DOCUMENT RESUME

ED 254 400 SE 045 411

AUTHOR Raizen, Senta A.
TITLE The Quantity and Quality of Teachers of Mathematics and Science, Grades 1 to 12.
PUB DATE Apr 85
NOTE 41p.; Paper presented at the Annual Meeting of the American Educational Research Association (69th, Chicago, IL, March 31-April 4, 1985). This paper is a modified version of a chapter in "Indicators of Precollege Education in Science and Mathematics," a report by the Committee on Indicators of Precollege Science and Mathematics Education, National Research Council.
PUB TYPE Reports - General (140) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Data Analysis; *Educational Planning; Educational Research; Educational Trends; Elementary Secondary Education; *Mathematics Education; *Mathematics Teachers; *Science Education; *Science Teachers; Teacher Qualifications; Teacher Shortage; *Teacher Supply and Demand
IDENTIFIERS Mathematics Education Research; Science Education Research

ABSTRACT

This paper discusses the data that are available on demand and supply of teachers of mathematics and science and points out discrepancies and difficulties in current statistics and in collecting the pertinent information. Estimates of supply hinge on indentifying who is to be included in the pool of mathematics and science teachers, but there are no commonly accepted measures of competence. Nor is there information on response behavior of potential teachers to various monetary and nonmonetary incentives for increasing the supply. Demand estimates are limited by lack of understanding of the impact of increased requirements for high school graduation and college admission. Some suggestions are made for improving future demand/supply estimates. Over 40 references are included. (MNS)

THE QUANTITY AND QUALITY OF TEACHERS OF MATHEMATICS AND SCIENCE, GRADES 1 TO 12*

Senta A. Raizen

Much of the concern regarding the condition of mathematics and science education has been about the supply of teachers who are qualified to teach mathematics and science courses in grades 9 through 12. The concern was heightened by several surveys conducted under the auspices of the National Science Teachers Association, all of them based on the opinions of various education authorities. In 1980, 1981, and 1982, Howe and Gerlovich (1982) surveyed state science supervisors and teacher certification directors on their opinion as to supply and demand for secondary school science and mathematics teachers. Their survey covered 53 jurisdictions: the 50 states, the District of Columbia, Puerto Rico, and American Samoa. They used a 5-point rating scale: 1, surplus; 2, slight surplus; 3, adequacy; 4, shortage; 5, critical shortage. In 1982, 44 of the 47 state authorities responding reported that they saw shortages or critical shortages of mathematics teachers, 45 of 50 saw shortages in physics, and 44 of 50 saw shortages in chemistry. A survey of teacher placement officers (Shymansky and Aldridge, 1982) indicated a

* This paper is a modified version of a chapter in INDICATORS OF PRECOLLEGE EDUCATION IN SCIENCE AND MATHEMATICS, a report by the Committee on Indicators of Precollege Science and Mathematics Education (list of members appended), National Research Council.

decline between 1971 and 1980 of 79 percent of persons who were pursuing teaching degrees in mathematics and a decline of 64 percent of those pursuing teaching degrees in science. (Smaller decreases of 64 percent and 33 percent, respectively, were found by National Center on Education Statistics (NCES) (1983) in an analysis of bachelor's degrees; see Table 2.) A third kind of survey (Shymansky and Aldridge, 1982), of secondary school administrators, revealed that half the science and mathematics teachers newly employed for the 1981-1982 school year were hired on an "emergency" basis, that is, without state certification.

The results of these surveys have been instrumental in drawing public attention to the issue of adequate supply and preparation of teachers in science and mathematics. Numerous initiatives at the national, state, and local levels have been directed toward providing both greater numbers and also better trained teachers for high schools. By fall 1983, 17 states had enacted undergraduate scholarship or loan programs, many of them targeted toward training teachers of science and mathematics (Flakus-Mosqueda, 1983). A number of states are focusing on the retraining of college graduates not now teaching or teaching other subjects. A third approach has been to make teaching more attractive through incentive pay and career ladders. Indeed, according to the Gallup Poll (Gallup, 1983), 50 percent of the people favor differentially higher pay for mathematics and science teachers (35 percent were opposed).

How good are the data being used to formulate such policies? A more recent survey conducted by the Education Commission of the States (Flakus-Mosqueda, 1983) shows 38 rather than 44 states reporting teacher shortages in either mathematics or the physical sciences (physics, chemistry, or earth sciences), with some of the most populous states in the east and midwest not reporting shortages. In its 1983-1984 survey of teacher demand and shortage based on head count data, NCES (U.S. Department of Education, 1985) found almost no shortages: in all fields, shortages were less than 1 percent. (Shortage was defined as "positions vacant, abolished, or transferred to another field because no candidate was found.") In physics, the shortage was one of the highest: 0.45 percent; in mathematics, it was 0.18 percent; by contrast, it was 0.88 percent in bilingual education, the field of greatest shortage. What accounts for such differences in reports of shortages? Is it largely the difference between people's perceptions (as reflected in opinion surveys) and head count data? Has there been an increase in the supply of teachers or a decrease in demand (e.g., fewer students) in the intervening year or two? Has the definition of shortage changed? Are different criteria, perhaps including perceptions of competence, being used to determine shortage in different responses? Are there gross errors in the data? What conclusions can be drawn from existing information? What additional information is needed to formulate effective policy regarding teachers at the national, state, and local levels?

Two sets of questions are paramount. First: Is the number of teachers adequate for the number of mathematics and science courses now being taught in secondary school? Will there be an adequate supply for the number to be taught at some point, say, five years, in the future? This set of questions requires a definition of who is to be counted in the available pool, which leads to a second set of questions: Are the teachers at all levels qualified to teach their current assignments in mathematics and science? Are they qualified for the responsibilities they will have in the future? Any response to this set of questions requires defining the term "qualified" at the different grade levels.

These are questions that entail both the setting of norms and the collection of descriptive data before they can be answered: What is the number of teachers available? What is the anticipated demand? How are teachers prepared? How does this preparation compare with existing standards? Are existing standards--for example, state certification--acceptable definitions of "qualified"? The importance of these questions varies according to different dimensions at different grade levels.

At the elementary school level, the question of numbers has not been at issue, since nationwide there has been an ample supply of elementary school teachers. This may begin to change in the mid-1980s when enrollments are expected to rise again (National Center for Education Statistics, 1982d, 1984a). However, there is concern about the preparation of teachers who are expected to teach mathematics and science in the self-contained classrooms of grades 1 to 6 and sometimes in the block programs of the middle school. For middle and junior high schools, the nature of the questions on numbers and qualification varies according to whether mathematics and various sciences are taught as separate subjects, as in high school, or as part of a core curriculum by a nonspecialist teacher. At the high school level, information is needed both as to the number of teachers and as to their qualifications. But the numbers are dependent on who is to be counted as a science or mathematics teacher and thus become confounded with questions on preparation and qualification. In the following section on number of teachers, the status of individuals being counted is defined in each case--for example, "assigned to mathematics or science classes," "degrees earned," "certified"--without judgment as to their qualifications. The problems of defining "qualified" are discussed in the next section.

