and math teachers than the proportion of minority students in the state. Representation of minority groups among science Math and Biology teachers is similar to the minority representation among all secondary teachers in most states, while Chemistry and Physics typically have greater proportions of white teachers.

- Teacher Certification: The proportion of Math teachers who are teaching "out of field" varies by state from 0% to 32%, the proportion of Biology teachers who are teaching "out of field" varies from 0% to 39%, and the proportion of Physics teachers teaching "out of field" varies from 0% to 76%.

Chapter 1
STATE-BY-STATE INDICATORS OF COURSE ENROLLMENT IN SCIENCE AND MATHEMATICS

One of the key issues in analyzing state policy reforms is the effect of state reforms on curriculum content that students receive. Questions have been raised about the reforms' effects on the amount of instruction, the quality of curriculum, and the proportion of students receiving a high quality curriculum. A second issue in analyzing state reforms is how curriculum change should be evaluated. Questions have been raised about the levels of the education system at which curriculum should be analyzed, measures that are appropriate for determining change, and how state-by-state comparisons can be made.

This chapter presents findings from an analysis of state policies on graduation requirements and curriculum using state data on course enrollments in mathematics and science. The results inform the more general question of the condition of science and mathematics education in our schools.

STATE POLICIES AND CURRICULUM IN MATHEMATICS AND SCIENCE

The curriculum for elementary and secondary education has been a central focus of education reforms in the 1980's. Curriculum content was specifically identified in many national commission reports that focused on mathematics and science education (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 poor performance of American students on international assessments in science and mathematics and the relatively low amount of instruction in these subjects for the average American student were frequently cited in the reports as evidence of the fundamental problems in our schools, and as a rationale for proposed education reforms.

In A Nation at Risk (1983), the National Commission recommended that three mathematics and three science courses be required for high school graduation. The Commission also recommended making science a "new basic" in elementary school. The report of the National Science Board, Educating Americans for the 21st Century (1983), recommended more time and resources for mathematics and science education, advocated teaching "science literacy" for all students, and outlined core mathematics and science knowledge and thinking skills that students should learn in school. One of the consistent themes across the various national reports was the need for students to gain scientific literacy and for schools to increase the level of mathematics and science instruction for all students.

Many of the state reforms in the 1980's were aimed at setting higher standards for the amount of mathematics and science instruction in schools. From 1980 to 1987, 43 states increased mathematics course requirements for graduation and 40 states increased science requirements (Education Commission of the States, 1985; Blank and Espenshade, 1988a). By 1987, 26 states had a state policy giving direction or recommendations to schools on the amount of time to be spent on elementary science and mathematics (Blank and Espenshade, 1988a).

A second area of state reforms related to curriculum has been in developing and revising state curriculum guidelines or frameworks. A 1987 survey of state departments of education by CCSSO showed that 38 states had a state curriculum framework which "establishes goals or standards for instruction" for mathematics and 38 states had a framework for science (Blank and Espenshade, 1988b). In some states the curriculum frameworks set a required curriculum for districts, while in others the frameworks are used by districts as goals or instructional objectives for development of local curricula.

Third, state policy initiatives in the 1980's increased the capacity of states to assess student learning through state assessment programs. Statewide student assessment tests have become a predominant method by which states monitor curriculum and instruction in schools, and assessment programs have increased the responsibility of state departments of education for educational accountability (Fuhrman, 1989). In 1984, 34 states had state achievement assessment tests in math and 13 states in science (CCSSO, 1984). By 1988, 43 states had achievement assessment tests in mathematics and 28 states in science (CCSSO, 1989a).

STUDIES OF STATE REFORMS AND CURRICULUM

The studies of the International Association for Evaluation of Education Achievement (IEA) refer to three levels of curriculum--"intended," implemented," and "achieved" curriculum (McKnight, et al, 1987). These terms for characterizing levels of curriculum will be used in this paper to analyze the relationship of state policy reforms to the intended and implemented curriculum.

Intended Curriculum. One research approach has been to identify and analyze changes in policies related to curriculum. Goertz (1986) conducted a 50-state analysis of state education policy changes and intensively studied the implementation process in four states. The Education Commission of the States (ECS) tracked changes in state graduation requirements (1985) and identified state curriculum reforms in all 50 states related to science, math, and computer science (1987). CCSSO annually reports on state policies in a variety of areas in its state-by-state education indicators (1989b).

Studies have also examined the content of state curriculum frameworks or guidelines. Freeman (1989) analyzed the integration of approaches to teaching higher order skills in state frameworks and the means by which state education agencies have tried to implement them in schools. An ECS study of the process of implementing new curriculum frameworks for science education in three states identified the steps the states have taken to move curriculum reforms from the intended to the implemented curriculum (Armstrong and Davis, 1988). A study conducted for the Southern Regional Education Board by Reilly and Gersh compared the content, goals, and standards for achievement in state curriculum guides (SREB, 1989).

Implemented Curriculum. Recent research on state reforms has analyzed course offerings and student participation in relation to state policies. Student enrollments in courses in specific subject areas is one possible indicator of the extent to which curriculum is being implemented in schools. Policy Analysis for California Education (PACE), a consortium of university scholars, conducted a study of change in course enrollments related to California policy changes in graduation requirements (Cagampang and Guthrie, 1988). The Center for Policy Research in Education (CPRE), supported by the U.S. Department of Education, studied district implementation of curriculum reforms in science and math in six states, and analyzed student course taking in science and mathematics (Clune, 1989).

The number of students taking a given type of course does not give sufficient information to determine the curriculum content that is taught, but the data do provide a useful indicator of the extent to which students receive instruction in a subject area, such as science and mathematics (Murnane and Raizen, 1988). Rates of course enrollments in subjects can provide a very useful indicator for policymakers and educators in assessing curriculum trends at national, state, district, and school levels.

A more in-depth approach to analyzing state curriculum reforms and the implemented curriculum involves identifying the curriculum content or topics that are actually taught in schools and classrooms. One method of measuring curriculum content at the classroom level is through an "opportunity-to-learn" survey with teachers and students, as used in IEA studies (e.g., McKnight, et al., 1987). With data on students' opportunity-to-learn the curriculum topics included in achievement tests, the implemented curriculum can be related to student achievement scores. A new study of methods of evaluating state education reforms finds that wide variation in course content among classrooms, schools, and districts results in course enrollment being an inadequate measure of curriculum content. The study recommends alternate methods of analyzing curriculum content (McDonnell, et al, 1990).

This report focuses on the use of course enrollment data to analyze science and mathematics education. This approach is taken with the assumption that course enrollment is not a measure of curriculum content, but that these data can provide useful policy and program indicators of the implemented curriculum.

DESIGN FOR STATE-BY-STATE DATA ON COURSE ENROLLMENT

A 1987 CCSSO survey of states produced 50-state information on state policies related to science and math education, state curriculum frameworks and guidelines, state assessment programs, and state data on course enrollments and other indicators. The survey results provided the basis for determining the availability of data from states on the selected priority indicators.

In the survey, state departments of education were asked to identify any data being collected on the implemented curriculum in districts, schools, and classrooms. Relatively few states reported having a method of directly monitoring the curriculum content being implemented in science and mathematics. Four different methods were identified (Blank & Espenshade, 1988b):

- o 12 states reviewed school curriculum in science and mathematics, either through accreditation, site visits, or approval of new courses.
- o 4 states conducted surveys of teachers, either during the accreditation process, through site visits, or with student assessments.

- 4 states observed classrooms, either during accreditation, with teacher appraisals, or in site visits.
- 7 states collected data on opportunity to learn in a subject or course, either through one-time studies, student assessments, or site visits.

These results are consistent with other recent research on the states' role in evaluating the curriculum being implemented in schools and classrooms. Fuhrman (1989) found that while state departments of education have increased their role in education accountability and compliance, most do not have a method of evaluating the implementation of curriculum in districts and schools other than state tests. A study of state accountability systems found that state tests of student learning have become the dominant method of accountability (OERI, 1988).

The CCSSO survey also showed that over two-thirds of states collect data on student enrollments in secondary courses in science and math. The Science/Math Indicators Project selected course enrollments as one of the priority indicators. A plan was developed for state reporting of data on course enrollments, and in the 1988-89 school year states reported these data to CCSSO for the first time. Data were collected by state departments of education (as of October 1, 1988) using regular state-designed information systems, and states reported totals to CCSSO using common definitions and reporting categories that were determined by a task force of state education representatives and project staff.

USES OF STATE COURSE ENROLLMENTS AS INDICATOR OF CURRICULUM

National-level data from transcripts of representative samples of high school graduates in 1982 and 1987 show that course enrollments in science and math increased in the 1980's (ETS, 1989; Kolstad and Thorne, 1989). For example, the percent of graduates who took physics increased from 14 to 20 percent; the percent who took Algebra II increased from 35 to 46 percent. In this period, the average number of credits earned in math increased from 2.4 to 2.98

and the average number of credits in science increased from 2.19 to 2.63 (ETS, 1989) which is an increase of half a credit in each subject. These increases appear to affirm that higher state graduation requirements did produce increased study in science and mathematics, particularly since many of the states raised graduation requirements from 1983 to 1985 effective for the class of 1987, 1988 or 1989.

State-level studies show that increases in course enrollments are related to state policies but the increases vary by course level. The PACE study (Cagampang and Guthrie, 1988) in California found that increased requirements for graduation produced enrollments increases of 27 percent in science, [illegible] percent in math, and 21 percent in foreign languages. In the same period, enrollments in vocational courses and other electives declined. The CPRE study showed that rates of course taking increased following reforms, but the largest increases were in lower-level science and math courses (Clune, 1989).

The state-by-state data reported to CCSSO for 1988-89 allows analysis of policy questions concerning state reforms as well as more general analyses of the condition of science and mathematics education in our secondary schools. Several of the key questions are analyzed in this paper.

1. **What level of science and math courses are high school students taking to meet state graduation requirements?**

To address this question, the state data are analyzed in two ways. First, in Tables 1 and 2, data are presented on enrollments in four courses that might be considered benchmarks of student participation in secondary math and science. In Tables 3 and 4, the total state enrollments in science and math during one year are presented to show the aggregate enrollments at several course levels.

The four math courses shown in Table 1 were selected to show enrollments at various levels and to compare state percentages with results from the 1987 National Transcript Study (Westat, 1988; Kolstad & Thorne, 1989). The transcript study reported the following percentages for the four math courses:

Algebra 1	76%	Geometry	62%
Trigonometry	19%	Calculus (incl. AP)	10%

Table 1 shows that 79% of students in the average (median) state take a "Formal Math Level 1" course, such as Algebra 1, over their four years of high school.[1] The state percentages vary from 47% in Hawaii to 98% in Louisiana and Montana. An average of 55% of students take Formal Math Level 2 (e.g., Geometry), with state percentages varying from 28% in Wyoming to 86% in Louisiana. The wide variation in percentage of students taking courses at Formal Math Levels 1 and 2 (Algebra 1 and Geometry) can be attributed to a number of factors, including differences in state requirements for graduation and variation by state in proportion of districts and schools offering Formal Math courses as opposed to Review and Informal Math courses. For example, Hawaii has 47% of students taking Algebra 1, but almost all students take a Review or Informal Math course during high school (see Table 3). The high percentages taking Formal Math Levels 1 and 2 in Louisiana can be attributed to a state policy requiring that Algebra 1 and Geometry be passed for high school graduation.

State percentages for some courses are affected by the degree of precision in the match between state categories and the CCSSO reporting categories. For example, Louisiana was not able to report "Basic Geometry" (under Informal Mathematics, Level 2) separately from "Plane

[1] The course enrollment reporting plan divided mathematics courses into three categories--Review, Informal, and Formal Mathematics. Within each category, courses were assigned a level from 1 to 5. This method of categorization allows comparison of mathematics enrollments among states using a standard taxonomy (CCSSO, 1988).

Geometry" under Formal Math Level 2. Thus, the 86% figure includes both levels of Geometry. ("Basic Geometry" was reported by 14 states, varying from 1% in Nevada to 33% in Wisconsin. The National Transcript study did not distinguish between two levels of Geometry.)

The percentage of students taking a Formal Math Level 4 (e.g., Trigonometry) course varies from 15 percent in Arkansas to 39% in North Dakota, and the percentage taking Level 5 (e.g., Calculus) varies from 3% (several states) to 14% in Pennsylvania. The state medians for mathematics are very similar to the national averages from the 1987 Transcript Study. The state-by-state data confirm the findings from the 1982 and 1987 transcript studies showing the effects of state reforms on increasing enrollments in mathematics.

The state percentages of high school students taking five selected science courses are reported in Table 2. The percentages for the corresponding categories from the 1987 Transcript Study are:

Earth Science	14%	Physical Science	35%	Chemistry	45%
Physics	20%	AP/Honors Biol.	3%		

Earth Science and Physical Science are generally lower-level high school science courses that are typically taken in 9th grade in order to meet a state or district science requirement. The median state percentages of 18% for Earth Science and 38% for Physical Science are similar to the national average. State enrollments vary widely--for Earth Science from no enrollment to 86% (Virginia) and for Physical Science from no enrollment to 100% (North Dakota). Different state curriculum mandates or guidelines for high school science have a strong effect in determining which of these courses (or General Science) are taught. For example, Virginia has strongly emphasized teaching of Earth Science and the emphasis is reflected in student enrollments.

The state medians for Chemistry (43%) and Physics (19%) are very close to the national figures. These averages show that state enrollment data confirm the findings of the national transcript study on increases in science enrollments during the 1980's. The range of state percentages for Chemistry is from 27% (Wyoming) to 56% (Virginia), and for Physics the range is from 10% (Oklahoma) to 29% (New York). The Advanced Biology enrollments reported by states (median of 14%) includes more second- year Biology courses than just the Advanced Placement and Honors Biology reported in the Transcript Study (3%). The high enrollments in second-year Biology in states such as Mississippi, Montana, Missouri, and Oklahoma indicate that schools and districts in these states offer students more opportunities for continued study in biology and it is likely that students meet state requirements through concentrating on biology and life science study.

In Table 3, state data on math enrollments provide analysis of the relative level at which students took Mathematics during the 1988-89 school year. A state percentage in this table represents the proportion of all students in grades 9-12 that took the course during one year. Math course enrollments are aggregated in four course levels: Review and Informal Math (e.g., General and Vocational Math, Pre-Algebra, Basic Geometry), Formal Math Level 1 (Algebra 1), Formal Levels 2-5 (Geometry through Calculus), and Other Math.