Number of Teachers

Supply of Teachers

At the elementary school level, only a small number of teachers specialize in mathematics and science, either as specialist teachers or in grades 7 and 8 when these grades are part of the elementary system. In a survey of teacher demand and supply conducted in 1979-1980, the National Center for Education Statistics (1982c) estimated that 1.4 percent of all elementary school teachers (16,400--15,400 full time) were assigned to teach mathematics specifically and 0.7 percent of all elementary school teachers (8,600--nearly all full time) were assigned to teach science. A large proportion of these teachers are probably in the upper grades.

At the secondary school level, there are available two data bases that have been analyzed regarding the number of mathematics and science teachers. The first is the survey of teacher demand and supply conducted in 1979-1980 by the National Center for Education Statistics (1982c), which yielded responses from administrators of 1,273 of a sample of 1,448 school systems (an 88 percent response rate). Based on this sample, NCES estimated that, during 1979-1980 in public secondary schools, 115,000 persons were assigned to teach mathematics either full or part time, and 104,700 persons were assigned to teach science courses either full or part time (see Table 1). This represented 11.4 percent and 10.4 percent of all secondary school teachers, respectively. At this time, there is no readily available information on the preparation or certification of these teachers. To fill this gap, at least partly, NCES is conducting a survey in 1985 of a national sample of public school teachers. About 2,800 schools and 10,750 teachers will be surveyed to obtain information on conditions within schools and on teaching conditions, including the training and background of the teachers, on how teachers spend their

TABLE 1: Secondary School Teachers Assigned to Mathematics and Science Classes in Public Schools in 1979-1980

Field of Assignment	Total[a]	Full Time
Mathematics	115,000	112,900
Science	104,700	101,000
Biology	25,000	24,300
Chemistry	11,400	10,500
Physics	6,700	5,700
General Science	59,600	58,600
Other Sciences	2,000	1,900

[a] Teachers assigned to more than one field were counted in the field in which they spent most of their time.

Source: National Center for Education Statistics (1982c)

time, assignment of homework, and availability of resources including teacher aids. However, since only four teachers per school will be surveyed, mathemtics and science teachers may or may not be included; therefore, it will not be possible to draw reliable national conclusions. A repeat of the 1977 survey of science and mathematics education (Weiss, 1978) is being planned, targeted on the teaching of these fields specifically, which may yield more detailed data on the preparation of teachers in the current pool.

The second data base regarding the number of science and mathematics teachers is derived from a survey by the National Science

Teachers Association (NSTA) conducted in the fall of 1982. Using a sample of 2,236 schools that offered high school curricula, NSTA asked principals how many classes in mathematics or science were being taught and how many teachers were teaching these classes. On the basis of the first 846 responses (a 38 percent response rate), the numbers of such teachers were estimated. Despite the low response rate and methodological differences in the way the estimates were made, the NSTA estimate of the number of persons teaching mathematics in secondary school is reasonably close to that derived from the NCES survey: 106,190 (Pelavin and Reisner, 1984), compared with the NCES estimate of 115,000. Part of the difference might be explained by falling high school enrollments in the three years between the two surveys. Estimates for specific science fields are more difficult to reconcile. For example, NCES estimates 10,500 full-time teachers in chemistry and 5,700 in physics; estimates for full-time equivalent teachers derived from the NSTA data are 13,620 and 6,900, respectively.

A third data base currently being analyzed is the NSTA list of science, mathematics, and social science teachers for grades 7 to 12, maintained by grade level, by state, and by subject taught. The list was updated in November 1983, with principals of more than 23,000 schools responding (a response rate of better than 80 percent). Preliminary analyses indicate that there are some 75,600 people teaching biology, chemistry, physics, or a combination of these subjects in grades 7 to 12. Over 50 percent teach biology only, 15 percent teach chemistry only, 11 percent teach physics only, and the rest teach some combination of these subjects. It should be pointed out that the numbers include all people listed by their principals as teaching in the designated fields, rather than only those teaching the subject(s) full time (or full-time equivalents).

The discrepancies in definitions and resulting numbers exhibited in these three surveys illustrate some of the problems with the current data. And lack of information on how many of the persons counted in any of the compilations are actually certified or otherwise qualified to teach science and mathematics raises additional uncertainties about the estimated numbers.

Whatever the uncertainties, the current number of teachers, while an important statistic, becomes meaningful as an indicator only when compared with the number needed. But if estimates of numbers now teaching are attended by some ambiguity, estimates of future supply and demand are even more so. Estimates of future supply must take into account, in addition to the existing pool, the number of teachers leaving and entering the field. Estimates of demand must take into account current vacancies, the desirability of replacing those teachers who lack minimum qualifications for their teaching assignments, changes in total student enrollment, and changes in percentage of the total number of enrolled students who take specific science or mathematics courses.

The teacher turnover rate (i.e., teachers leaving the profession) has been estimated at 6 percent for the last decade (Froomkin, 1974; National Center for Education Statistics, 1978, 1982a). However, these estimates are based on studies that go back a decade or more. In an unpublished analysis of the survey of principals and a separate teacher survey, NSTA estimated the rate to be 5 percent for science and mathematics teachers in 1981-1982. A recent California study estimated a teacher turnover rate of 11.5 percent; in Illinois, the rate in 1983 was

5.5 percent for science and mathematics teachers and 7 percent for all other teachers. Pelavin and Reisner (1984), in an analysis of the availability of teachers, use a 6 percent turnover rate and an estimate of 110,000 mathematics teachers and 103,500 science teachers for 1982-1983, reconciling the NCES and NSTA estimates. Thus, they project a loss of 6,600 mathematics teachers and 6,200 science teachers (800 in chemistry, 500 in physics, and 4,900 in other science areas) in 1983-1984. (A 5 percent turnover rate would mean a loss of 5,500 mathematics teachers and 5,100 science teachers.) There is evidence that the teacher pool is aging (National Center for Education Statistics 1983; Feistritzer, 1983), which may mean a higher turnover rate a decade from now due to retirements--at a time when high school enrollment will be increasing and the cohort of young adults that might furnish new teachers will be decreasing.

The supply of teachers can be increased either by persons newly entering the field or by persons returning to mathematics or science teaching. No national data are available on this second component, although one state reports that 55 percent of vacancies in all fields in 1982-1983 were filled by returning teachers (Flakus-Mosqueda, 1983). The potential pool is considerable. According to Graybeal (1983), as of fall 1981, about 6.1 million people (aged 21 to 65) had been certified as public school teachers: of this total, only about 2.2 million were teaching in 1980-1981; 1.9 million had left teaching; 1.9 million had not entered the profession; and 140,000 were newly qualified.

With respect to new entrants, the number prepared to teach mathematics or any of the sciences, particularly the physical sciences, has been decreasing over the past decade. Data from NCES show that the decline in the number of college students majoring in science or mathematics education has taken place in the context of a general decline of teaching degrees conferred over the last decade (with the exception of degrees in special education); see Table 2. (The discrepancy between NCES data and the data from the NSTA survey of teacher placement officers cited above may be due to problems with the response rate on the NSTA survey and to somewhat differently worded questions on this survey and

TABLE 2: Bachelor's Degrees Conferred in Selected Areas of Education, by Level and Speciality: 1971-1981

Field of Bachelor's Degree	1970-1971	1980-1981	Percent Change
Education, total	176,614	108,309	-38.7
Elementary education, general	90,432	38,524	-57.4
Special education, all specialties	8,360	13,950	66.9
Art education	5,661	2,392	-57.7
Music education	7,264	5,332	-26.6
Mathematics education	2,217	798	-64.0
Science education	891	597	-33.0
Physical education	24,732	19,095	-22.8
Business, commerce, and distributive education	8,550	3,405	-60.2
Industrial arts, vocational and technical education	7,071	5,772	-18.4
Home economics education	6,449	1,767	-72.6

Note: Numbers do not include individuals certified to teach a subject but graduating with a different type of major.

Source: National Center for Education Statistics (1983:188)

the NCES survey.) It should be noted, however, that neither the NSTA data nor Table 2 include newly certified entrants who obtained bachelor's degrees in fields other than mathematics education or science education, including degrees in mathematics or a science. For example, as shown in Table 3, there were 3,150 newly certified entrants in mathematics and about 3,600 in the sciences who graduated in 1980.

TABLE 3: Certification of Newly Graduated Teachers: 1979-1980

		Certified or Eligible for Certification			
Subject or Field Currently Teaching	Number[a]	In Some Field(%)	In Field Currently Teaching(%)	In Field Other than Currently Teaching(%)	Not Eligible or Don't Know(%)
Total	79,800	93.8	77.9	15.9	6.2
Special Education teachers, all	16,700	96.1	77.3	18.8	3.9
"Self-contained class" teachers	26,400	94.8	80.0	14.8	5.2
English language arts	10,200	84.6	50.6	34.0	15.5
Foreign languages and fine arts	11,000	91.6	72.3	19.2	8.4
Biological and physical sciences	7,900	88.3	45.4	43.0	11.7
Mathematics	7,500	85.4	42.0	43.4	14.6
Health and physical education	10,600	93.6	68.5	25.0	6.4
Social sciences/social studies	6,600	90.5	63.3	27.2	9.5

[a] 1979-1980 bachelor's degree recipients teaching elementary or secondary school full time in May 1981.

Source: National Center for Education Statistics (1983)

These entrants could replace half or more of the teachers lost through teacher turnover, although in the sciences the distribution of incoming teachers is likely to be skewed, with proportionally more being added in the biological than in the physical sciences.

Table 3 indicates the modest proportion of new teachers in science and mathematics who are reported to be certified or eligible to be certified in the field in which they are teaching, 45 percent and 42 percent, respectively. These data suggest that many newly graduated high school teachers who are not prepared in science or mathematics nevertheless may be assigned to teach these subjects, one possible explanation of the apparent nonexistence of shortages emerging from head count data of vacancies. Current initiatives to encourage entry into the field may increase the proportion of adequately prepared entering teachers and reverse earlier forecasts of continuing declines of individuals available to teach mathematics or science with competence.

Demand for Teachers

On the demand side, the National Center for Education Statistics (1982c) survey on teachers also included data on vacancies as of fall 1979: they were estimated to be 900 unfilled teaching positions in mathematics and 900 in science, including 400 in chemistry and 200 in physics. (Preliminary data for fall 1983 indicate 260 vacancies in mathematics and 230 in the sciences.) The vacancies for mathematics and science as a whole, as in 1983, represented less than 1 percent of the total number of persons teaching in those fields. However, that percentage does not take into account the number of teachers already in the system who were assigned to classes they were not qualified to teach. Particularly in times of shrinking enrollments, it is not unusual to fill a vacancy in a shortage area with a tenured teacher from an area with a teacher surplus. Fourteen states have no rules prohibiting out-of-field teaching.

Total high school enrollment (grades 9-12) is a major determinant of teacher demand. The National Center for Education Statistics (1984a) projects enrollment at 13.7 million in 1985, down from 14.7 million in 1980, and at 12.1 million in 1990--a decrease of more than 17 percent over ten years. The National Center for Education Statistics (1984a) also estimates a somewhat smaller decline in the total number of teachers in public secondary schools, about 10 percent over the same decade. A relatively larger decrease already took place between 1980 and 1982, when the number of secondary school teachers declined from 1,074,000 to 1,039,000. If that rate were to continue until 1990, the ten-year loss would be more than 15 percent. On the assumption that NCES's estimate of a 10 percent decrease over ten years is more nearly correct, a decrease of some 72,000 teachers for 1982-1990 can be expected, for a total 1980-1990 decrease of 107,000. After 1990, however, there is expected to be an increase of teachers, as high school enrollments begin to increase again starting in 1991. If mathematics and science teachers were to continue to represent, respectively, 11 percent and 10 percent of the high school teaching force, the total number of teachers needed for mathematics would decrease by 7,700 by 1990 in comparison with the number needed in 1982, and the total number of teachers needed for science would decrease by 7,000.

A countervailing factor to decreasing enrollments is the increase in high school graduation requirements already mandated by some states and being considered by others (see Table 4). It should be noted that these increased requirements would not affect all students: in 1982, about 46 percent of high school graduates had taken three years or more of mathematics in grades 9-12; 30 percent had taken three years or more of science (National Center for Education Statistics, 1984b). However, where recent state or local mandates would require more courses than were actually taken before the new requirements, additional mathematics and science teachers would be needed.

A number of state university systems also have recently increased entrance requirements, often beyond those required for high school graduation (U.S. Department of Education, 1984). The National Commission on Excellence in Education (1983) recommended that all students be required to take three years of mathematics, three years of science, and one-half year of computer science for high school graduation. If these recommendations were to be implemented, it would certainly require a large increase in the number of mathematics and science teachers. In the estimates of annual demand for the next few years made below, it is assumed that decreased demand due to lower high school enrollments will be balanced by increased demand due to higher graduation requirements. However, Pelavin and Reisner (1984) estimate the increased demand to be 8,600 mathematics teachers and 6,500 science teachers.