Among the 29 reporting states an average of 82% of students were taking Math courses in October 1988. An average of 25% of students took a Review or Informal Math course; an average of 21% took Formal Math Level 1 (e.g., Algebra 1); and an average of 34% of high school students took a Formal Math course at Levels 2 through 5 (e.g., Geometry, Algebra 2, Trigonometry, Calculus). In Iowa, Louisiana, Minnesota, Nebraska, North Dakota, and Pennsylvania, 40% or more of high school students took a more advanced math course, while less than 30% took an advanced math course in Alabama, California, Delaware, Hawaii, Montana, Nevada, Wisconsin, and Wyoming.

Table 4 shows the percentage of grade 9-12 students that were taking science courses as of October 1988. The science course enrollments are aggregated in four categories: a) Earth, Physical, or General Science; b) First-year Biology, c) Chemistry, Physics, or Second-year Biology, and d) Other Science. The average percentage of high school students enrolled in a science course was 71%. An average of 25% took a first-year Biology course and 24% took an Earth, Physical, or General Science course. Thus, half of all high school students, and over two-thirds of those taking science, were taking a science course to meet their graduation requirement at the first two course levels. Twenty percent of students were taking a more advanced science course. In Alabama, Indiana, Kentucky, Minnesota, Mississippi, and Virginia the more advanced science courses (second-year Biology, Chemistry, and Physics) were taken as frequently as either of the categories of lower level courses.

Considering the state-by-state rates of student course-taking in science and math raises a question about the relationship of these rates to state policies.

2. Do states with higher requirements for graduation have more students taking science and math?

Table 5 shows a cross-tabulation of the percentage of students taking math courses by the number of math course credits required for graduation. State math requirements were divided into two categories for purposes of analysis--states requiring 3 course credits vs. states requiring 2 credits. Each column shows the total percentage of students taking math and the percent taking Formal Math Levels 2-5 (i.e., Geometry, Algebra II, Trigonometry, or Calculus courses). The median percentage for all math enrollments among states requiring 3 credits is 90%, while the median among states requiring 2 courses is 80%. The median percentage for enrollment in more advanced math courses is 36 to 38% while the median for states with 2 courses required is 33%.

The number of credits that states require appears to have a strong relationship to total math enrollment in a state (average difference of 10%), and a positive, but less strong, relationship to the level of courses that are taken (average difference of 3 to 5% for enrollments in advanced math courses).

In Table 6, the percentage of high school students taking science courses is cross-tabulated by state graduation requirements for science. Among the 29 states that reported data, seven require one course or have no state requirement (local policy). The median total percentage taking science among the seven states is 69%, and the median for advanced science courses is 22% of students. Eighteen states require two science courses and two states require three courses. Among these 20 states the median percentage for total science enrollment is 71% and the median for advanced science courses is 20%. These data indicate a weak relationship between number of science credits required for graduation and the rate of students taking secondary science courses. It is possible that the number of states (7) in the low requirement category is too small for meaningful comparisons of category averages.

In sum, states that increased the graduation requirement in mathematics in the 1980's from two to three courses have higher enrollments in mathematics. Course-taking is also higher for these states in more advanced courses, but the difference from other states is smaller. The data also indicate a 2-credit requirement in science does not yield higher science enrollments as compared to those states with a 1-credit requirement or no state requirement.

3. Have state reforms increased student enrollments in basic or lower-level science and math courses?

The state-by-state data can provide further evidence related to the findings of the CPRE and PACE studies concerning the effect of higher state course requirements on the types and level of courses students take in science and math to meet the requirements (Cagampang and Guthrie, 1988; Clune, 1989). One way of viewing this issue is whether state curriculum reforms have the effect of expanding existing curriculum and instruction in science and math to more students, or have the effect of increasing the proportion of students that take more basic, lower-level courses to meet the requirements. However, another view is that regardless of the level of difficulty students are likely to learn more science and mathematics by taking more courses, even if the courses are less rigorous (NASSP, 1989; Raizen and Jones, 1985). For an analysis of curriculum, trends in student enrollments in basic or applied courses is an important indicator of the effects of state policies even though interpretations of the indicator may differ.

In the analysis of state data on enrollments, it was noted that one-fourth of high school students were taking General Math or Pre-Algebra (i.e., lower-level) math courses in 1988-89, and about one-fourth were taking a lower-level science course in Earth Science, General Science, or Physical Science. It is also possible to more closely examine the level of science courses students were taking in other science fields. The CCSSO course taxonomy and reporting definitions include separate categories for "applied" vs. "general" first-year courses in Biology, Chemistry, and Physics. This distinction reflects a strong interest of state science supervisors in the use of the state indicators to track the level of courses students are taking to meet science requirements.

A "general" first-year course in Biology, Chemistry, and Physics is the traditional first-year course in these fields, typically a broad survey course that introduces the field to students but also is aimed at students planning to pursue further study in science. An "applied" course is a more basic course emphasizing central principles, concepts, and applications, and typically is aimed at students who are not planning further study in science.

In Table 7, state-by-state data are reported on student enrollments in applied and general courses in first-year Biology, Chemistry, and Physics. There is wide variation among states that reported data in each subject. For example, the state percentage of first-year Biology enrollments in applied courses varies from 44% (Delaware) to 1% (North Carolina, Montana); the percentage taking applied Chemistry varies from 39% to .3%; and the percentage taking applied Physics varies from 44% to 1%. These comparative data on enrollments by state provide an initial indicator of the extent to which lower-level, "applied" courses are being taken by students, and the extent to which schools are offering the courses. However, many states do not include the different course levels in their data collection, and thus state-by-state analyses are limited.

A question that can be pursued further is how state course titles are allocated to the categories of "general" vs. "applied." The example of first-year Biology will be used to examine this question. The CCSSO taxonomy defines first-year "General" Biology as:

> ...a first level course which uses the knowledge of scientific principles and concepts in the context of living systems to understand how these living systems interact with each other.

First-year "Applied" Biology is defined as:

> ...a first level course which uses the knowledge from biological principles and concepts in a concrete and practical way to understand everyday societal problems. Relates to the basic knowledge of humankind as its primary focus.

The state course titles included under "General" and "Applied" Biology are listed in Table 8. All 18 of the states listed a course entitled "Biology I" or "General Biology" under the CCSSO category of General Biology. Thus, within a district or school there may be wide variation in course content, but there is relatively little variation among states on courses included in this category. The course categories in Alabama, Delaware, Indiana, and New York do include both college preparatory and non-college bound General Biology courses.

Among the states reporting Applied Biology courses, one listed "Introductory Biology" and eight listed "Life Science." Life science and introductory biology courses are often taught in the seventh or eighth grade, but not to all students. Applied biology in high school may be providing instruction in basic concepts or initial laboratory instruction to students who are taking a first biology course. Three states indicated that the courses taught in the Applied Science category were geared toward students who were not on a college preparatory track. Alabama noted that the Applied Biology course was a "basic course" using a "simplified" approach. Delaware listed courses in the Applied Biology category that were the same as those taught in the General Biology category, but the "applied" courses were those targeted to average or below average students. Indiana offered a variety of courses under the "Applied Biology" heading that were "designed for students who could find it more beneficial than Biology Level I." Other titles in the Applied Biology category are: Animal Science, Animal Behavior, Plant Science, and Health.

The review of first-year Biology course titles by level shows that states can divide courses by title into "general" vs. "applied" categories, as defined by the CCSSO taxonomy, and that the two categories have comparability across states. As more states see the value of making this distinction in their data collection, it will be possible to analyze course-taking trends with more specificity. The state enrollment data broken out by more course levels provide a better indicator of curriculum. However, the distinction of "general" vs. "applied" science courses, while useful as a policy indicator, is still limited as a measure of differences in course content. At the school and district level, there may be as much variation in content among General Biology courses as there is between General and Applied Biology courses.

The present data show that in most of the states reporting general vs. applied science categories there is a substantial portion of students taking applied courses, especially in Biology and Physics. Trend data are needed to determine if enrollments in the applied courses are actually increasing. As the state science/math indicators continue, CCSSO will be able to collect data from more states and time-series data will become available.

4. How does course taking in science and mathematics differ between girls and boys?

Results from the National Assessment of Educational Progress (NAEP) have shown that boys have higher scores than girls on the earth science, chemistry, and physics portions of the test, but scores for boys and girls are approximately equal on the biology portion of the assessment (ETS, 1988). On the NAEP in mathematics, boys consistently perform better on more complex mathematical procedures than girls (ETS, 1988). Given these findings from student achievement tests, it is important for policy analysts to track course enrollments for girls and boys in mathematics and science courses as a possible source of differences in student learning. The Science/Math Indicators Project requested that states report course enrollment data by student gender. For 1988-89, seven states were able to report course enrollments categorized by gender.

State data on mathematics reported in Table 9 show that as course difficulty increases, the percentage of girls taking the course diminishes. For example, in Algebra I the ratio of girls to boys is evenly distributed. In Trigonometry all states except Hawaii report higher male enrollments than female enrollments. The disparity is larger in Calculus--for example, South Carolina reported that only 38% of the students taking Calculus were girls, and Wyoming reported that only 32% of those taking AP Math were girls.

The data on science in Table 10 shows that across the seven states the ratio of girls to boys taking science courses was relatively equal in first-year Biology and Chemistry. For example, California reported first-year Biology had 49% girls, and first-year Chemistry had 50% girls. In Earth Science, Physics and advanced Chemistry courses, more boys were enrolled than girls. For example, in California, first-year Earth Science had 46% girls, first-year Physics had 41% girls, advanced Chemistry had 42% girls, and advanced Physics had 43% girls. The exception is advanced Biology--for example, California had 55% girls in this course. This pattern is consistent across the reporting states.

The results from the state data on course-taking by gender indicate that differences in student achievement scores between boys and girls in Mathematics, Earth Science, Chemistry, and Physics could be a result of significantly higher numbers of boys taking advanced courses. The pattern of state-level findings of enrollments by gender is very similar to findings from the 1987 Transcript Study (Kolstad and Thorne, 1989). Trend data at the state level would be important for analyzing gender differences particularly to determine if some states are able to make more progress in closing the gender gap.

SUMMARY

State-by-state data on course enrollments in science and mathematics provide one kind of indicator of the effects of state policies on curriculum. The results from the initial year of the CCSSO state reporting system on science/math indicators show that state-collected data can be used to analyze patterns and trends among states in student course-taking. The findings indicate that course enrollments can be a useful indicator for analyzing curriculum policies and the implementation of policies and programs in schools. State course enrollment data provide a measure of the implemented curriculum by showing the proportion of students receiving various types and levels of science and math curriculum. The data are not very useful for analyzing the content of courses being taught in schools.

The findings show that state course enrollment patterns vary at each of the various course levels in science and math. However, the averages among the states confirm findings from national transcript studies on increases in course-taking related to state policy changes in the 1980's. The analysis of state policies showed that states with a three-credit course requirement for mathematics have higher rates of course-taking in mathematics and slightly higher rates of course enrollment in advanced math courses as compared to states with lower requirements. States with a two-credit in science did not have higher rates of course enrollments than states with lower requirements.

The analysis of state data provided findings on the issue of the level of science and math courses that students are taking to meet state requirements. In science, one-fourth of the high school students in the average state took a first-year Biology course in 1988-89 and one-fourth took a course in Earth Science, Physical Science, or General Science. Twenty percent of high school students took a course more advanced than first-year Biology. Thus, the great majority of students in most states do not go beyond first-year Biology. Data from some states reveal that enrollments in basic or applied courses comprise up to a third of enrollments in first-year Biology and Physics. In mathematics, one-fourth of high school students in the average state took a math course below the level of Algebra 1 in 1988-89, 21 percent took an Algebra 1 course, and 34 percent took a more advanced math course. Thus, even though total enrollments in more advanced math courses increased during the 1980's, a significant portion of students in the average state are taking math courses in high school which are below first-year Algebra, that is, courses offering the content of middle school or junior high school mathematics.

The data on course enrollments by gender from seven states showed that boys have higher rates of enrollment in Physics, Earth Science, and advanced mathematics courses, and enrollments of girls and boys are similar in other courses.

The state-by-state data on science and mathematics reported in the paper are part of an ongoing system of education indicators being developed by the Council of Chief State School Officers. Additional cycles of data reporting by states are expected to provide more complete data as well as providing the basis for trends analyses.

Table 1
PERCENTAGE OF HIGH SCHOOL STUDENTS TAKING SELECTED MATH COURSES OVER FOUR YEARS OF HIGH SCHOOL
(Percentages Computed from 1988-89 Data)

STATE	FORMAL MATH LEVEL 1 (E.G. ALGEBRA)	FORMAL MATH LEVEL 2 (E.G. GEOMETRY)	FORMAL MATH LEVEL 4 (E.G. TRIGONOMETRY)	FORMAL MATH LEVEL 5 (E.G. CALCULUS)
Alabama	57%	45%	18%	5%
Arkansas	90	52	15	4
California	76	45	22	9
Delaware	53	43	26	6
Hawaii	47	35	22	3
Idaho	87	[illegible]	23	6
Illinois	80	63	24	11
Indiana	59	49	30	7
Iowa	90	73	36	7
Kentucky	68	57	23	6
Louisiana	98	86	31	3
Minnesota	86	67	30	10
Mississippi	74	60	33	3
Missouri	[illegible]	55	27	8
Montana	98	68	14	5
Nebraska	95	81	36	10
Nevada	88	47	22	4
New Mexico	89	51	35	10
New York	69	55	28	10
North Carolina	64	55	35	7
North Dakota	90	64	39	3
Ohio	70	57	35	10
Oklahoma	87	48	17	10
Pennsylvania	82	54	NA	14
South Carolina	54	50	26	6
Texas	73	68	20	4
Virginia	77	61	34	10
Wisconsin	79	48	23	9
Wyoming	NA	28	18	6
Median	79%	55%	26%	7%

Notes: For each course, percentage of students in one cohort taking the course over 4 years is estimated by the one-year enrollment for grades 9-12 divided by the total student enrollment for the grade level at which most students take the course.
Illinois data collected 1986-87 school year; Nebraska data includes first and second semester enrollments.
Median = Median state percentage

Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 2
PERCENTAGE OF HIGH SCHOOL STUDENTS TAKING SELECTED SCIENCE COURSES OVER FOUR YEARS OF HIGH SCHOOL
(Percentages Computed from 1988-89 Data)

STATE	EARTH SCIENCE 1st Year	PHYSICAL SCIENCE	CHEMISTRY 1st Year	PHYSICS 1st Year	BIOLOGY 2nd Year
Alabama	1%	61%	36%	23%	15%
Arkansas	27	30	34	13	--
California	8	44	31	16	10
Delaware	15	73	45	19	5
Hawaii	12	59	39	20	5
Idaho	58	16	34	15	8
Illinois	20	29	42	21	12
Indiana	26	32	41	19	21
Iowa	26	[illegible]	54	26	10
Kentucky	4	38	43	13	28
Louisiana	16	57	51	22	6
Minnesota	15	74	44	22	15
Mississippi	--	--	54	16	66
Missouri	11	58	37	16	36
Montana	46	37	40	21	66
Nebraska	42	43	55	27	30
Nevada	47	7	39	15	17
New Mexico	11	47	36	14	9
New York	54	24	54	29	7
North Carolina	7	87	46	14	14
North Dakota	1	100	48	28	20
Ohio	18	34	47	20	11
Oklahoma	7	31	37	10	35
Pennsylvania	21	[illegible]	51	27	13
South Carolina	--	64	48	14	10
Texas	--	80	40	12	6
Virginia	86	4	56	24	[illegible]
Wisconsin	21	47	50	23	21
Wyoming	33	20	27	11	15
Median	18%	38%	43%	19%	14%

Notes: For each course, percentage of students in one cohort taking the course over 4 years is estimated by the one-year enrollment for grades 9-12 divided by the total student enrollment for the grade level at which most students take the course.