It has been argued that demand projections should take account of the need to replace teachers of science and mathematics who have been assigned to teach those subjects without the requisite qualifications. At present, fewer than half of new entries into these fields appear to be

TABLE 4: Minimum High School Graduation Requirements in Mathematics and Science, as of August 1984

State	Years of Instruction Mathematics	Science	Total Credits[a] Required	Requirements Increased Since 1980 Mathematics	Science	Statewide Mandate for Testing[b]
Alabama	2	1	20	X	+	X
Alaska	2	2	21	X	X	X
Arizona	2	2	20	X	X	X
Arkansas	2-3 (5 total)	2-3	20	X	X	X
California	2	2	13	X	X	X
Colorado	Local determination				X	
Connecticut	3	2	20	X	X	X
Delaware	2	2	19	X	X	X
D. C.	2	2	20.5	X	X	X
Florida	3	3	24	X	X	X
Georgia	2	2	21	X	X	X
Hawaii	2	2	20			X
Idaho	2	2	20	X	X	X
Illinois	2	1	16	X	X	X
Indiana	2	2	19.5	X	X	X
Iowa						
Kansas	2	2	20	X	X	X
Kentucky	3	2	20	X	X	X
Louisiana[c]	3	3	23	X	X	X
Maine	Local determination		16			X
Maryland	2	2	20	+	+	X
Massachusetts	Local determination					
Michigan	Local determination					X
Minnesota	1	1	20	X	X	X
Mississippi	1	1	16	X	X	X
Missouri	2	2	22	X	X	X
Montana	2	1	20			X
Nebraska	Local determination		20			X
Nevada	2	1	20	X		X
New Hampshire[c]	2	2	19.75	X	X	X
New Jersey	2	1	18.5	+	+	X
New Mexico	2	2	21	X	X	X
New York	1	1	16	+	+	X
N. Carolina	2	2	20	+	+	X
N. Dakota	2	2	17	X		

TABLE 4: Minimum High School Graduation Requirements in Mathematics and Science, as of August 1984 (con't)

State	Years of Instruction Mathematics	Years of Instruction Science	Total Credits[a] Required	Requirements Increased Since 1980 Mathematics	Requirements Increased Since 1980 Science	Statewide Mandate for Testing[b]
Ohio	2	1	18	X		
Oklahoma	2	2	20	X	y	
Oregon	2	2	22	X	X	X
Pennsylvania	3	3	21	X	X	X
Rhode Island	1	1	16	+	+	X
S. Carolina	3	2	20	X	X	X
S. Dakota[c]	2	2	20	X	X	
Tennessee	2	2	20	X	X	X
Texas	3	2	21	X	X	X
Utah[c]	2	2	24	X	X	X
Vermont	3	3	15.5	X	X	X
Virginia	2-3 (5 total)	2-3	18	X	X	X
Washington	2	2	16	X	X	X
W. Virginia	2	1	20		+	X
Wisconsin[c]	2	2	13.5	X	X	X
Wyoming	Local determination		18			

X Requirements increased since 1980

+ Additional requirements under study

[a] A credit is defined as a year of instruction. Some of the listed requirements are to be phased in over the next three to five years.

[b] May include competency-based tests required for high school graduation, testing at selected grade levels, use of standardized tests, or tests developed by the state or districts. Proficiency tests in basic mathematical skills usually are included; tests in science are less frequent (see Table A3, Appendix).

[c] States requiring .5-1 year of computer science or computer literacy in addition to mathematics and science requirements. Several more states are evaluating computer literacy requirements.

Source: Adapted from Parrish (1980), Dougherty (1983), U.S. Department of Education (1984), Education Commission of the States (1984), and Council of Chief State School Officers (1984) qualified (see Table 3), and unless countermeasures are taken, erosion of the competence of the existing teaching pool will continue. Countermeasures could include increasing the numbers of qualified new entrants (or reentrants), in-service education, and replacement of unqualified teachers. As to the last, likely replacement rates are difficult to estimate, since the feasibility of replacing teachers, especially if tenured, depends on conditions within individual school systems. Many local systems and states may choose to retrain rather than replace underqualified teachers.

For the purpose of projecting demand, three alternative replacement rates per year may be considered: a no-replacement rate of 0 percent; a moderate replacement rate of 2.5 percent of the current pool of mathematics and science teachers; and a high replacement rate of 5 percent. The alternative estimates of annual demand, supply, and shortage of high school mathematics and science teachers for the next few years under these conditions are shown in Table 5.

As can be seen, annual shortages are at least 3,700 for mathematics teachers and 2,800 for science teachers; that is, the annual demand for new or returning high school teachers of mathematics and science is projected to be at least twice the expected supply. If school systems were to make a concerted effort to replace unqualified teachers, the need would be for three or four times the expected supply of new (or returning) teachers. Among the various sciences, data show that shortages will continue to be most acute in physics but also prevalent in chemistry and the earth sciences; few shortages in biology are projected.

The preceding summary of the data indicates the considerable

TABLE 5: Alternative Estimates of Annual Demand, Supply, and Shortage of High School Mathematics and Science Teachers

	Replacement Assumptions					
	Zero		2.5 Percent - Moderate		5 Percent - High	
	Mathematics	Science	Mathematics	Science	Mathematics	Science
Unfilled positions	900	900	900	900	900	900
Resignations, retirements	6,000	5,500	6,000	5,500	6,000	5,500
Replacements	-	-	2,700	2,600	5,500	5,200
Total need	6,900	6,400	9,600	9,000	12,400	11,600
Less new entrants	3,200	3,600	3,200	3,600	3,200	3,600
Net Shortage	3,700	2,800	6,400	5,400	9,200	8,000

NOTE: The estimates are for the next three to five years. They do not take into account any possible changes in the function or structure of education. All the estimates assume that decreased demand for teachers due to lower higher school enrollments will be balanced by increased demand due to higher requirements for high school graduation.

uncertainties attached to all the estimates. Moreover, the projections are based on the assumption that the education system will continue to operate essentially as it does at present; the possible effects of structural changes that might be brought about by the application of information technology to education and by other reform efforts are not taken into account.

Also, national projections are not very useful for state and local planning. As the Education Commission of the States survey (Flakus-Mosqueda, 1983) shows, there is considerable variation in teacher supply and demand among the states. Some states are losing students, others are gaining them. Some of the most populous states in the northeast and midwest report no teacher shortages in mathematics or science, while other states are reporting critical shortages. The numbers of teachers do not vary in proportion to student enrollment, since there is a set of constraints operating differently on different communities with respect to hiring or firing teachers. Even among districts within a state, supply and demand is likely to vary, depending in part on the sociodemographic characteristics of communities (National Center for Education Statistics, 1982b).