Illinois data collected 1986-87 school year; Nebraska data includes first and second semester enrollments.

Median = Median state percentage

Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 3
PROPORTION OF STUDENTS IN GRADES 9-12 ENROLLED IN MATH COURSES IN 1988-89 BY LEVEL

STATE	Total Students 9-12	Review & Informal	Formal Level 1 (Algebra 1)	Formal Levels 2-5 (Geom.-Calc.)	Other Math	TOTAL MATH
Alabama	203,101	28%	16%	27%	–	72%
Arkansas	99,680	NA	30	36	–	66
California	1,269,986	21	21	28	5%	76
Delaware	27,792	34	15	28	0.1	77
Hawaii	43,858	62	13	22	–	97
Idaho	58,359	19	23	31	2	76
Illinois	500,680	19	21	38	–	78
Indiana	285,367	31	15	32	–	78
Iowa	135,963	17	22	43	8	91
Kentucky	181,861	35	18	34	–	87
Louisiana	201,564	14	30	45	–	88
Minnesota	215,671	11	21	40	–	72
Mississippi	130,119	24	21	37	–	82
Missouri	236,860	21	22	36	3	82
Montana	42,104	19	30	29	--	78
Nebraska	78,132	21	27	49	8	--
Nevada	49,032	28	22	25	--	75
New Mexico	76,688	40	26	33	–	99
New York	743,290	23	19	34	8	81
North Carolina	322,087	31	18	36	–	84
North Dakota	33,627	15	23	41	1	80
Ohio	549,160	28	18	36	1	83
Oklahoma	164,630	22	23	33	2	79
Pennsylvania	500,536	14	21	47	–	82
South Carolina	177,948	46	16	32	2	96
Texas	891,628	34	22	34	–	90
Virginia	283,213	30	21	39	0.4	90
Wisconsin	238,207	34	21	29	–	84
Wyoming	27,286	26	NA	19	1	--
Median		25%	21%	34%	2%	82%

Note: Illinois data collected 1986-87 school year; Nebraska data includes first and second semester enrollments.
Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 4

PROPORTION OF STUDENTS IN GRADES 9-12 ENROLLED IN SCIENCE COURSES IN 1988-89 BY LEVEL

STATE	Total Students 9-12	Earth Sci., Physical Sci., General Sci.,	Biology 1st Year	Bio. 2nd Year, Chemistry + Physics 1 & 2	Other Science	TOTAL SCIENCE
Alabama	203,101	23%	26%	22%	1%	72%
Arkansas	99,680	27	34	15	3	79
California	1,267,036	19	24	15	3	61
Delaware	27,792	27	24	18	0.4	69
Hawaii	43,858	29	23	17	4	73
Idaho	58,359	23	23	15	4	65
Illinois	500,680	20	24	19	0.5	64
Indiana	285,367	22	25	23	1	70
Iowa	135,963	23	28	23	1	75
Kentucky	181,861	11	26	27	0.1	64
Louisiana	201,564	31	25	20	9	84
Minnesota	215,671	22	22	23	2	69
Mississippi	130,119	10	31	34	0.2	75
Missouri	236,860	29	22	26	2	79
Montana	42,104	25	18	33	2	78
Nebraska	78,132	29	34	28	6	96
Nevada	49,032	19	19	22	6	66
New Mexico	76,688	32	33	16	1	82
New York	743,290	27	33	23	5	87
North Carolina	322,067	27	25	15	1	68
North Dakota	33,627	27	27	29	2	85
Ohio	549,160	24	24	19	4	71
Oklahoma	164,630	18	24	21	9	72
Pennsylvania	500,536	19	27	25	--	71
South Carolina	177,948	27	25	18	1	71
Texas	891,628	26	26	14	2	67
Virginia	283,213	25	25	27	0.5	78
Wisconsin	236,207	24	24	20	2	71
Wyoming	27,286	17	16	14	5	52
Median		24%	25%	20%	2%	71%

Note: Illinois data collected 1986-87 school year; Nebraska data includes first and second semester enrollments.
Source: State Departments of Education, Data on Public Schools, Fall 1988.

30

Table 5

PROPORTION OF STUDENTS IN GRADES 9-12 TAKING MATHEMATICS COURSES BY STATE GRADUATION REQUIREMENTS

3 COURSES REQUIRED			2 COURSES REQUIRED		
State	Students Taking Mathematics	Students Taking Geom-Calc	State	Students Taking Mathematics	Students Taking Geom-Calc
Arkansas	91%	36%	Alabama	72%	27%
Kentucky	87	34	California	76	28
Louisiana	88	45	Delaware	77	28
New Mexico	99	38	Idaho	76	31
Pennsylvania	82	47	Indiana	78	32
South Carolina	96	32	Mississippi	82	37
Texas	90	34	Missouri	82	36
Virginia	90	39	New York	81	34
			North Carolina	84	36
			North Dakota	80	41
			Ohio	83	36
			Oklahoma	79	33
			Wisconsin	84	29
MEDIAN	90%	36/38%	MEDIAN	80%	33%

Note: Arkansas % students taking math was estimated by adding 66% reported for Formal Math plus 25% median state percentage for Review and Informal math. New Mexico required 3 math courses 1985-88, currently 2 courses.

Sources: Graduation requirements from CCSSO, 1989; Enrollment data from State Departments of Education, Data on Public Schools, Fall 1988.

Table 6

PROPORTION OF STUDENTS IN GRADES 9-12 TAKING SCIENCE COURSES BY STATE GRADUATION REQUIREMENTS

2-3 COURSES REQUIRED

State	Students Taking Science	Students Taking Adv. Science
Alabama (2)	72%	22%
Arkansas	79	15
California	61	15
Delaware	69	18
Idaho	65	15
Indiana	70	23
Kentucky	64	27
Louisiana (3)	84	20
Mississippi	75	34
Missouri	79	26
New Mexico	82	16
New York	87	23
North Carolina	68	15
North Dakota	85	29
Oklahoma	71	21
Pennsylvania (3)	71	25
South Carolina	71	18
Texas	67	14
Virginia	78	27
Wisconsin	71	20
MEDIAN	71%	20%

1 COURSE OR NO STATE REQUIREMENT

State	Students Taking Science	Students Taking Adv. Science
Illinois (1)	64%	19%
Iowa (Local)	75	23
Minnesota (Local)	69	23
Montana (1)	78	33
Nevada (1)	66	22
Ohio (1)	71	19
Wyoming (Local)	52	14
MEDIAN	69%	22%

Sources: Graduation requirements from CCSSO, 1989; Enrollment data from State Departments of Education, Data on Public Schools, Fall 1988.

Table 7
ENROLLMENTS IN FIRST-YEAR BIOLOGY, CHEM.STRY, & PHYSICS BY GENERAL VS. APPLIED

STATE	BIOLOGY-1ST YEAR					CHEMISTRY-1ST YEAR					PHYSICS-1ST YEAR				
	Total	General		Applied		Total	General		Applied		Total	General		Applied	
Alabama	53,808	38,042	71%	15,764	29%	17,315	16,939	98%	376	2%	10,350	6,594	64%	3,756	36%
California	300,075	201,840	67%	98,235	33%	97,208	*	*	*	*	40,909	*	*	*	*
Delaware	6,565	3,657	56%	2,908	44%	2,835	2,145	76%	690	24%	1,309	1,062	81%	247	19%
Hawaii	10,121	6,574	65%	3,547	35%	4,267	2,602	61%	1,665	39%	1,991	1,119	56%	872	44%
Idaho	13,224	*	*	*	*	4,787	*	*	*	*	2,022	1,986	98%	36	2%
Illinois+	120,534	*	*	*	*	51,079	50,524	99%	555	1%	2[illegible]42	*	*	*	*
Indiana	70,556	55,683	79%	14,873	21%	28,531	28,067	98%	464	2%	13,314	12,816	96%	498	4%
Minnesota	48,195	45,643	95%	2,552	6%	23,502	*	*	*	*	13,068	*	*	*	*
Mississippi	39,759	34,956	88%	4,803	12%	16,492	*	*	*	*	4,573	*	*	*	*
Montana	7,578	7,543	99.5%	35	.5%	4,081	4,067	99.7%	14	.3%	2,[illegible]90	2,276	99%	14	1%
Nebraska+	26,219	20,349	78%	5,870	22%	10,845	*	*	*	*	5,334	5,138	96%	196	4%
Nevada	9,229	*	*	*	*	4,762	*	*	*	*	1,805	1,611	89%	194	11%
New Mexico	25,289	22,266	88%	3,023	12%	6,391	*	*	*	*	2,434	*	*	*	*
New York	243,630	196,924	81%	46,706**	19%	100,537	*	*	*	*	47,444	*	*	*	*
North Carolina	81,678	81,632	99.9%	46	.1%	34,757	*	*	*	*	10,649	*	*	*	*
North Dakota	9,102	8,828	97%	274	3%	3,943	*	*	*	*	2,188	2,134	98%	54	2%
Pennsylvania	134,953	11,049	82%	23,904	18%	63,513	*	*	*	*	34,184	*	*	*	*
South Carolina	44,331	*	*	*	*	19,398	*	*	*	*	5,686	4,741	83%	945	17%
Texas	232,628	177,034	76%	55,594	24%	80,134	*	*	*	*	24,228	*	*	*	*
Virginia	70,683	63,323	90%	7,360	10%	37,015	32,654	88%	4,361	12%	16,318	16,006	98%	312	2%
Wisconsin	56,566	53,477	94%	3,089	6%	28,673	*	*	*	*	13,826	*	*	*	*
Wyoming	4,460	4,460	100%	*	*	1,798	*	*	*	*	725	633	87%	92	13%

*State does not collect or cannot report for category

**Estimated from totals for 7-9

+Illinois data collected 1986-87 school year; Nebraska data includes first and second semester enrollments

Source: State Departments of Education, Data on Public Schools, Fall 1988.

Table 8

State Course Titles for First-Year Biology: General Vs. Applied

State	General Biology	Applied Biology
Alabama	College Preparatory Biology, General Biology	Biology, Basic
California	Biology	Life Science
Delaware	Biology I (the first of two biology courses); Life Science A & B. Biology A, Biology 10 Biology 1, Lab A & B, Biology BSCS, Biology X (course targeted at college prep and academic students.	Life Sciences A& B, Biology A, Biology 10, Biology 1, Lab A & B (courses targeted to general, average, or below average grade level students)
Hawaii	Biology I	Biology BSCS I, Biology BSCS--SM Plant and Animals
Indiana	Biology Level I	Basic Biological Science, Practical Biological Science, Animal Science, Plant Science,
Minnesota	General Biology	Life Science
Mississippi	General Biology	Science, Applied Life
Montana	General Biology	Applied Biology
Nebraska	Biology	Life Science
New Mexico	Biology	Life Science
New York	Biology (regents) General Biology (state group II) Biology (local), Other Biology	
North Carolina	Biology I	Animal Behavior
North Dakota	Biology	Health (Under Bio/Sci category)
Pennsylvania	Biology I	Life Science
Texas	Biology I	Introductory Biology
Virginia	Biology I	Applied Biology
Wisconsin	Biology, First Year, General	Life Science
Wyoming	Biology, First Year, General	Applied Biology

Table 9

ENROLLMENTS IN MATHEMATICS BY GENDER

STATE	Formal Level 1 (Algebra) Total	Boys	Girls	Formal Level 2 (Geometry) Total	Boys	Girls
California	270.851	50%	50%	154,025	49%	51%
Hawaii	5,559	46	54	3,867	46	54
Illinois+	103,371	50	50	80,422	49	51
Iowa	30,177	50	50	23,607	49	51
South Carolina	28,676	49	51	22,809	47	53
Wisconsin	50,164	50	50	28,198	49	51
Wyoming	1,779	54	46	1,958	57	49

STATE	Formal Level 3 (Algebra 2) Total	Boys	Girls	Formal Level 4 (Trigonometry) Total	Boys	Girls
California	130,271	49%	51%	56,327	53%	47%
Hawaii	3,544	47	53	2,166	49	51
Illinois+	69,753	50	50	29,117	54	46
Iowa	19,439	49	51	13,113	54	46
South Carolina	21,667	47	53	10,146	48	52
Wisconsin	20,338	49	51	14,154	54	46
Wyoming	1,534	46	52	1,209	53	47

STATE	Formal Level 5 (Calculus) Total	Boys	Girls	Formal Level 5, Adv Place (Calculus) Total	Boys	Girls
California	23,338	56%	44%	*	*	*
Hawaii	94	41	59	186	54%	46%
Illinois+	10,524	56	44	2,804	59	41
Iowa	2,588	55	45	*	*	*
South Carolina	607	62	38	1,548	51	49
Wisconsin	5,232	55	45	*	*	*
Wyoming	237	54	46	146	68	32

*State does not collect or cannot report data for category

+School year 1986-87

Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 10

ENROLLMENTS IN BIOLOGY, CHEMISTRY, PHYSICS, & EARTH SCIENCE BY GENDER

	BIOLOGY					
	First Year			2nd Year (AP/Other Advanced)		
STATE	Total	Boys	Girls	Total	Boys	Girls
California	300,075	51%	49%	34,764	45%	55%
Hawaii	10,121	48	52	504	34	66
Illinois+	120,534	49	51	14,818	47	53
Iowa	37,534	[illegible]	50	3,197	40	60
South Carolina	44 331	50	50	4,530	44	56
Wisconsin	56,566	51	49	12,524	47	53
Wyoming	4,480	52	48	1,011	46	54

	CHEMISTRY					
	First Year			2nd Year (AP/Other Advanced)		
STATE	Total	Boys	Girls	Total	Boys	Girls
California	97,206	50%	50%	6,876	58%	42%
Hawaii	4,267	44	56	147	58	42
Illinois+	51,079	49	51	4,931	59	41
Iowa	18,321	50	50	*	*	*
South Carolina	19,396	47	53	1,409	58	42
Wisconsin	28,673	48	52	5,294	54	46
Wyoming	1,796	52	48	153	52	48

	PHYSICS					
	First Year			2nd Year (AP/Other Advanced)		
STATE	Total	Boys	Girls	Total	Boys	Girls
California	40,909	59%	41%	6,976	57%	43%
Illinois+	25,342	60	40	1,329	72	28
Hawaii	1,991	55	45	504	34	66
Iowa	9,402	59	41	[illegible]	*	*
South Carolina	5,696	61	39	142	75	25
Wisconsin	13,826	60	40	2,642	58	42
Wyoming	725	63	37	24	79	21

	EARTH SCIENCE					
	First Year			Advanced		
STATE	Total	Boys	Girls	Total	Boys	Girls
California	29,642	54%	[illegible]	9,030	51%	49%
Illinois+	25,854	54	[illegible]	3,1[illegible]	62	38
Hawaii	1,390	56	44	2,020	56	44
Iowa	8,586	53	17	2,020	56	44
South Carolina	*	*	[illegible]	177	66	34
Wisconsin	12,628	54	[illegible]	2,305	59	41
Wyoming	2,256	56	43	58	64	36

*State does not collect or cannot report data for category

+School year 1986-87

Source: State Departments of Education, Data on Public Schools, Fall 1988.