A troubling problem is that none of the models currently used to project teacher demand and supply includes policy-relevant factors. For example, how would changes in salary scales and structure affect the supply of teachers? How would changes in certification and hiring rules or in working conditions affect supply? How will changes in curriculum, graduation requirements, and financing for mathematics and science education affect demand? To evaluate the potential effects of various policies for improving the teaching of mathematics and science, teacher supply and demand functions rather than fixed estimates of numbers must be constructed--functions that could generate conditional estimates connected to specific assumptions about policies or about external conditions. Particularly on the teacher supply side, however, there are formidable obstacles to constructing such policy-sensitive estimates in that the necessary observations of response behavior of teachers and potential teachers to various policy alternatives are largely lacking.

Quality of Teachers

If the objective is to gauge the adequacy of science and mathematics teaching in the schools, then simply providing a count of the number of teachers in front of science and mathematics classes without any assessment as to their quality is not sufficient. There is, however, no measure available for evaluating teacher quality; there is not even a measure for assessing competence, that is, whether a teacher possesses adequate knowledge of what is to be taught and knows how to teach it. Certification has been used as a first-order approximation of competence, but, as shown in Table 6, certification standards vary so greatly from state to state that certification becomes problematic as a measure of competence at the national level. Certification requirements range from a degree from any of the accredited teacher education programs in the state (which may themselves vary quite widely) to a number of college credit hours in education courses and in areas of specialization. Even requiring a given number of credit hours can result in quite different levels of preparation, however, depending on the content of courses taken.

TABLE 6: Teacher Certification Requirements

State	Elementary[a] Math	Elementary[a] Sci	Secondary[b] Math	Secondary[b] Sci	Test
Alabama	12 combined		12 combined		S
Alaska	U	U	U	U	
Arizona	12-30	12-30	30	30	S
Arkansas	6	9	21	24	NTE
California	U	U	U	U	S/NTE
Colorado	U	U	U	U	S
Connecticut	6	R	30	30	S
Delaware	U	U	30	39-45	S
D.C.	9	6	30	30	
Florida	6-12 combined		21	20	S
Georgia	U	U	45 qh	40-75 qh	S
Hawaii	U	U	major	major	
Idaho	6	8	20-45	20-45	
Illinois	5	7	24-32	24-32	
Indiana	R	R	24-52	24-52	
Iowa	U	R	30	30	
Kansas	12 combined		18	24	
Kentucky	12 combined		48	48	
Louisiana	6	6	20	20-32	S/NTE
Maine	U	U	18-50	18-50	
Maryland	6	12	24	3;5	
Massachusetts	U	U	36	36	
Michigan	U	U	30	30	
Minnesota	U	U	major	major	
Mississippi	15 combined		12 combined		NTE
Missouri	5	5	30	30	
Montana	U	U	20-40	20-40	
Nebraska	U	U	U	U	
Nevada	U	U	16-36	16-36	
New Hampshire	U	U	U	U	
New Jersey	R	R	24-30	24-30	
New Mexico	R	R	24-54	24-54	S/NTE
New York	R	R	24	36	NTE
N. Carolina	U	R	major	major	NTE
N. Dakota	U	R	U	U	

TABLE 6: Teacher Certification Requirements (con't)

State	Elementary[a] Math	Elementary[a] Sci	Secondary[b] Math	Secondary[b] Sci	Test
Ohio	6	8	20	20-60	
Oklahoma	R	R	[illegible]	36	S
Oregon	12	U	[illegible]-42	45	
Pennsylvania	U	U	U	U	
Rhode Island	U	U	18	18	
S. Carolina	U	12	12-60	12-60	S/NTE
S. Dakota	2	4	major	major	
Tennessee	3 qh	12 qh	27 qh	24-48 qh	
Texas	U	U	U	U	NTE
Utah	U	U	16-46	16-46	S
Vermont	U	U	U	U	
Virginia	6	6	16-27	24	NTE
Washington	U	U	U	U	
W. Virginia	U	U	U	U	S
Wisconsin	U	U	22-34	22-34	
Wyoming	R	R	R	R	

Code

- U = credits in mathematics and/or science may be required for certification; these subjects, however, are not specifically mentioned.
- R = credits in mathematics and/or science are required for certification; number of credits required is not indicated
- S = State-constructed test
- NTE = National Teacher Examination
- qh = quarter hour

NOTE: Unless otherwise noted, requirements are given in college semester hours required in mathematics and science for state certification for elementary school teachers and to teach mathematics or science in secondary school.

[a] Certification to teach; requirements given are for the lowest-level certificate. Many states require additional credit hours for certification as a specialist teacher in mathematics or science or for teaching in junior high school.

[b] Certification to teach mathematics or science. A wide spread in credit hours (e.g., 18-50 for Maine) generally means that the higher number includes courses in several sciences for certification to teach in all of them.

Source: Adapted from Woellner (1983) and Flakus-Mosqueda (1983)

In the 1960s and 1970s, various professional groups such as the Mathematical Association of America (Committee on the Undergraduate Program in Mathematics, 1961a, 1961b) and the American Association for the Advancement of Science (1970), in conjunction with the National Association of State Directors of Teacher Education and Certification, developed and published standards for the preparation of elementary and secondary school teachers in mathematics and science. The guidelines have been updated periodically (see, e.g., American Chemical Society, 1977). These activities led to an increase in several states in the number of credit hours required in the pertinent academic field for certification of secondary school teachers and of hours of mathematics required for elementary school teachers. Revised guidelines for preparation in mathematics for elementary school teachers and for mathematics teachers for grades 7-12 have recently been prepared by the National Council of Teachers of Mathematics (1981a) in association with the Mathematical Association of America (see also Committee on the Undergraduate Program in Mathematics, 1983); the National Science Teachers Association (1983) has published standards for preparation in science for elementary and middle/junior high school teachers and, more recently, for secondary school teachers of science (Ritz, 1984). As in the past, the effect of these guidelines is likely to vary from state to state.

In an effort to help ensure quality, a number of states have added competency-based tests to their certification requirements, as shown in Table 6; at least 15 more states are considering the use of such tests. Several states provide long-term certification; others require periodic recertification based on continuing inservice education. Districts may impose their own standards in addition to those required by the state.

Certification standards are changed periodically as new priorities are set for schools, but teachers already certified are generally excluded from having to meet the new standards or can meet them through inservice training. Hence, certification granted at different times may represent different preparation even within the same state.

Elementary School

In many states elementary certification depends mainly on obtaining a college degree and on a specified period of teaching within the state. In some states, such elementary school certification is also valid for teaching grades 7 and 8; certification provisions usually call for a specialist teaching degree requiring more credit hours in the relevant academic field than for grades 1-6 but fewer than for secondary school certification.

Since teachers for grades 1-6 generally major in elementary education, their college preparation in mathematics or science tends to be limited, as indicated by the requirements (or lack thereof) shown in Table 6. According to a recent survey of teacher education programs (Kluender and Egbert, 1983), 40-50 percent of an elementary school teacher's preparation consists of professional education courses; the rest i usually distributed among general liberal arts courses. If science is taken at all in college, it is usually limited to one discipline. Certification may be an even less appropriate indicator of qualification for teaching mathematics and science in elementary school than it is for secondary school teachers. In any case, little information is available regarding the subject-matter expertise of elementary school teachers presently in classrooms.

Secondary School

Certification to teach a particular subject in secondary school may require as few as 18 or as many as 48 college credits in the relevant and related disciplines. Kluender and Egbert (1983) found that the average requirements of teacher preparation programs for secondary school teaching consist of 25-60 percent of courses required in the academic field to be taught, 20 percent in professional education courses, and the rest distributed among general liberal arts courses. In the large state universities, the credits needed for teaching degrees often represent preparation equivalent to that of a major in the academic discipline, but little is known about the types of courses taken by teachers in smaller, less prestigious institutions.

Because of the great range over locale and over time in teacher education programs and certification standards, and because of the device of issuing emergency certificates, documenting the number of teachers actually certified to teach science or mathematics is only a first step toward establishing whether they are qualified. Even so, no national data are currently available on how many teachers now assigned to teach science or mathematics courses are fully certified for their assignments. As noted above, a new NCES sample survey on teachers is planned for 1985 to provide data on the certification status and preparation of public school teachers in all fields; additional information will come from the replication of the science education survey.

More information is available on certification of new entrants than on certification of teachers already teaching. NSTA surveyed secondary school principals in 1980-1981 and again in 1981-1982 to gather information on their teachers. Table 7 shows the percentage of newly hired science and mathematics teachers who were not certified to teach the courses to which they were assigned, as estimated from the NSTA surveys. This table also gives some indication of the variations among different regions of the country. It is evident that regions losing population, like the northeastern states, are having less difficulty in staffing their schools than are the regions of high growth, like the Pacific states, where a large majority of newly hired teachers in science and mathematics are not certified.

TABLE 7: Newly Hired Science and Mathematics Teachers Not Certified in Subject

Census Region	Percent of Teachers Newly Hired 1980-1981	1981-1982
Pacific States	75	84
Mountain States	44	43
West North-central States	26	43
West South-central States	63	63
East North-central States	23	32
East South-central States	43	40
Northeastern States	11	9
Middle Atlantic States	40	46
South Atlantic States	48	50
Nationwide	45	50

Source: Franz et al. (1983)

Similar findings come from the periodic NCES surveys of recent college graduates; as noted above, only 42 percent of 1980 bachelor degree recipients teaching and 45 percent teaching science were certified to do so (see Table 3). These percentages are far lower than for other fields, although English teachers also were drawn from out of field in considerable numbers.

Defining Teacher Quality

It bears repeating that certification is only a poor approximation of competence at the secondary school level and even less meaningful at the elementary school level with respect to teaching science and mathematics. At present, however, there is no other standard that might be used to establish how many of the teachers with instructional responsibilities in science and mathematics are qualified to carry out their assignments.

It might be possible to develop a continuum of qualifications, not just a dichotomy of "qualified" or "unqualified", and collect information on where samples of teachers fall on the continuum, given their teaching responsibilities. One unresolved problem, however, is the appropriate combination of knowledge of subject matter and of teaching (pedagogy) and how that should vary by level of instruction (Druva and Anderson, 1983). Obviously, teachers must understand the subject matter they are responsible for teaching, although there is evidence that in mathematics, at least, more advanced knowledge by the teacher does not correlate highly with increased student performance (Begle, 1973). Nevertheless, the equivalent of a college major in the relevant discipline(s) is generally thought necessary for secondary school teachers with the number of credits required for certification specified by many states.

Sequence and content of the courses is often left up to individual institutions, and practice reflects disagreement about such matters as the suitability of courses designed for mathematics or science majors as well as the mix of disciplinary and pedagogy courses. Research evidence provides little guidance. The National Longitudinal Study of Mathematical Abilities (NLSMA), for example, included a detailed study of the relationships between teacher background and attitudes and student performance. Concerning teacher preparation, the strongest positively correlated variable was found to be credits in mathematics methods courses, but the positive correlation appeared in only 24 percent of the cases (Begle, 1979). Generally, teachers with graduate credits or advanced degrees are deemed to be more competent and are paid better, yet the evidence on the relationship between graduate work or inservice education and student achievement is equally tenuous (Summers and Wolfe, 1977; Begle, 1979; Shymansky et al., 1983; Druva and Anderson, 1983; Hilton et al., 1984; U.S. General Accounting Office, 1984).

There is even more question about the suitable academic preparation of elementary school teachers, since they are responsible for teaching subject matter from several disciplines. For elementary school teachers in particular, but also for secondary school teachers to some extent, the importance of pedagogy is stressed by those who hold the model of the college lecture to be inadequate for precollege education. Teaching prospective teachers <u>how</u> to teach science or mathematics is deemed as necessary as <u>what</u> science or mathematics to teach. The how appears to be especially important with respect to teaching such higher-order skills as analyzing and solving problems, reasoning from evidence, checking one's procedures, and in-depth understanding (Glaser, 1983). A third element in teacher qualification is experience, rated by skilled classroom observers and school administrators as a key element in the development of competent teachers.

Experts have not settled their differences, with mathematicians and scientists generally arguing for increased training in subject matter, teacher educators for more training in pedagogy, and principals and school superintendents for teaching experience. Almost all the recent reports on education and several national bodies have made suggestions for how to improve teacher education. (For a listing of these suggestions, see National Commission on Excellence in Teacher Education, 1984.) At this time, efforts are going forward to increase the number of people teaching science and mathematics. These "natural experiments" range from training out-of-field teachers by giving them special courses in mathematics or the relevant science to hiring professional scientists and engineers as teachers without requiring the usual education courses or teaching experience. It would be useful to track a selected number of these experiments through a carefully designed research effort in order to help identify the critical attributes of competent science and mathematics teachers.