Chapter 2
STATE-BY-STATE INDICATORS OF TEACHERS IN SCIENCE AND MATHEMATICS

This chapter presents an analysis of state-by-state data on the characteristics of teachers in science and mathematics. The data on teachers are cross-sectional, but they are useful for considering issues in supply and demand of science and mathematics teachers.

The chapter addresses three policy issues:

1. the current numbers and allocation of science and math teachers by state and teaching subject/field, and projected demand for teachers in the 1990's;

2. the problem of relatively low numbers of female and minority teachers in science and math; and

3. the proportion of science and math teachers teaching "out-of-field," and the relationship to projected shortages.

NEED FOR IMPROVED STATISTICS ON TEACHER DEMAND AND SUPPLY

In 1984, Darling-Hammond reviewed data on science and math teachers and predicted severe shortages in the 1990's. Four reasons were cited: a) the number of teachers currently teaching "out-of-field," b) the low number of new entering science and math teachers, c) the high numbers of science and math teachers reaching retirement age, and, d) the high numbers of science and math teachers leaving teaching before retirement age. The National Science Teachers Association (NSTA) estimated in 1984 that 30 percent of all secondary science and mathematics teachers are "completely unqualified or severely underqualified" to teach these subjects (Johnston and Aldridge). NSTA also found that in the 1982-83 school year 12 teachers left teaching for each newly trained science/math teacher, and 40 percent of science and math teachers would retire by 1995 (Aldrich, 1983). Recently, researchers at the RAND Corporation projected that the total number of new science and math teachers that will need to be hired by 1995 is equal to the current teaching force in these subjects of about 300,000 teachers (Shavelson, et al, 1989, p.80).

Several questions can be raised about the projections of shortages of science and math teachers. First, the shortage projected by NSTA in 1983 (40 percent will retire by 1995) is not any greater than the average yearly demand for teachers by 1995. NCES projections for teacher demand show that the equivalent of 10 percent of the total of about 1.1 million secondary teachers (110,000) will need to be hired in 1990. By 1995 the equivalent of 8 percent of the total secondary teachers will need to be hired each year. These projections take into account rates of turnover (retirement plus job change) and enrollment change. Thus, from 1990 to 1995 the equivalent of approximately 50% of the total secondary teacher force will need to be hired.

Second, there is not current evidence that turnover of science and math teachers is as high as predicted in 1983. Recent NCES projections show a small increase in teacher turnover rate--from current 6% to about 8% in 1995 (NCES, 1989a). In science, higher turnover rates are specific to chemistry and physics teachers, and are not general to math and all science fields. Weiss (1989) conducted a follow-up survey with the secondary science and math teachers surveyed in 1985-86 and found that about 85 percent were still in teaching in 1988, which is a turnover rate of 5 percent. National survey responses from principals on the difficulty of hiring teachers showed that over half the principals reported that physics and chemistry teachers were hard to hire (Weiss, 1987). Murnane, et al. (1988) analyzed the career patterns of science and math teachers in three states and found that attrition rates were higher among chemistry and physics teachers than among biology, mathematics, or history teachers. Chemistry and physics teachers had shorter periods of initial teaching years and were less likely to return to teaching than other teachers.

Third, the hiring of teachers in science and math is not dependent on the number of new graduates of teacher education programs. A committee of the National Research Council studying statistics on teacher supply and demand reported that evidence from recent hiring patterns of school districts shows that a majority of new hires are from the "reserve pool" of teachers who left teaching and decide to return as openings increase (National Research Council, 1987).

Finally, the evidence on the proportion of current teachers that are not qualified in their field of teaching is very mixed. National surveys of teachers show that a significant proportion of teachers are not qualified to teach subjects or courses to which they are assigned. However, the exact numbers vary with the measure of teacher "qualifications" that is used. The Carnegie Foundation for Advancement of Teaching found that an average of 20 percent of elementary and secondary teachers said they were "teaching subjects they were not qualified to teach," and states varied in percentage of non-qualified teachers from 12 percent (New Hampshire) to Utah (30 percent) (National Center for Education Statistics, 1989b). In a survey with a nationally-representative sample of science and mathematics teachers in 1985-86, teachers were asked to report on their degrees and course preparation. The results showed that only 7 percent of high school math teachers were teaching "out-of-field," and a lower percentage of science teachers were not trained in a science field. However, one-third of physics classes and one-fifth of chemistry classes were taught by a teacher not trained in those specific disciplines (Weiss, 1987).

DESIGN FOR STATE INDICATORS ON SCIENCE AND MATH TEACHERS

The review of existing data sources and the varying predictions concerning teacher shortages in specific teaching fields illustrate the need for improvements in capacity for making statistical projections at the national level. This need will largely be addressed with the results from the Schools and Staffing Survey being conducted on a periodic basis by NCES. However, while national statistics and projections give a general picture, teacher shortages vary widely by state, region, and district. Education decision-makers are likely to want data on the status of the teaching force that are more specific to their situation, and one approach is to provide state-level statistics. The National Research Council committee on teacher supply and demand statistics recommended development of improved state-level statistics for specific fields in science and mathematics (1987).

The CCSSO Science/Math Indicators Project is beginning to address the need for better data on the teaching force at the state level. These data will help to identify current and projected teacher shortages in specific teaching fields, and highlight the demographic characteristics of the teaching force. These data might assist education policy-makers in determining strategies and programs for improving the teaching force, such as with incentives to attract people to teaching in science and mathematics. For example, Weiss' (1987) analysis of national data on teacher characteristics showed that minority and female science and math teachers are vastly under-represented considering the student population in our schools, and state-level data are needed on teachers in these groups.

The CCSSO Project advisory panel recommended that teacher characteristics be aggregated and reported by state departments of education, and that the data should be collected and reported for one point in time during a school year (e.g., October 1). The resulting state-by-state statistics would not provide projections of teacher demand and supply by state, but they could provide reliable, valid comparative data on science/math teachers by state without high costs to states. Additionally, with periodic reporting of teacher characteristics by state, trend analyses could be carried out.

State-level data on teacher assignments by state certification status is an important state-level indicator of teacher shortages. Knowing whether or not a teacher is certified for the courses he/she is teaching does not provide a good measure of teaching quality or of the individual's preparation in the field (Murnane and Raizen, 1988). However, the proportion of teachers who are teaching "out-of-field" is a useful policy indicator because it is a quantifiable measure of the proportion of teachers in a district or state that do not meet basic qualifications. This indicator has often been used to identify current teacher shortages in science, math, and other subjects (Shavelson, et al, 1989). A major advantage of state data on teacher assignments and certification is that the data can be computed from state administrative records and computerized data files, thereby alleviating the need for special surveys of teachers and use of data based on teacher self-reports. Since certification standards for each teaching field differ by state (Blank and Espenshade, 1988a), it is important to report state-by-state statistics on teacher certification along with information on states' standards.

To obtain comparable state-by-state data, a Project task force comprised of state specialists in science, mathematics, and information systems designed a plan for state reporting of teacher characteristics. The plan specified that teacher data be reported according to percent of time teachers are assigned to mathematics, computer science, and six fields of science. Two categories of percent of time were specified: a) teachers who have their "primary assignment" in a subject/field (i.e., at least 50% of teaching time), and b) teachers who have a "secondary assignment" in a subject/field (less than 50% of teaching time in the field).

There are several reasons for reporting data on teachers by these two assignment categories. First, it is important to account for all teachers of science and mathematics, regardless of the number of courses or amount of time they spend teaching science or math. Second, to analyze the condition of the teaching force in science and math it is important to differentiate between teachers who are assigned to a specific subject or field, e.g., Biology or Physics, for the majority of the teaching day vs. teachers who may teach only one or two courses in a subject or field. For example, in order to offer a course in Physics, a school district may assign a teacher who is certified in Chemistry to teach the course because it is not possible to hire a full-time Physics teacher. That teacher may or may not also be certified to teach Physics. Thus, to analyze teacher certification data, the Project advisory panel recommended cross-tabulating certification by "primary assignment" vs. "secondary assignment," as well as cross-tabulating teacher age, sex, and race/ethnicity by the two assignment categories.

USES OF STATE-BY-STATE INDICATORS ON SCIENCE/MATH TEACHERS

In the first year of state reporting on science/math indicators, 39 states reported data on science/math teachers. In 1989-90 the same indicators were requested and CCSSO expects that all 50 states will report teacher data. The initial results can be used to address several policy issues concerning teacher supply and demand, and these results illustrate how these indicators of the teaching force can be used on a continuing basis.

Distribution of Science/Math Teachers

State-by-state data on the distribution of teachers to science and mathematics fields are shown in Tables 1 and 2. The "Total" at the bottom of each column shows the sum by assignment category and all teachers for each subject or field. With data from all 50 states, national totals would be available.

In Mathematics (Table 1), the state-by-state data show that two-thirds to three-fourths of math teachers in each state have their primary assignment (50% or more) in Mathematics. Exceptions to this pattern are in Arkansas (70 percent secondary assignment, or "part-time"), Illinois (47 percent), and Hawaii (46 percent). Smaller states, such as Montana, Nevada, South Dakota, and Utah, have more part-time Math teachers which comprise about one-third of all Math teachers in these states. In Computer Science, a majority of teachers are teaching Computer Science as a secondary assignment (less than 50% time).

The state-by-state data on science teachers in Table 2 show that in 23 of 39 states a majority of Biology teachers have their primary assignment (50% or more time) in Biology. For example, of 800 teachers in Alabama assigned to teach Biology, 491 teachers (61%) have their primary assignment in Biology. The proportion of Biology teachers with a primary assignment in the field varies from 89% in Pennsylvania to 26% in North Dakota. In Chemistry, 15 states had a majority of teachers assigned 50% or more in Chemistry with the proportions varying from a high of 84 percent in Pennsylvania to a low of 21 percent in South Dakota. In Physics only 4 states had a majority of teachers assigned 50% or more in Physics (Connecticut, Idaho, North Carolina, Pennsylvania), and most teachers in the other 35 states teach Physics on a part-time basis.

States with more rural districts, such as Arkansas, Oklahoma, and North Dakota had fewer teachers with primary assignments in any of the science fields while states with a greater proportion of urban and suburban districts, such as Connecticut, New York, and Pennsylvania, had more teachers with primary assignments in one field. Southern states with whole-county districts, such as Mississippi, North Carolina, South Carolina, and Virginia, have higher proportions of math and science teachers with primary assignments in one field.

(The states also reported data on characteristics of teachers assigned in Earth Science, General Science, and Physical Science. These data are not analyzed in the paper but they are available from the author.)

A question that might be asked about the teaching force in science and mathematics in each state is how the number of teachers compares with the student population to be educated. A student:teacher ratio was computed for mathematics and three science fields, as shown in Table

3. A statistic of "estimated full-time equivalent teachers (FTE)" by subject/field was computed. Since the data were not requested from states in FTEs, estimated FTEs were computed from the state totals for primary and secondary assignments (.75 times the number with primary assignments (50% or more time) plus .25 times the number with secondary assignments (less than 50%)). The student:teacher ratio is the total grade 9-12 enrollment in the state divided by the estimated FTE for each subject/field.

The student:teacher ratios for mathematics vary from 62 students per teacher in Hawaii to 242 in Mississippi, with a median state ratio of 144. The low ratio in Hawaii may be due to inclusion of grades 7-8 in the total. In Biology, the ratio varies from 249 students per teacher in New York to 639 in California, with a median of 428. In Physics the ratios vary from 868 in North Dakota to 7,654 in Mississippi, with a median of 1,907. A large portion of high school students at each grade level are taking a Mathematics course and every high school has several Math teachers. Thus, the state student:teacher ratios reflect the average student load for a full-time math teacher. There are more Biology teachers than teachers in other science fields because almost all schools offer Biology. Since most students take only one Biology course, the ratios are higher than for Mathematics. The student:teacher ratios for Chemistry and Physics might be interpreted as an indicator of the capacity of schools in a state to offer courses in these fields. In Chemistry, almost all states have an average of a full-time equivalent teacher for the number of students that would comprise a large high school (i.e., 800 to 1800 students). Thus, on average, smaller high schools are likely to have only a part-time Chemistry teacher. In Physics, 12 of 29 states have a student:teacher ratio of over 2,000 students per full-time equivalent teacher and all but two states have a ratio over 1,000 students per teacher. These ratios indicate that on average only the largest high schools in a few states would have a full-time Physics teachers.

The student:teacher ratios for Chemistry and Physics provide an indication of the distribution of teachers to students, but possibly a school does not need a "full-time equivalent" teacher in physics. Decision-makers may be more interested in whether each school has someone to teach physics, if even one course. Table 4 displays the number of high schools in each state by the total "headcount" of teachers assigned to to each of the four subjects (i.e., teachers with primary assignment or secondary assignment). These data reveal that 9 of 33 states have more high schools than Chemistry teachers, and 21 of 33 states have more high schools than Physics teachers. In California, Idaho, Mississippi, New Mexico, Oklahoma, South Dakota, and Utah two-thirds to one-half of the schools are able to offer a Physics course (unless several schools are cooperating in sharing a Physics teacher, which is not reflected in the state totals). These state-level data on number of schools per science teacher are consistent with findings of the 1985-86 national survey (Weiss, 1987) and a national survey of Physics teachers (Neuschatz and Covalt, 1989). State-level data provide more specific information that can be related to state or district policies, and can be useful in gauging the degree of severity of a problem such as shortages of Chemistry and Physics teachers.