Summary

The Committee on Indicators of Precollege Science and Mathematics Education of the National Research Council, after reviewing the available information, summarized its findings as follows:

A. On Supply and Demand

Aggregate Quantity

- Forecasts of aggregate supply and demand of secondary school teachers in the physical and biological sciences and in mathematics show shortages over the next several years in mathematics and the physical sciences. A low estimate, based on little change in current trends of overall supply and demand, indicates an annual shortage of 2,800 science teachers, mostly in the physical sciences, and 3,700 mathematics teachers. If teachers currently assigned to mathematics and science classes but not qualified to teach these subjects were to be replaced at a rate of 5 percent per year of all teachers in these fields, the annual shortage would be 9,200 in mathematics and 8,000 in science. Both these forecasts are driven by the education system as presently constituted and do not take into account the possibility of structural reform.

- Aggregate estimates of teacher supply and demand mask great differences among regions of the nation, states, and local school districts within states.

- Models currently being used to forecast teacher supply and demand have little connection to policies being considered or already instituted for increasing teacher supply, hence the effects of these policies cannot be assessed.

Uncertainties

- All estimates of teacher supply and demand are accompanied by large uncertainties.

With respect to supply, there are three major gaps in knowledge.

(1) The data on the actual numbers of teachers assigned to mathematics and science classes are inadequate, especially as aggregated at the national level.

(2) The number of inactive teachers who return each year to fill vacancies is unknown. Since the number of trained teachers who do not enter teaching or who leave teaching is sizable, this represents a considerable resource. The number of teachers drawn from the inactive pool may increase as desirable job opportunities arise.

(3) The most recent data on the annual supply of newly certified entrants to teaching--3,200 in mathematics and 3,600 in science--are four years old. Hence, the effects of current incentives to draw people into the field are unknown. The incentives include loan programs for college students preparing to be teachers, inservice training for out-of-field teachers, and employment of retired scientists and engineers as teachers.

With respect to demand, there are four unknowns:

(1) While enrollments are dropping, vacancies tend to e filled with teachers from other fields who have tenure in a district, rather than with new entrants certified in the field with vacancies. This practice, the extent of which is unknown, reduces the demand for additional teachers, even though it may be detrimental to the quality of science and mathematics teaching.

(2) The extent to which school systems will seek to replace out-of-field teachers or will choose instead to provide

in-service training is unknown. Such choices will in part be influenced by state and federal support policies for teacher education and in part by local board policies and teacher contracts.

(3) To the degree that increased high school graduation requirements will entail having to offer more courses in mathematics and science, teacher shortages will be aggravated, but how much is unknown.

(4) Demand forecasts are generally based on extrapolation of current conditions, taking account of likely changes in enrollment, class size, and curriculum. They do not take into account possible structural changes in the education system.

B. On Quality

Lack of Information

- Adequate information is lacking on the qualifications of the teachers who are responsible for teaching mathematics and science in high school, middle/junior high school, or elementary school.

- Information on certification, the only proxy available for qualification, is lacking for all but new entrants, although data on national samples of the teaching force are now being collected.

Requirements for Teaching Mathematics and Science

- Even if available, information on certification is of questionable use as a measure of qualification because state certification requirements and preservice college curricula reflect a wide range of views on what constitutes a qualified or competent teacher in mathematics or science. Moreover, teachers currently certified obtained their certification at different times that may have required different types of preparation; therefore, certification even within the same state does not connote equivalent preparation.

- Although guidelines on teacher preparation developed by professional societies are generally available, they have not been uniformly adopted.

The committee concluded that a suitable indicator to assess the sufficiency of secondary school science and mathematics teachers, for example, the ratio of or the difference between projected demand and anticipated supply of qualified teachers, is at present not feasible at the national level because of the lack of a meaningful common measure of qualification. Individual states and localities might construct this type of indicator by using certification as an approximation for qualification or developing alternative criteria for teacher competence. In each case, an adequate determination would entail estimates of both demand and supply under alternative sets of assumptions about anticipated enrollments in mathematics and science classes and new or returning entrants into the teaching of these fields. Aggregation of the state data might provide a useful national picture, especially if, in addition, information was reported concerning differences among states.

With respect to developing definitions of quality, the disparate views on teacher qualification and the variation in certification standards indicate the need to rethink the initial preparation and continuing training appropriate for teachers with instructional responsibilities in science and mathematics. Guidelines that have been prepared by professional societies need to be considered by the wider educational community, including bodies responsible for the certification of teachers and accreditation of teacher education programs. Requirements should be detailed separately for teachers in elementary school (grades 1 to 5 or 6), middle or junior high school (grades 6 or 7 to 8 or 9), and high school (grades 9 or 10 to 12), with particular attention to requirements that can be translated into effective college curricula and in-service education for teachers.

The development of guidelines for the preparation and continuing education of teachers would be advanced if the attributes of successful teaching in science or mathematics were better understood. Further research is necessary on the relationships between teacher training and student outcomes, for example, the effects on student achievement of different types of preservice and in-service training and of teaching experience. Current initiatives to augment the pool of science and mathematics teachers should be monitored to assess their effectiveness.

REFERENCES

American Association for the Advancement of Science
1970 Preservice Education of Elementary School Teachers. Washington D.C.: American Association for the Advancement of Science.

American Chemical Society
1977 Guidelines and Recommendations for the Preparation and Continuing Education of Secondary School Teachers of Chemistry. Washington, D.C.: American Chemical Society.

Begle, Edward G.
1973 Some lessons learned by SMSG. Mathematics Teacher 66(3):207-214.

1979 Critical Variables in Mathematics Education. Washington, D.C.: Mathematical Association of America and National Council of Teachers of Mathematics.

Committee on the Undergraduate Program in Mathematics
1961a Course Guides for the Training of Teachers of Junior High and High School Mathematics. Washington, D.C.: Mathematical Association of America.

1961b Recommendations for the Training of Teachers of Mathematics. Washington, D.C.: Mathematical Association of America.

1983 Recommendations on the Mathematical Preparation of Teachers. Washington, D.C.: Mathematical Association of America.

Council of Chief State School Officers
1984 "A Review Profile of State Assessment and Minimum Competency Testing Programs." Prepared for Meeting of Chief State School Officers, August 1984.

Dougherty, Van
1983 State Programs of School Improvements, 1983: A 50-State Survey. Working Paper No. 1. Prepared for the Education Commission of the States, Denver, Colo.

Druva, Cynthia A., and Anderson, Ronald D.
1983 Science teacher characteristics by teacher behavior and by student outcome: A meta-analysis of research. Journal of Research in Science Teaching 20(5):467-479.

Education Commission of the States
1984 Clearinghouse Notes: Minimum High School Graduation Course Requirements in the States. Denver, Colo.: Education Commission of the States,

Feistritzer, C. Emily
1983 The Condition of Teaching: A State by State Analysis. Princeton, N.J.: Carnegie Foundation for the Advancement of Teaching.

Flakus-Mosqueda, Patricia
1983 Survey of States' Teacher Policies. Working Paper No. 2. Prepared for the Education Commission of the States, Denver, Colo.