Age, Sex, Race/Ethnicity of Science and Math Teachers

With state-by-state data on the demographic characteristics of teachers, it is possible for education decision-makers to see differences in the current teaching force in science and math which may be related to state policies and programs such as recruitment, certification, or early retirement, as well as to identify problems that need to be addressed such as the aging of the teaching force or under-representation of women and minority teachers. For the 1988-89 school year, 39 states reported data on the age, sex, and race/ethnicity of teachers assigned 50% or more to a math or science field. For purposes of comparison, states also reported the age, sex, and race/ethnicity of all high school teachers.

Age of Teachers. Table 5 lists the percentage of science and math teachers who are under age 30 and the percentage over age 50. These statistics can be used for estimating the future demand for teachers, i.e., number of younger teachers as compared to older teachers. The median state percentage of Math teachers under age 30 is 14% and the median percentage over age 50 is 16%, which indicates that in most states math teaching is not dominated by older teachers. State percentages vary considerably--from a high of 23% under 30 in Wyoming to a high of 2[illegible]% over 50 in Minnesota. Eleven states reported more math teachers under 30 than over 50. The state-reported data can be compared with national averages from survey data. For example, in the 1985-86 national survey of science and math teachers, 13 percent of math teachers in grades 10-12 were over 50 (Weiss, 1989).

In Biology, Chemistry, and Physics, there are higher percentages of older than younger teachers in most states, although the differences vary by field. Biology has an average of 11% under 30 and 17% over 50 (6 percent more teachers over 50 than under 30), Chemistry has an average of 12% under 30 and 22% over 50 (difference of 10 percent), and Physics has an average of 8% under 30 and 23% over 50 (difference of 15 percent). In states such as California, Delaware, Idaho, Minnesota, Mississippi, and Wisconsin the differences in ages of Chemistry and Physics teachers show that the demand will be higher for these teachers in the 1990's. From the higher percentage of younger teachers, states such as Kentucky, Nevada, Ohio, Pennsylvania, South Carolina, and Utah are less likely to have shortages in these fields. The national survey showed an average of 11 percent of science teachers in grades 7-9 over age 50 and 15 percent of science teachers in grades 10-12 (Weiss, 1989).

The state-by-state data on all high school teachers is not shown in a table. However, the median for all teachers is 11 percent under 30 and 17 percent age 50 and over. Eleven states had more teachers under 30 than over 50.

Sex of Science/Math Teachers. The 1985-86 national survey reported that 46 percent of math teachers in grades 10-12 and 51% in grade 7-9 were female, and that 31 percent of science teachers in grades 10-12 and 41 percent in grades 7-9 were female (Weiss, 1989). State-by-state the proportions of math and science teachers that are male and female vary widely, as shown in Table 6. For example, in mathematics the percent of female teachers varies from 20% in Minnesota to 76% in Texas, and the median is 43%. (The data on all high school teachers in these states shows 40% female in Minnesota and 67% female in Texas.) Ten states have more female than male math teachers and all but New Jersey and Hawaii are states in the southeast. In Biology, the percentage of female teachers varies from 14% in Montana to 76% in Texas, and the median is 38%. Eight states have more female than male Biology teachers. Chemistry and Physics have lower average percentages of female teachers--30% median female in Chemistry and 18% median female in Physics. Eight states have more female than male Chemistry teachers, but only one state (Texas) has more female than male Physics teachers. The state median percentages for all high school teachers are 51% male and 49% female.

Race/Ethnicity. In 1985-86, the national figures for minority teachers' in science and math were: 10% minority math teachers in grades 7-9, 6% of grades 10-12 math teachers, 12% of grade 7-9 science teachers, and 8% of grades 10-12 science teachers (Weiss, 1989). The state-by-state data on race/ethnicity of teachers assigned 50% or more to four science and math fields are displayed in Tables 7-1 and 7-2. These percentages can be compared with the student race/ethnicity distributions (K-12) by state. (Student statistics were obtained from the NCES Common Core of Data for the 1988-89 school year.) Nationally, 30 percent of elementary and secondary students are minorities, and 70 percent are white.

Figure 1 shows a cross-tabulation of percentage minority teachers in three fields by the percentage minority students in the state. Among the 19 states that reported teacher race/ethnicity by field and student race/ethnicity, only eight states had over 10 percent minority Math teachers. Of the 13 states with more than 20% minority students, only 4 states had more than 15% minority math teachers (Alabama, Hawaii, Mississippi, and South Carolina). In Biology and Chemistry, the percentages of minority teachers are about the same as for Mathematics. Among the 13 states with over 20% minority students, five states had over 15% minority Biology teachers and five states had over 15% minority Chemistry teachers. Other than Hawaii, the four states with the highest proportions of minority teachers are all in the southeast: Alabama, Mississippi, North Carolina, and South Carolina. The data show that except for Hawaii no state has representation of minority teachers which is similar to the racial/ethnic background of students.

The current findings should be considered preliminary since data were reported on race/ethnicity of only the science and math teachers assigned 50% or more of their time. For 1989-90, race/ethnicity of all teachers in these fields will be reported. With data reported over time on the proportion of minority science and math teachers by the proportion minority students an important trend indicator can be developed.

Figure 1

Percentage Minority Teachers of Teachers Assigned 50% or More in Mathematics, Biology, and Chemistry By Percentage Minority Students (K-12)

STATE	STUDENTS % MINORITY	% MINORITY TEACHERS Math	Biology	Chemistry
Utah	7%	2%	2%	1%
North Dakota	8	0	0	0
Kentucky	10	2	4	1
Wisconsin	14	1	1	2
Ohio	16	3	5	2
Pennsylvania	17	3	3	1
Nevada	23	9	8	3
Colorado	24	4	NA	NA
Connecticut	24	3	4	3
Arkansas	25	11	10	7
Oklahoma	25	5	4	2
Delaware	31	9	7	4
New Jersey	33	10	7	4
North Carolina	33	14	17	11
Alabama	37	19	19	15
South Carolina	42	23	25	16
Texas	49	15	NA	17
Mississippi	51	27	31	31
Hawaii	77	72	72	63

Source: Data on Public Schools, State Departments of Education, October 1988.

Certification of Science/Math Teachers

An important component of an analysis of teacher shortages and the demand for teachers is the proportion who are teaching "o .-of-field," i.e., not trained in the field in which they are assigned to teach. For states, a relevant measure of out-of-field teaching, and teacher shortages, is the proportion of teachers that are not state-certified in the subject or field in which the teachers are assigned.

States reported teacher assignments in science and math by certification status. The data are displayed in Tables 8-1 through 8-4. Teachers were defined as "out of field" if they were certified in a field/subject other than the one assigned or if they had a temporary, provisional, or emergency certification. As outlined in the Project design, the certification statistics are reported by teachers' primary assignment (50% or more time) and secondary assignment (less than 50% time). For state-by-state comparisons, information is reported in Table 8-5 on the number of credits required for state certification in each field.

Mathematics. Table 8-1 shows that the proportion of math teachers assigned out-of-field is widely varied--from three states (Connecticut, North Dakota, and Wyoming) having 0 percent out-of-field to Colorado having 32 percent out-of-field. The medians of 3 percent out-of-field for primary assignments and 3 percent for secondary assignments tend to mask the high numbers in a few states. In two states (Montana and Oregon) the large majority of teachers out-of-field are those with a secondary assignment as math teachers, but in other states the percentages are fairly even for both assignment categories.

One possible explanation for variation among the states in the proportion of teachers out-of-field is the differences in certification requirements. If a state has more stringent requirements, it might be expected that more teachers would be teaching out of field because it is harder to hire new teachers who are certified or to assign current teachers who also have a Math certification. States with lower requirements would be predicted to have fewer teachers out-of-field.

To test the hypothesis, the total percentage of teachers out-of-field in each state was cross-tabulated by the number of math credits required for certification, as shown in Figure 2. The pattern of results show some support for the hypothesis--three states with the highest percentage of math teachers out-of-field have high credit requirements (Montana, Kentucky, and California) and two states with the lowest requirements (Idaho and North Dakota) have few teachers out-of-field in Math. However, there are contradictions to the hypothesis--Nevada and South Dakota have low requirements but high proportions of teachers out-of-field (16%, 29%), and Missouri and Ohio have high requirements but only 1% of teachers out of field. An alternate explanation for the pattern in these states may be the extent of change in school age population. Nevada's teacher shortage might be attributed to its 16 percent school-age population increase from 1977-87 (as compared to the U.S. total of 9 percent decrease). Decline in school-age population could explain the lack of shortage of teachers in Missouri (13% decrease) and Ohio (17 % decrease). South Dakota had a 13 percent decrease in school-age population, but still has a teacher shortage in Mathematics. A factor may be the number of small, rural districts (81% of districts under 1000 students vs. 61% for the U.S.). However, there may be a number of factors that affect teachers in individual states such as low pay or early retirement options.

Figure 2

PERCENTAGE OF MATHEMATICS TEACHERS OUT-OF-FIELD BY CREDITS REQUIRED FOR STATE CERTIFICATION

Math Credits Required	0 - 10 % Out-Of-Field	11 - 32 % Out-Of-Field
20 Credits or Less	Idaho (6%) North Dakota (0)	Nevada (16%) South Dakota (29%)
21 - 29 Credits	Alabama (6%) Mississippi (9) Virginia (3) Wyoming (0) New York (8)	Oregon (12%)
30 - 45 Credits	Missouri (1%) Ohio (1) Oklahoma (8)	Montana (20%) Kentucky (13) California (31)
Credits set by degree-granting institution	Minnesota (3%) North Carolina (5) Utah (5) Pennsylvania (8) South Carolina (9)	Colorado (32%)

Source: Data on Public Schools, State Departments of Education, October 1988.
Blank and Espenshade (1988a)

Biology. An analysis of assignment by certification in science teaching fields requires the additional variable of type of science certification. Forty states have a "broad-field" science certification which typically provides certification for teaching in any secondary science field. Although the certification requirements for broad-field certification vary among states (see Table 9), in most states the reason for this type of certification is to provide districts and schools with greater flexibility in hiring and assigning science teachers. Some offer teachers the option of "specific-field" or broad-field certification, but 10 states offer science certifications for only specific fields--Biology, Chemistry, Physics, Earth Science, etc. One hypothesis concerning science certifications would be that states with broad-field certification have fewer teachers out-of-field than states with only specific-field certification.

The state data in Table 8-2 show that on average a smaller proportion of Biology teachers are assigned out-of-field than are Math teachers. However, as with Math teachers, the low average percentages out-of-field (medians: 1% and 2%) obscure the substantial proportion of teachers out-of-field in states such as California, Mississippi, Montana, New York, and South Dakota. A large proportion of Biology teachers are certified with broad-field certification (medians of 12% and 11%), and particularly in California, Nevada, North Carolina, Ohio, and South Carolina.

A cross-tabulation of percentage of Biology teachers out-of-field by state certification requirements, in Figure 3, provides an analysis of differences in level of requirements and broad-field vs. specific field certification. The results show that states with a broad-field certification do not have lower rates of out-of-field teaching. The three states with the highest percentages out-of-field--South Dakota, California, and Montana--all have broad-field certification. However, there is some evidence that a higher credit requirement for either specific-field or broad-field certification is related to a higher proportion of teachers assigned out-of-field. Of the three states

Figure 3

PERCENTAGE OF BIOLOGY TEACHERS OUT-OF-FIELD BY STATE CERTIFICATION REQUIREMENTS

Biology Credits Required	0 - 10 % Out-Of-Field	11 - 39 % Out-Of-Field
Specific-Field Certification		
12 to 24 Credits	Connecticut (0%) Virginia (3)	
25 to 45 Credits	New York (8%) Oklahoma (5)	Mississippi (11%)
Broad-Field Certification		
18 To 36 Credits	North Dakota (0%) Wyoming (0) Missouri (3) Nevada (6)	South Dakota (25%)
37 to 60 Credits	Alabama (3%) Idaho (2) Kentucky (2) Ohio (1) Oklahoma (7)	California (28%) Montana (39)
Credits set by degree-granting institution	Minnesota (3%) North Carolina (2) South Carolina (5) Utah (7) Pennsylvania ([illegible])	

Source: Data on Public Schools, State Departments of Education, October 1988.
Blank and Espenshade (1988a)

with 0 percent out-of-field, Connecticut requires only 18 credits (specific-field), North Dakota requires 21 credits for broad-field certification and 12 credits for specific-field certification, and Wyoming requires 30 credits for broad-field and 12 credits for specific-field certification.

It is likely that state demographic variables contribute to the high rates of teachers out-of-field in several states. California (28%) experienced a 3 percent increase in school-age population over 10 years and the state requires 45 credits for a "Life Science" certification. South Dakota (25%) and Montana (39%) have a high proportion of small, rural districts, and these kinds of districts have greater difficulty in hiring certified science and math teachers.

Physics. State data on assignment by certification status for Chemistry are in Table 8-3 and data for Physics are in Table 8-4. This analysis will be limited to Physics, although some of the patterns are similar for Chemistry. Of the total Physics teaching force, an average of 72% are teaching Physics as a secondary assignment. The median percentages of Physics teachers out-of-field (2% primary assignment and 12% secondary assignment) show that certified Physics teachers are much harder to hire than teachers of Biology.

The cross-tabulation of percent out-of-field with state requirements shows that neither broad-field vs. specific-field or the number of credits is related to percent of Physics teachers out-of-field. All but six states with state requirements have more than 16 percent of Physics teachers out-of-field, with the highest percentages in Mississippi (61%), South Dakota (53%), and Montana (76%). States with many small districts (South Dakota, Montana), mostly rural districts (Alabama, Mississippi, Kentucky) as well as states with more urban districts (California, New York) have shortages of Physics teachers. It should be noted that some states

Figure 4

PERCENTAGE OF PHYSICS TEACHERS OUT-OF-FIELD
BY STATE CERTIFICATION REQUIREMENTS

Physics Credits Required	0 - 10 % Out-Of-Field	11 - 76% Out-Of-Field
Specific-Field Certification		
12 to 24 Credits	Connecticut (0%)	Virginia (16%)
25 to 45 Credits		New York (20%) Oklahoma (26) Mississippi (61%)
Broad-Field Certification		
18 to 36 Credits	North Dakota (0%) Wyoming (0) Nevada (2)	Missouri (16%) South Dakota (53)
37 to 60 Credits	Ohio (2%) Idaho (2)	Kentucky (18%) Alabama (27) California (23) Montana (76)
Credits set by degree-granting institution	Utah (2%) North Carolina (5) South Carolina (11) Pennsylvania (7)	Minnesota (13%)

Source: Data on Public Schools, State Departments of Education, Oct ber 1988.
Blank and Espenshade (1988a)

with low percentages of Physics teachers out-of-field were states identified in Table 3 as having low numbers of teachers relative to the number of high schools in the states, including Idaho, North Dakota, Utah, Ohio, Nevada, Wyoming. In these states, districts and schools assign few teachers out-of-field, but the state also offers only limited opportunities for Physics since many schools have no Physics teacher either certified or non-certified.

If we know the proportion of Physics teachers (or teachers in other fields) that are certified vs. assigned out-of-field in a state, is this a useful indicator of the qualifications or preparation of Physics teachers (or teachers in other fields)? Using the example of Physics, other data on teacher qualifications can be considered. From a national survey of Physics teachers, Neuschatz and Covalt (1988) found that 26 percent of Physics teachers have a college degree in Physics. Of the current Physics teachers, about one-third started their teaching career in Physics, about one-third started in another science teaching field but have 10 years experience in Physics teaching, and about one-third are assigned for the first time or have occasionally taught Physics. Only about 1 percent of current Physics teachers were trained in a field other than science or math. Data from the 1985-86 survey of science and math teachers show that 65 percent of Physics classes were taught by a teacher with 6 or more courses in Physics, whereas 88 percent of Biology classes were taught by a teacher with 6 or more courses in Biology (Weiss, 1987). Weiss (1987) also found that all but 6% of teachers assigned to teach a science course have a degree in a science (Weiss, 1987).

These national-level studies show that a large proportion of Physics teachers do not have extensive preparation in Physics, although almost all have preparation in a field of science or math. Thus, the state data on certification status could be viewed as an estimate of the proportion of Physics teachers that do not meet basic standards for the field, but the data do not measure the extent or quality of preparation. The advantages of certification data for state-level analyses is that the data can be produced from existing data files, they can be related to state policies, and they can be used for state-by-state comparisons.

SUMMARY

The analysis of state-level data on science and mathematics teachers shows that national statistics on teacher supply and demand are sometimes insufficient for analyzing specific policy issues. The analysis of age of science and math teachers by state showed that projections of high teacher attrition due to retirements over the next 10 years will present a severe problem in some states if actions are not taken. However, national survey data do not show a severe problem of attrition except in selected fields of science. Similarly, large state differences in the proportions of female and male math and science teachers are averaged out in national totals, and the national average can mask the degree to which students in different states have opportunities to learn from female (or male) science and math teachers. State-by-state data on teacher race/ethnicity accentuate the disparity between teacher and student populations indicated by national averages.

The state-by-state analysis of the distribution of science and math teachers revealed some very specific information about teacher shortages. Current shortages in math and science were identified for some states by the proportion of teachers assigned out-of-field, while in other states shortages are identified by analyzing the number of teachers per school and student:teacher ratios. The state data show that differences in state requirements for certification have some relationship to the proportion of teachers assigned out-of-field. However, other state characteristics are also related such as the number of small districts and rural location, as well as the rate of change in school-age population. It is also apparent from the data on teachers per school that decisions about offering courses in science fields have an effect on the proportion of teachers in a state assigned out-of-field. Some states have few teachers out-of-field but also offer relatively few student opportunities to take courses such as Physics.

As education decision-makers ask for improved data and statistics to track progress in our educational system, it is important to ensure that key policy questions can be addressed by the statistics. The initial results from state-by-state reporting on teachers in science and mathematics show that state-level data and statistics can be very informative about policy issues. This is particularly the case with data on teachers since states have a large role in defining the conditions by which teachers are trained, certified, hired, and assigned, as well as the school conditions for teaching and how teachers are paid. This report illustrates how state-level data on key teacher characteristics can be used to inform education decision-makers and to identify potential problems with teacher shortages that could be further analyzed with more complex models.

Table 1

MATHEMATICS AND COMPUTER SCIENCE TEACHERS (GRADES 9-12) BY PERCENT OF TEACHING ASSIGNMENT

STATE	MATHEMATICS 50% or More	MATHEMATICS Less Than 50%	MATHEMATICS Total	COMPUTER SCIENCE 50% or More	COMPUTER SCIENCE Less Than 50%	COMPUTER SCIENCE Total
Alabama	1,226	383	1,609	40	73	113
Alaska	--	--	--	--	--	--
Arizona	--	--	--	--	--	--
Arkansas	729	1,723	2,452	--	--	--
California	6,440	3,163	9,603	92	504	596
Colorado	1,251	134	1,385	--	--	--
Connecticut	1,535	89	1,624	63	196	259
Delaware	316	*	316	9	--	9
Dist. of Columbia	--	--	--	--	--	--
Florida	--	--	--	--	--	--
Georgia	--	--	--	--	--	--
Hawaii**	736	619	1,355	4	29	33
Idaho	526	81	607	--	--	--
Illinois	3,516	3,296	6,812	304	457	761
Indiana	--	--	2,321	--	--	212
Iowa	*	*	1,820	*	*	448
Kansas**	*	*	1,799	*	*	344
Kentucky	1,382	309	1,691	24	137	161
Louisiana	*	*	3,466	*	*	626
Maine	--	--	--	--	--	--
Maryland	*	*	2,296	*	*	*
Massachusetts**	*	*	3,658	*	*	*
Michigan	--	--	--	--	--	--
Minnesota	1,333	527	1,860	54	189	243
Mississippi	694	69	762	54	28	82
Missouri	1,738	300	2,038	232	284	516
Montana	346	182	528	52	185	237
Nebraska	--	--	--	--	--	--
Nevada	480	162	642	51	67	118
New Hampshire	--	--	--	--	--	--
New Jersey	4,596	*	4,596	259	443	702
New Mexico	538	58	596	*	*	*
New York	6,197	2,014	8,211	228	928	1,156
North Carolina	2,656	310	2,966	136	146	282
North Dakota	287	185	472	38	259	297
Ohio	3,802	395	4,197	304	345	649
Oklahoma	1,487	196	1,683	91	209	300
Oregon	1,062	263	1,325	*	*	*
Pennsylvania**	5,393	156	5,549	*	*	*
Rhode Island	444	*	444	42	*	42
South Carolina	1,687	208	1,895	54	76	130
South Dakota	305	153	458	75	160	235
Tennessee	--	--	--	--	--	--
Texas	7,398	2,336	9,734	655	821	1,476
Utah	687	259	946	63	59	122
Vermont	--	--	--	--	--	--
Virginia	2,602	531	3,133	67	164	251
Washington	--	--	--	--	--	--
West Virginia	--	--	--	--	--	--
Wisconsin	2,834	403	3,237	135	455	590
Wyoming	263	100	363	*	*	*
Total	64,466	18,614	98,461	3,146	6,214	10,990

*State does not collect or cannot report data for category

**Kansas, Hawaii and Pennsylvania: grades 7-12; Massachusetts: grades K-12 includes 96 math/science teachers

-- State did not report data on teacher assignments for 1988-89

Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 2

BIOLOGY, CHEMISTRY, AND PHYSICS TEACHERS (GRADES 9-12) BY PERCENT OF TEACHING ASSIGNMENT

	BIOLOGY			CHEMISTRY			PHYSICS		
STATE	50% or More	Less Than 50%	Total	50% or More	Less Than 50%	Total	50% or More	Less Than 50%	Total
Alabama	491	309	800	125	235	360	51	273	324
Alaska	--	--	--	--	--	--	--	--	--
Arizona	--	--	--	--	--	--	--	--	--
Arkansas	287	312	599	75	194	269	6	219	225
California	2,152	1,476	3,628	685	629	1,314	226	619	845
Colorado+	*	*	*	*	*	*	*	*	*
Connecticut	485	81	566	234	59	293	128	53	181
Delaware	60	*	60	24	*	24	39	*	39
Dist. of Columbia	--	--	--	--	--	--	--	--	--
Florida	--	--	--	--	--	--	--	--	--
Georgia	--	--	--	--	--	--	--	--	--
Hawaii**	80	80	160	35	16	51	13	24	37
Idaho	184	16	200	53	1	54	23	4	27
Illinois	1,244	296	1,540	639	307	946	270	349	619
Indiana	*	*	1,001	*	*	501	*	*	370
Iowa	*	*	414	*	*	116	*	*	98
Kansas**	*	*	742	*	*	404	*	*	290
Kentucky	276	433	709	151	196	347	15	195	210
Louisiana	*	*	827	*	*	430	*	*	244
Maine	--	--	--	--	--	--	--	--	--
Maryland+	*	*	*	*	*	*	*	*	*
Massachusetts**	*	*	758	*	*	458	*	*	254
Michigan	--	--	--	--	--	--	--	--	--
Minnesota	453	299	752	195	292	487	96	282	378
Mississippi	336	82	419	93	51	144	11	35	46
Missouri	668	335	1,003	226	340	566	59	315	374
Montana	87	125	212	30	107	137	17	100	117
Nebraska	--	--	--	--	--	--	--	--	--
Nevada	102	91	193	34	27	61	15	30	45
New Hampshire	--	--	--	--	--	--	--	--	--
New Jersey	853	--	853	137	--	137	137	--	137
New Mexico	194	107	301	52	70	122	13	59	72
New York	3,349	1,875	5,224	1,262	663	1,925	504	685	1,189
North Carolina	1,036	145	1,181	469	84	553	264	67	331
North Dakota	66	192	258	21	126	147	6	137	143
Ohio	1,228	457	1,686	632	353	985	203	539	742
Oklahoma	576	336	912	135	334	469	25	197	222
Oregon	263	53	316	*	*	*	*	*	*
Pennsylvania**	1,552	185	1,737	829	153	982	457	184	641
Rhode Island	160	*	160	75	*	75	41	*	41
South Carolina	452	180	632	198	124	322	41	173	214
South Dakota	87	145	232	31	117	148	9	121	130
Tennessee	--	--	--	--	--	--	--	--	--
Texas	2,242	1,616	3,858	753	802	1,555	180	743	923
Utah	311	127	438	69	33	102	21	42	63
Vermont	--	--	--	--	--	--	--	--	--
Virginia	779	222	1,001	395	148	543	156	176	332
Washington	--	--	--	--	--	--	--	--	--
West Virginia	--	--	--	--	--	--	--	--	--
Wisconsin	848	248	1,096	309	244	553	118	280	398
Wyoming	72	70	142	29	70	99	8	70	78
Total	20,973	9,893	34,609	7,986	5,775	15,681	3,152	5,971	10,379

*State does not collect or cannot report data for category

**Kansas, Hawaii and Pennsylvania: grades 7-12; Massachusetts: grades K-12 includes 98 math/science teachers

-- State did not report data on teacher assignment for 1988-89

+ Colorado: 1,218 science teachers (all fields); 1,060 50% or more, 158 less than 50%; Maryland: 2,060 science teachers (all fields)

Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 3
RATIO OF STUDENTS IN GRADES 9-12 TO MATHEMATICS AND SCIENCE TEACHERS

STATE	MATHEMATICS		BIOLOGY		CHEMISTRY		PHYSICS	
	Estimated FTE Teachers	Students Per Teacher	Estimated FTE Teachers	Students Per Teacher	Estimated FTE Teachers	Students Per Teacher	Estimated FTE Teachers	Students Per Teacher
Alabama	1,015	200	446	456	153	1,332	107	1,907
Arkansas	978	102	293	340	105	952	59	1,682
California	5,621	225	1,963	639	671	1,868	324	3,908
Colorado	972	162	--	--	--	--	--	--
Connecticut	1,174	113	384	344	190	694	109	1,209
Hawaii*	707	62	80	548	30	1,450	16	2,785
Idaho	415	141	142	411	40	1,459	18	3,198
Illinois	3,461	145	1,007	497	556	901	290	1,728
Kentucky	1,114	163	315	577	162	1,121	60	3,031
Minnesota	1,132	191	415	520	219	984	143	1,513
Mississippi	538	242	273	478	83	1,577	17	7,654
Missouri	1,379	172	585	405	256	931	123	1,926
Montana	305	138	97	436	49	855	38	1,115
Nevada	401	122	99	494	32	1,520	19	2,615
New Mexico	418	183	172	445	57	1,357	25	3,130
New York	5,151	144	2,981	249	1,112	668	549	1,353
North Carolina	2,070	156	813	396	373	864	215	1,500
North Dakota	262	129	98	345	47	712	39	868
Ohio	2,950	186	1,035	530	562	977	287	1,913
Oklahoma	1,164	141	516	319	185	891	68	2,421
Oregon	862	154	211	630	--	--	--	--
Pennsylvania*	4,084	123	1,210	414	660	758	389	1,288
South Carolina	1,317	135	384	463	180	991	74	2,405
South Dakota	267	127	102	335	53	648	37	919
Texas	6,133	145	2,086	428	765	1,165	321	2,780
Utah	568	192	265	411	60	1,815	26	4,148
Virginia	2,084	136	640	443	333	850	161	1,759
Wisconsin	2,226	106	698	338	293	807	159	1,490
Wyoming	222	123	72	382	39	695	24	1,161
Median		144		428		952		1,907

*Hawaii and Pennsylvania: grades 7-12

Notes: Estimated FTE (Full-time equivalent) Teachers = 0.75 times the number with primary assignment (50% or more time) in subject/field plus 0.25 times number with secondary assignment (less than 50% time) in subject/field.

Students Per Teacher = Total Students 9-12 divided by Estimated FTE Teachers.

Souce: State Departments of Education, Data on Public Schools, Fall 1988

Table 4
NUMBER OF HIGH SCHOOLS BY TOTAL MATHEMATICS AND SCIENCE TEACHERS (GRADES 9-12)

STATE	HIGH SCHOOLS	TOTAL TEACHERS			
		Mathematics	Biology	Chemistry	Physics
Alabama	244	1,609	800	360	324
Arkansas	331	2,452	599	269	225
California	1,261	9,603	3,628	1,314	845
Colorado	262	1,385	*	*	*
Connecticut	165	1,624	566	293	181
Hawaii**	31	1,355	160	51	37
Idaho	115	607	200	54	27
Illinois	678	6,812	1,54[illegible]	946	619
Indiana	341	2,321	1,001	501	370
Iowa	423	1,820	414	116	96
Kansas**	346	1,799	742	404	290
Kentucky	259	1,691	709	347	210
Louisiana	291	3,466	827	430	244
Massachusetts	296	3,658	758	458	254
Minnesota	429	1,860	752	487	378
Mississippi	170	762	419	144	46
Missouri	492	2,038	1,003	566	374
Montana	172	528	212	137	117
Nevada	54	642	193	61	45
New Mexico	119	596	301	122	72
New York	715	8,211	5,224	1,925	1,189
North Carolina	319	2,966	1,181	553	331
North Dakota	224	472	258	147	143
Ohio	716	4,197	1,685	965	742
Oklahuma	479	1,663	912	469	222
Oregon	219	1,325	316	*	*
Pennsylvania**	585	5,549	1,737	982	641
Rhode Island	40	444	160	75	41
South Carolina	200	1,695	632	322	214
South Dakota	178	458	232	148	130
Texas	1,070	9,734	3,858	1,556	923
Utah	142	946	436	102	63
Virginia	276	3,133	1,001	543	332
Wisconsin	437	3,237	1,096	553	396
Wyoming	76	363	142	99	78
Median	276	1,695	709	360	225

*State does not collect or cannot report data for category

**Hawaii, Kansas, and Pennsylvania: grades 7-12; Massachusetts: grades K-12 includes 96 math/science teachers

Note: Total Teachers = Teachers with primary or secondary assignment in subject/field, i.e. "headcount" of teachers. High School = Low grade 7-12, high grade 12.