Franz, Judy R., Aldridge, Bill G., and Clark, Robert B.
1983 Paths to a solution. Physics Today 36(9):44-49.

Froomkin, Joseph
1974 Demand and Supply of Elementary and Secondary School Teachers. Joseph Froomkin, Inc., Washington, D.C.

Gallup, George H.
1983 The 15th annual gallup poll of the public's attitudes toward the public schools. Phi Delta Kappan 65(1):33-47.

Glaser, Robert
1983 Education and Thinking: The Role of Knowledge. Technical Report PD5-6. University of Pittsburgh.

Graybeal, William S.
1983 Teacher Supply and Demand in Public Schools, 1981-82. Washington, D.C.: National Education Association.

Hilton, Thomas L., Rock, Donald A., Ekstrom, Ruth, Goertz, Margaret E., and Pollack, Judith
1984 Study of Excellence in High School Education: Cross-Sectional Study, 1972-1980. Draft Technical Report: Relational Analysis Section. Educational Testing Service, Princeton, N.J.

Howe, Trevor G., and Gerlovich, Jack A.
1982 National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers. Ames: Iowa State University.

Kluender, M.M., and Egbert, Robert L.
1983 The Status of American Teacher Education. Draft Report. National Institute of Education, Washington, D.C.

National Center for Education Statistics
1978 Projections of Education Statistics to 1986-87. M.M. Frankel, ed. Washington, D.C.: U.S. Department of Education.

1982a Projections of Education Statistics to 1990-91. Prepared by M.M. Frankel and D.E. Gerald. Volume II: Methodological Report. Washington, D.C.: U.S. Department of Education.

1982b Teacher Demand: A Socioethnographic Phenomenon. Prepared by Jane L. Crane. NCES no. 381-054. Available from the U.S. Governme~t Printing Office. Washington, D.C.: U.S. Department of Education.

1982c Teachers Employed in Public Schools 1979-80. A Report on the 1979-80 Survey of Teacher Demand and Shortage. Prepared by A.S. Metz and J.P. Sietsma. Washington, D.C.: National Center for Education Statistics.

1982d Teacher Shortage May Occur in the Late 1980's. Supt. of Doc. no. NCES 82-403b. Available from the U.S. Government Printing Office. Washington, D.C.: U.S. Department of Education.

1983 The Condition of Education. Prepared by V.W. Plisko. Supt. of Doc. no. NCES 83-400. Available from the U.S. Government Printing Office. Washington, D.C.: U.S. Department of Education.

1984a The Condition of Education. Prepared by V.W. Plisko. Supt. of Doc. no. NCES 84-401. Available from the U.S. Government Printing Office. Washington, D.C.: U.S. Department of Education.

1984b Science and Mathematics Education in American High Schools: Results from the High School and Beyond Study. NCES 84-211b. Washington, D.C.: U.S. Department of Education.

National Commission on Excellence in Education

1983 A Nation At Risk: The Imperative for Educational Reform. Supt. of Doc. no. 065-000-00177-2. Available from the U.S. Government Printing Office. Washington, D.C.: U.S. Department of Education.

National Commission on Excellence in Teacher Education

1983 What the Reports Said About Teacher Education: A Sumary. Prepared for the May 2, 1984, meeting of the Commission. American Association of Colleges for Teacher Education, Washington, D.C.

National Council of Teachers of Mathematics

1981a Guidelines for the Preparation of Teachers of Mathematics. Prepared by the Commission on the Education of Teachers of Mathematics. Reston, Va.: National Council of Teachers of Mathematics.

National Science Teachers Association

1983 Recommended Standards for the Preparation and Certification of Teachers of Science at the Elementary and Middle/Junior High School Levels. Washington, D.C.: National Science Teachers Association.

Parrish, William C.
1980 State-Mandated Graduation Requirements, 1980. Reston, Va.: National Association of Secondary School Principals.

Pelavin, Sol H., and Reisner, Elizabeth R.
1984 An Analysis of the National Availability of Mathematics and Science Teachers. Pelavin Associates, Inc., Washington, D.C.

Ritz, William C.
1984 Recommended Standards for the Preparation and Certification of Secondary School Teachers of Science. Washington, D.C.: National Science Teachers Association.

Shymansky, James A., and Aldridge, Bill G.
1982 The teacher crisis in secondary school science and mathematics. Educational Leadership (Nov):61-62.

Shymansky, James A., Kyle, William C., Jr., and Alport, Jennifer M.
1983 The effects of new science curricula on student performance. Journal of Research in Science Teaching 20(5):387-404.

Summers, Anita A., and Wolfe, Barbara L.
1977 Do schools make a difference? American Economic Review 67(4):639-652.

U.S. Department of Education
1984 The Nation Responds. Washington, D.C.: U.S. Department of Education.

1985 Indicators of Education Status and Trends. Washington, D.C.: U.S. Department of Education.

U.S. General Accounting Office
1984 New Directions for Federal Programs to Aid Mathematics and Science Teaching. GAO/PEMD-84-5. Washington, D.C.: U.S. General Accounting Office.

Weiss, Iris S.
1978 Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education. Prepared for the National Science Foundation. Supt. of Doc. no. 083-000-0364-0. Available from the U.S. Government Printing Office. Washington, D.C.: National Science Foundation.

Woellner, Elizabeth H.
1983 Requirements for Certification for Elementary Schools, Secondary Schools, Junior Colleges: Teachers, Counselors, Librarians, Administrators. Chicago, Illinois: University of Chicago Press.

NATIONAL RESEARCH COUNCIL

COMMITTEE ON INDICATORS OF PRECOLLEGE SCIENCE AND MATHEMATICS EDUCATION

LYLE V. JONES (Chair), L. L. Thurstone Psychometric Laboratory, University of North Carolina (psychology, statistics)

RICHARD D. ANDERSON, Council of Scientific Societies Presidents, Washington, D.C. (mathematics)

NORMAN M. BRADBURN, Provost, University of Chicago (survey research)

DENIS F. JOHNSTON, Washington, D.C. (statistics, social indicators)

C. THOMAS KERINS, Illinois Office of Education, Springfield (program evaluation and testing)

HAROLD NISSELSON, Westat, Inc., Rockville, Maryland (statistics)

DONALD B. RUBIN, Departments of Statistics and Education, University of Chicago (statistics)

MARSHALL S. SMITH, Wisconsin Center for Education Research, University of Wisconsin (educational research and policy)

MARY L. TENOPYR, AT&T, New York, N.Y. (industrial psychology)

WAYNE W. WELCH, Department of Education, University of Minnesota (educational psychology, science education)

SENTA A. RAIZEN, Study Director