Source: State Departments of Education, Data on Public Schools, Fall 1988; National Center for Education Statistics, Fall 1988

Table 5

TEACHERS UNDER AGE 30 AND OVER 50 ASSIGNED 50% OR MORE IN MATHEMATICS, BIOLOGY, CHEMISTRY, PHYSICS (GRADES 9-12

STATE	MATH			BIOLOGY			CHEMISTRY			PHYSICS		
	50% or More	Under 30	Over 50	50% or More	Under 30	Over 50	50% or More	Under 30	Over 50	50% or More	Under 30	Over 50
Alabama	1,226	10%	14%	491	8%	12%	125	8%	11%	51	18%	20%
Arkansas	729	14%	15%	287	10%	14%	75	8%	17%	6	0%	33%
California	6,440	14%	41%	2,152	10%	22%	685	12%	26%	226	9%	29%
Colorado	1,251	9%	21%	*	*	*	*	*	*	*	*	*
Connecticut	1,535	5%	21%	485	6%	23%	234	8%	29%	128	3%	35%
Delaware	316	7%	19%	60	5%	18%	24	4%	21%	39	8%	21%
Hawaii**	736	6%	12%	80	13%	16%	35	9%	23%	13	8%	15%
Idaho	526	16%	17%	184	8%	18%	53	6%	25%	23	17%	30%
Illinois	3,516	12%	21%	*	*	*	*	*	*	*	*	*
Kentucky	1,382	21%	9%	276	11%	16%	151	13%	12%	15	13%	13%
Minnesota	1,333	8%	26%	453	8%	28%	195	9%	36%	96	7%	33%
Mississippi	694	16%	17%	337	12%	17%	93	13%	22%	11	0%	36%
Missouri	1,738	15%	15%	668	14%	14%	226	12%	19%	59	5%	19%
Montana	346	13%	12%	87	8%	23%	52	6%	17%	17	0%	24%
Nevada	480	11%	19%	102	11%	22%	34	21%	9%	15	13%	13%
New Jersey	4,596	9%	20%	853	9%	23%	137	14%	24%	137	14%	23%
New York	6,197	9%	16%	3,349	11%	17%	1,262	10%	22%	504	7%	21%
North Carolina	2,656	20%	10%	1,036	21%	13%	469	46%	29%	264	15%	17%
North Dakota	287	21%	13%	66	11%	17%	21	0%	24%	6	0%	17%
Ohio	3,802	17%	11%	1,228	[illegible]	13%	632	13%	16%	203	10%	15%
Oklahoma	1,487	20%	14%	576	16%	14%	91	26%	24%	25	12%	24%
Oregon	1,062	14%	17%	283	8%	[illegible]	*	*	*	*	*	*
Pennsylvania**	5,393	6%	0%	1,562	6%	1%	829	6%	1%	457	8%	0%
South Carolina	1,687	17%	11%	452	15%	10%	198	15%	15%	41	7%	17%
South Dakota	306	20%	15%	87	14%	24%	31	13%	16%	9	0%	22%
Utah	677	18%	21%	311	12%	22%	69	13%	18%	21	10%	19%
Virginia	2,602	12%	16%	779	12%	16%	396	13%	18%	156	13%	31%
Wisconsin	2,834	12%	25%	848	6%	27%	309	8%	26%	118	7%	37%
Wyoming	263	23%	12%	72	15%	16%	29	7%	31%	8	0%	100%
Total	56,096	6,972	9,997	17,134	1,86[illegible]	2,802	6,454	1,081	1,210	2,648	236	526
Median		14%	16%		11%	17%		12%	19%		8%	23%

*State does not collect or cannot report data for category

**Grades 7-12

Source: State Departments of Education, Data on Public Schools, Fall 1988

64

Table 6

GENDER OF TEACHERS ASSIGNED 50% OR MORE IN MATHEMATICS, BIOLOGY, CHEMISTRY, PHYSICS (Grades 9-12)

STATE	MATH 50% or More	MATH Male	MATH Female	BIOLOGY 50% or More	BIOLOGY Male	BIOLOGY Female	CHEMISTRY 50% or More	CHEMISTRY Male	CHEMISTRY Female	PHYSICS 50% or More	PHYSICS Male	PHYSICS Female
Alabama	1,226	34%	66%	491	36%	64%	125	38%	62%	51	55%	45%
Arkansas	729	39%	61%	287	49%	51%	75	59%	41%	6	100%	0%
California	6,440	52%	48%	2,152	70%	30%	685	70%	30%	226	87%	13%
Colorado	1,251	62%	38%	*	*	*	*	*	*	*	*	*
Connecticut	1,535	55%	45%	485	65%	35%	234	69%	31%	128	89%	11%
Delaware	316	51%	49%	60	62%	38%	24	71%	29%	39	67%	33%
Hawaii**	736	35%	59%	80	49%	51%	35	40%	57%	13	69%	31%
Idaho	526	72%	28%	184	80%	20%	53	94%	6%	23	91%	9%
Illinois	3,516	59%	41%	*	*	*	*	*	*	*	*	*
Kentucky	1,382	41%	59%	276	56%	44%	151	53%	47%	15	80%	20%
Minnesota	1,333	80%	20%	453	82%	18%	195	84%	16%	98	89%	11%
Mississippi	694	35%	65%	337	39%	61%	93	45%	55%	11	73%	27%
Missouri	1,738	49%	51%	668	61%	39%	226	65%	35%	59	78%	22%
Montana	346	68%	23%	87	82%	14%	52	48%	10%	17	76%	18%
Nevada	480	60%	40%	102	72%	28%	34	79%	21%	15	87%	13%
New Jersey	4,596	41%	59%	853	56%	44%	137	65%	35%	137	65%	35%
New York	6,197	57%	43%	3,349	62%	38%	1,282	72%	28%	504	86%	14%
North Carolina	2,656	31%	69%	1,036	43%	57%	469	46%	54%	284	61%	39%
North Dakota	287	67%	33%	66	86%	14%	21	86%	14%	6	100%	0%
Ohio	3,802	59%	41%	1,228	71%	29%	632	71%	28%	203	82%	18%
Oklahoma	1,487	50%	50%	576	62%	38%	91	96%	51%	25	96%	4%
Oregon	1,062	73%	27%	283	78%	22%	*	*	*			
Pennsylvania**	5,393	61%	39%	1,552	72%	28%	829	72%	28%	457	88%	12%
Rhode Island	*	*	*	160	62%	38%	*	*	*	*	*	*
South Carolina	1,687	31%	69%	452	38%	62%	198	43%	57%	41	59%	41%
South Dakota	305	71%	29%	87	83%	17%	31	74%	26%	9	89%	11%
Texas	7,398	24%	76%	2,242	24%	76%	753	21%	79%	180	21%	79%
Utah	677	70%	30%	311	78%	22%	69	83%	17%	21	90%	10%
Virginia	2,602	34%	66%	779	42%	58%	395	44%	56%	156	70%	30%
Wisconsin	2,834	66%	34%	848	85%	15%	309	84%	16%	118	87%	13%
Wyoming	263	63%	37%	72	81%	19%	29	90%	10%	8	75%	25%
Total	63,495	31,178	32,273	19,537	11,419	8,113	7,208	4,455	2,768	2,829	2,167	659
Median		57%	43%		62%	38%		70%	30%		82%	18%

*State does not collect or cannot report data for category

**Grades 7-12

Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 7-1

RACE/ETHNICITY OF TEACHERS ASSIGNED 50% OR MORE IN MATHEMATICS AND BIOLOGY (GRADES 9-12)

	MATHEMATICS TEACHERS						BIOLOGY TEACHERS					
STATE	Total 50% or More	Hispanic	White	Black	Asian	Indian	Total 50% or More	Hispanic	White	Black	Asian	Indian
Alabama	1,226	0	80.9%	18.8%	0	0	491	0	80.9%	18.7%	0	.2%
Arkansas	729	0	89.0%	10.7%	.3%	0	287	0	89.9%	9.4%	.3%	.3%
California	6,440	5.1%	83.2%	4.5%	5.7%	.71%	2,152	5.2%	84.1%	4.4%	4.7%	.7%
Colorado	1,251	2.4%	95.6%	1.0%	.5%	.56%	*	*	*	*	*	*
Connecticut	1,535	.8%	97.1%	1.8%	.3%	0	485	.4%	95.9%	3.3%	.7%	0
Delaware	316	0	90.8%	8.9%	0	0	60	0	93.3%	6.7%	0	0
Hawaii**	736	0	12.9%	.7%	48.8%	0	80	0	27.5%	1.3%	71.3%	0
Idaho	526	0	98.5%	0	1.1%	.38%	184	0	98.9%	.0%	0	1.1%
Kentucky	1,382	0	97.9%	2.0%	.1%	0	276	.4%	95.7%	3.6%	.4%	0
Mississippi	694	*	73.2%	26.7%	*	*	337	0	68.5%	30.9%	0	.6%
Montana	346	0	91.0%	0	.3%	0	87	0	98.4%	.0%	0	1.1%
Nevada	480	3.3%	90.8%	2.9%	2.1%	.8%	102	4.9%	92.2%	2.9%	0	0
New Jersey	4,596	1.5%	90.3%	7.3%	1.0%	.04%	853	.8%	92.7%	5.7%	.7%	0
North Carolina	2,656	*	85.9%	13.1%	.2%	.8%	1,036	*	83.4%	15.8%	.2%	.6%
North Dakota	287	0	99.7%	0	0	.3%	66	0	100.0%			0
Ohio	3,802	.1%	97.0%	2.6%	.3%		1,228	.2%	94.7%	5.0%	.2%	0
Oklahoma	1,487	.1%	95.0%	2.9%	.1%	1.9%	576	.2%	95.5%	2.3%	.2%	1.9%
Pennsylvania	5,393	.1%	96.9%	2.9%	.1%	.02%	1,552	.2%	97.0%	2.5%	.1%	0
South Carolina	1,687	0	77.0%	22.8%	.2%	.1%	452	0	74.8%	25.2%	0	0
Texas	7398	5.2%	85.4%	8.6%	.5%	.3%	--	--	--	--	--	--
Utah	677	.1%	98.1%	.3%	.9%	.6%	311	0	98.1%	.0%	.96%	.96%
Virginia	2,602	.3%	86.7%	12.4%	.4%	.2%	779	0	85.4%	13.5%	.9%	3%
Wisconsin	2,834	4	2,797	27	5	1	848	2	834	8	2	2
Total	49,080	859	43,579	3,246	884	144	12,242	134	10,944	904	189	45

*State does not collect or cannot report data for category

**Grades 7-12

Source: State Departments of Education, Data on Public Schools, Fall 1988

66

Table 7-2

RACE/ETHNICITY OF TEACHERS ASSIGNED 50% OR MORE IN CHEMISTRY & PHYSICS (Grades 9-12)

	CHEMISTRY						PHYSICS					
STATE	50% or More	Hispanic	White	Black	Asian	Indian	50% or More	Hispanic	White	Black	Asian	Indian
Alabama	125	0	84.8%	14.4%	0	.8%	51	0	86.3%	13.7%	0	0
Arkansas	75	0	93.3%	6.7%	0	0	6	0	100.0%	0	0	0
California	665	2.3%	88.8%	2.6%	4.2%	.7%	226	.4%	93.8%	.9%	4.4%	.4%
Connecticut	234	1.3%	97.4%	1.3%	0	0	128	0	99.2%	0	.8%	0
Delaware	24	0	95.8%	4.2%	0	0	39	0	94.9%	5.1%	0	0
Hawaii**	35	0	34.3%	0	62.9%	0	13	0	15.4%	0	84.6%	0
Idaho	53	0	100.0%	0	0	0	23	4.3%	95.7%	0	0	0
Kentucky	151	0	98.7%	.7%	.7%	0	15	0	100.0%	0	0	0
Mississippi	93	*	68.8%	31.2%	*	*	11	*	72.7%	27.3%	*	0
Montana	52	0	58.0%	.0%	0	0	17	0	94.0%	0	0	0
Nevada	34	0	97.1%	.0%	2.9%	0	15	0	93.3%	0	6.7%	0
New Jersey	137	.7%	95.6%	2.9%	1.5%	0	137	.7%	95.6%	2.9%	.7%	0
North Carolina	469	*	88.9%	9.6%	.4%	1.3%	264	*	94.3%	4.5%	.4%	.8%
North Dakota	21	0	100.0%	0	0	0	6	0	100.0%	0	0	0
Ohio	632	0	97.5%	2.1%	.5%	0	203	0	99.5%	.5%	0	0
Oklahoma	135	0	97.8%	1.5%	0	.7%	25	4.0%	96.0%	0	0	0
Pennsylvania	829	.1%	99.0%	.8%	*	*	457	0	99.3%	.4%	.2%	0
South Carolina	198	.5%	83.8%	14.6%	.5%	.5%	41	0	87.8%	9.8%	2.4%	0
Texas	763	4.1%	83.0%	8.3%	.6%	.1%	160	3.9%	89.4%	6.7%	0	0
Utah	69	0	98.6%	0	1.4%	0	21	4.8%	95.2%	0	0	0
Virginia	395	.3%	90.1%	8.1%	1.5%	0	156	1.3%	91.7%	6.4%	.6%	0
Wisconsin	309	0	98.4%	.6%	1.0%	0	118	0	99.2%	.8%	0	0
Total	5,538	56	5,068	274	76	15	2,152	14	2,046	60	26	3

*State does not collect or cannot report data for category

**Grades 7-12

Source: State Departments of Education, Data on Public Schools, Fall 1988

67

Table 8-1
MATHEMATICS TEACHERS (GRADES 9-12) BY PERCENT OF TEACHING ASSIGNMENT AND CERTIFICATION STATUS

STATE	TOTAL	ASSIGNED MATH 50% OR MORE		ASSIGNED MATH LESS THAN 50%	
		CERTIFIED MATHEMATICS	OUT OF FIELD	CERTIFIED MATHEMATICS	OUT OF FIELD
Alabama	1,809	74%	2%	20%	4%
California	9,603	52	15	16	16
Colorado	1,385	66	24	2	8
Connecticut	1,624	95	0	5	0
Idaho	607	87	0	7	6
Kentucky	1,691	79	3	9	10
Minnesota	1,860	71	1	26	2
Mississippi	763	85	6	6	3
Missouri	2,038	85	0	14	1
Montana	528	60	5	19	15
Nevada	642	66	9	18	7
New York	8,211	70	6	23	2
North Carolina	2,966	87	3	8	2
North Dakota	472	61	0	39	0
Ohio	4,197	89	1	9	0
Oklahoma	1,683	83	5	8	3
Oregon	1,325	80	0	8	12
Pennsylvania**	5,549	92	7	2	1
South Carolina	1,895	84	5	7	4
South Dakota	458	53	13	18	16
Utah	946	69	3	26	2
Virginia	3,133	82	1	15	2
Wyoming	363	72	0	28	0
Median		79%	3%	14%	3%

**Grades 7-12

Note: Alabama 50% or more, 2 teachers certified general secondary; less than 50%, 9 teachers
California 50% or more, 1,142 teachers certified general secondary; less than 50% 675 teachers
Source: State Departments of Education, Data on Public Schools, Fall 1988

Table 8-2

BIOLOGY TEACHERS (GRADES 9-12) BY PERCENT OF TEACHING ASSIGNMENT AND CERTIFICATION STATUS

STATE	TOTAL	ASSIGNED BIOLOGY 50% OR MORE: Certified Biology	ASSIGNED BIOLOGY 50% OR MORE: Certified Broad Field	ASSIGNED BIOLOGY 50% OR MORE: Out of Field	ASSIGNED BIOLOGY LESS THAN 50%: Certified Biology	ASSIGNED BIOLOGY LESS THAN 50%: Certified Broad Field	ASSIGNED BIOLOGY LESS THAN 50%: Out of Field
Alabama	800	48%	12%	2%	28%	10%	1%
California	3,628	*	44	15	*	28	13
Connecticut	566	85	*	0	14	*	0
Idaho	200	92	*	0	7	*	2
Kentucky	709	38	1	0	57	2	2
Minnesota	752	46	14	1	28	9	2
Mississippi	418	72	*	9	14	*	3
Missouri	1,003	65	*	1	31	*	2
Montana	212	25	*	16	36	*	23
Nevada	193	16	35	3	7	37	3
New York	5,224	59	*	5	33	*	3
North Carolina	1,181	47	39	1	6	5	1
North Dakota	258	22	4	0	53	21	0
Ohio	1,685	15	57	1	10	17	0
Oklahoma	912	61	*	2	34	*	3
Oregon	316	83	*	1	11	*	6
Pennsylvania**	1,737	61	5	3	10	1	0
South Carolina	632	40	30	1	9	16	4
South Dakota	232	22	11	5	31	11	20
Utah	438	65	*	6	28	*	1
Virginia	1,001	77	*	1	20	*	2
Wyoming	142	51	*	0	49	*	0
Median		51%	12%	1%	28%	11%	2%

*State does not have certification in category

**Grades 7-12

Note: California 50% or more, 353 teachers certified general secondary; less than 50%, 218 teachers

Alabama less than 50%, 1 teacher certified general secondary

Source: State Departments of Education, Data on Public Schools, Fall 1988

Certified in Field/Subject: Regular or Standard certification offered in a state or Probational certification (i.e., the initial certification issued after satisfying all requirements except the completion of probationary period)

Specific Field: State certification in specific science field of assignment

Broad-Field: Broad-field science certification

General Secondary: Teachers with only a general secondary certification, i.e., certification to teach any subject at secondary level

Out-of-Field: Regular/standard/ probationary certification in a field/subject other than the one assigned, or temporary, provisional, or emergency certification

Table 8-3
CHEMISTRY TEACHERS (GRADES 9-12) BY PERCENT OF TEACHING ASSIGNMENT AND CERTIFICATION STATUS

STATE	TOTAL	ASSIGNED CHEMISTRY 50% OR MORE			ASSIGNED CHEMISTRY LESS THAN 50%		
		Certified Chemistry	Certified Broad Field	Out of Field	Certified Chemistry	Certified Broad Field	Out of Field
Alabama	360	21%	14%	0%	27%	33%	6%
California	1,314	*	39	13	[illegible]	34	14
Connecticut	293	80	*	0	20	*	0
Idaho	54	[illegible]3	*	0	2	*	0
Kentucky	347	40	4	0	45	6	5
Minnesota	487	23	15	2	33	20	7
Mississippi	144	49	*	16	19	*	17
Missouri	566	39	*	1	57	*	4
Montana	137	19	*	3	31	*	47
Nevada	61	25	30	2	5	39	0
New York	1,925	60	*	6	32	*	3
North Carolina	553	22	63	0	3	12	0
North Dakota	147	8	6	0	27	59	0
Ohio	985	28	35	1	19	16	0
Oklahoma	469	28	*	1	65	*	7
Pennsylvania	982	66	15	4	10	5	1
South Carolina	322	13	47	2	4	28	6
South Dakota	148	8	10	3	14	21	44
Utah	102	63	*	5	30	*	2
Virginia	543	71	*	2	22	*	5
Wyoming	99	29	*	0	71	*	0
Median		29%	15%	2%	22%	20%	3%

*State does not have certification in category

Note: California 50% or more, 124 teachers certified general secondary; less than 50%, 86 teachers

Source: State Departments of Education, Data on Public Schools, Fall 1988

70

Table 8-4
PHYSICS TEACHERS (GRADES 9-12) BY PERCENT OF TEACHING ASSIGNMENT AND CERTIFICATION STATUS

STATE	TOTAL	ASSIGNED PHYSICS 50% OR MORE: Certified Physics	Certified Broad Field	Out of Field	ASSIGNED PHYSICS LESS THAN 50%: Certified Physics	Certified Broad Field	Out of Field
Alabama	324	3%	9%	4%	10%	52%	23%
California	845	*	20	6	*	56	17
Connecticut	161	70	*	0	29	*	0
Idaho	27	85	*	0	7	*	7
Kentucky	210	4	2	1	61	14	17
Minnesota	376	16	8	1	36	26	12
Mississippi	46	13	*	11	28	*	50
Missouri	374	15	*	1	70	*	15
Montana	117	8	*	7	16	*	69
Nevada	45	13	18	2	16	47	0
New York	1,189	34	*	6	46	*	12
North Carolina	331	10	66	4	2	16	1
North Dakota	143	1	3	0	16	76	0
Ohio	742	13	14	1	40	32	1
Oklahoma	222	9	*	3	66	*	23
Pennsylvania	641	53	13	5	14	12	2
South Carolina	214	4	[illegible]	1	7	64	10
South Dakota	130	2	4	2	10	32	51
Utah	63	32	*	2	67	*	0
Virginia	332	44	*	3	40	*	13
Wyoming	78	10	*	0	90	*	0
Median		13%	13%	2%	28%	32%	12%

*State does not have certification in category

Note: California 50% or more, 45 teachers certified general secondary; 50% or less, 94 teachers

Source: State Departments of Education, Data on Public Schools, Fall 1986

Table 8-5

STATE CERTIFICATION REQUIREMENTS FOR SECONDARY SCIENCE AND MATHEMATICS TEACHERS

STATE	Course Credits by Certification Field: MATH	SCIENCE, BROAD FIELD	BIOLOGY CHEMISTRY PHYSICS	Teaching Methods Required: Science/Math	Superv. Teaching Experience Required
Alabama	27	52	27	Yes	9
Alaska	*	*	*	*	*
Arizona	30	30	30	Yes	8
Arkansas	21		24	No	12 wks
California	45	45 (Biological, Physical)		No	***
Colorado	*	*	*	Yes	400 hrs
Connecticut	18		18	No	6
Delaware	30		39-45	Yes	6
Dist. of Columbia	27	30	30	Yes	1 sem.
Florida	21		20	Yes(S)	6
Georgia	60 qtr	45qtr	40 qtr	Yes(M)	15 qtr hrs
Hawaii	*	*	*	*	*
Idaho	20	45	20	No	6
Illinois	24	32	24	Yes	5
Indiana	36	36	36	Yes	9 wks
Iowa	24	24	24	Yes	Yes
Kansas	*	*	*	*	*
Kentucky	30	48	30	No	9-12
Louisiana	20		20	No	9
Maine	18	18		Yes	6
Maryland	24	36	24	Yes	6
Massachusetts	36	36	36	Yes	300 hrs
Michigan	36	30	30	No	6
Minnesota	**	**	**	**	**
Mississippi	24		32	Yes(S)	6
Missouri	30	30	20	Yes	8
Montana	30	[illegible]	30	Yes	10 wks
Nebraska	30	45	24	Yes	320 hrs
Nevada	16	36	16	No	8
New Hampshire	*	*	*	*	*
New Jersey	30	30	30	No	*
New Mexico	24	24	24	Yes	6
New York	24		36	No	*
North Carolina	**	**	**	**	**
North Dakota	16	21	12	No	6
Ohio	30	60	30	Yes	***
Oklahoma	40		40	No	12 wks
Oregon	21	45	45	Yes(M)	15 qtr hrs
Pennsylvania	*	*	*	*	*
Rhode Island	30	30	30	Yes	6
South Carolina	*	*	*	*	*
South Dakota	18	21	12	No	6
Tennessee	36 qtr	48 qtr	24 qtr	Yes	4
Texas	24	48	24	No	6
Utah	**	**	**	**	**
Vermont	18	18	18	Yes	*
Virginia	27		24	No	6
Washington	24	41	34	No	Yes
West Virginia	**	**	**	**	**
Wisconsin	34	54	34	Yes	5
Wyoming	24	30	12	No	1 course

Notes:

Blank space = No certification offered

Course credits = Semester credit hours, unless otherwise specified (e.g., qtr = quarter credit hours)

* Certification requirements determined by degree-granting institution or approved/competency-based program

**Major or minor - North Dakota, Utah; 30-40% of program - Minnesota, North Carolina; Courses matched with requirements - West Virginia

***1 semester full-time or 2 semesters half-time—California; supervised teaching experience and 300 hours clinical/field-based experience—Ohio

Source: State Departments of Education, June 1987

REFERENCES

Aldrich, H. (1983, July 27). "Teacher Shortage: Likely to get Worse Before It Gets Better." Education Week.

Armstrong, J. and Davis, A. (1988) "Designing State Curriculum Frameworks and Assessment Programs to Improve Instruction." Denver: Education Commission of the States.

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

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

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

Cagampang, H. H. & Guthrie, J. W., (1988) Math, Science, and Foreign Language Instruction in California: Recent Changes and Prospective Trends. Berkeley: University of California, Policy Analysis for California 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. (1989) The Implementation and Effects of High School Graduation Requirements: First Steps Toward Curriculum Reform, New Brunswick, NJ: Center for Policy Research in Education, Rutgers University.

Council of Chief State School Officers (1984) CCSSO Assessment and Evaluation: Notebook. Washington, DC: CCSSO.

Council of Chief State School Officers (1988) "Instructions and Reporting Forms for Data on Science and Mathematics Education in (each state)." Washington, DC: CCSSO, State Education Assessment Center.

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

Council of Chief State School Officers (1989b) 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.

Education Commission of the States (1985) New Directions for State Teacher Policies. Denver: Education Commission of the States.

Educational Testing Service (1989) What Americans Study, Princeton, NJ: ETS.

Educational Testing Service (1988) The Science Report Card/The Mathematics Report Card, Princeton, NJ; ETS.

Freeman, D.J. (1989) "State Guidelines for Reshaping Academic Curricula in Elementary Schools: A 50-State Survey." East Lansing, MI: Michigan State University.

Fuhrman, S. (1989) "Diversity Amidst Standardization: State Differential Treatment of Districts". Madison, WI: Wisconsin Center for Education Research, University of Wisconsin

Goertz, M. (1986) Educational Standards: A 50-State Survey. Princeton, NJ: Educational Testing Service.

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.

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.

McDonnell, L.M., Burstein, L., Ormseth, T., Catterall, J.S., & Moody, D. (1990). "Discovering What Schools Really Teach: Designing Improved Coursework Indicators. Los Angeles: UCLA/Center for Research, Evaluation, Standards, and Student Testing.

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

Murnane, R.J., Singer, J.D., & Willett, J.B. (1988). "The Career Patterns cf Teachers: Implications for Teacher Supply and Methodological Lessons for Research." Educational Researcher, August-September: 22-30.:"sn:

Murnane, R. J. & Raizen, S. A. (eds.) (1988) Improving Indicators of the Quality of Science and Mathematics Education in Grades K-12. National Research Council. Washington, D National Academy Press.

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

National Center for Education Statistics (1989b). Digest of Education Statistics. Washington, D.C.: U.S. Department of Education

National Research Council, Committee on National Statistics (1987). Toward Understanding Teacher Supply and Demand. Washington, D.C.: National Academy Press.

National Commission on Excellence in Education (1983) A Nation at Risk: The Imperative for Educational Reform. Washington, DC: U.S. Department of Education.

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 Association of Secondary School Principals (1989) "Teaching Science in Schools: A Two-Fold Task", Curriculum Report, Vol. 18, Number 4, March 1989, Reston, VA: NASSP.

Neuschatz, M. & Covalt, M. (1988). 1986-87 Nationwide Survey of Secondary School Teachers of Physics. New York: American Institute of Physics.

Oakes, J. (1989) "What Educational Indicators? The Case for Assessing the School Context." Educational Evaluation and Policy Analysis, Vol. 11, Number 2.

Office of Educational Research and Improvement (1988). Creating Responsible and Responsive Accountability Systems. Report of the OERI State Accountability Study Grp Washington, D.C.: OERI.

Raizen, S. A., and Jones, L. V., (eds.) (1985) Indicators of Precollege Education in Science and Mathematics. Committee on Indicators of Precollege Science and Mathematics Education, National Research Council. Washington, DC: National Academy Press.

Shavelson, R., McDonnell, L., Oakes, J., Carey, N. (1987) Indicator Systems for Monitoring Mathematics and Science Education. Santa Monica, CA: Rand Corporation.

Shavelson, R., McDonnell, L., Oakes, J. (1989) Indicators for Monitoring Mathematics and Science Education: A Sourcebook. Santa Monica, CA: Rand Corporation.

Southern Regional Education Board (1989) "Assessing the Quality of High School Courses." Atlanta: SREB.

Task Force on Education for Economic Growth (1983) Action for Excellence: A Comprehensive Plan to Improve Our Nation's Schools. Denver, CO: Education Commission of the States.

Twentieth Century Fund Task Force (1983) A Report of the Twentieth Century Fund Task Force on Federal Elementary and Secondary Education Policy. New York, NY: The Twentieth Century Fund.

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.