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ABSTRACT

Many reports have pointed to the need to improve the quality of mathematics and science teaching in schools in the United States and to alleviate the shortage of qualified teachers. A policy focus on the teaching force is reinforced by the fact that the ability of the United States to compete in an increasingly technological world economy depends in part on the production of a larger, better, trained scientific workforce, while further educational improvement depends largely on improving the caliber of the teaching force. However, development of appropriate policies for effecting the required changes has been hindered by the lack of data and analyses on the nation's teacher workforce. Without a clear understanding of the scope and qualifications of that workforce, targeted policies are difficult to design and implement. This document reviews the available data on teacher supply, demand, and qualifications, examining both what they reveal about the nature of the mathematics and science teaching force, and how existing data on teacher supply and demand may be better utilized. A list of 70 references is included. (CW)

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A RAND NOTE

Pre-College Science and Mathematics Teachers: Supply, Demand, and Quality

Linda Darling-Hammond, Lisa Hudson

December 1989

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Center for the Study of
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PREFACE

Recent reports have documented inadequacies in the mathematical and scientific understanding of American schoolchildren and insufficient numbers of college students preparing for mathematics- and science-related careers. Imbalances in the supply and qualifications of science and mathematics teachers both contribute to and result from these larger problems: With fewer individuals pursuing post-secondary study in mathematics and science, the supply of qualified mathematics and science teachers is declining. Fewer well-qualified teachers, in turn, limits the range and caliber of educational opportunities available to precollege students. Efforts to improve science and mathematics achievement and participation thus depend to a large degree on the availability of a well-qualified teaching force.

In recognition of these issues, the National Science Foundation asked RAND to review the relevant data on mathematics and science teacher supply, demand, and qualifications. This Note, which was published as a chapter in the 1989 edition of the *Review of Research in Education*, examines the existing data for analyzing these issues, discusses their limitations and potential for answering key policy questions, and describes how data collection and analysis can be improved and expanded.

The Note should be of interest to federal, state, and local researchers and policymakers interested in monitoring the size and sufficiency of the mathematics and science teacher workforce. It should also be useful to state and local educators responsible for teacher preparation and hiring.

The research described in this Note was initially supported by the National Science Foundation. Additional funding was provided by RAND's Center for the Study of the Teaching Profession.

SUMMARY

Recent reports have pointed to the need to improve the quality of mathematics and science teaching in our nation's schools and to alleviate the shortage of qualified teachers. A policy focus on the teaching force is reinforced by the fact that America's ability to compete in an increasingly technological world economy depends in part on the production of a larger, better-trained scientific workforce, while further educational improvement depends largely on improving the caliber of the teaching force.

However, development of appropriate policies for effecting the required changes has been hindered by the lack of data and analyses on the nation's teacher workforce. Without a clear understanding of the scope and qualifications of that workforce, targeted policies are difficult to design and implement. This Note reviews the available data on teacher supply, demand, and qualifications, examining both what they reveal about the nature of the mathematics and science teaching force, and how existing data on teacher supply and quality may be better utilized.

TEACHER SHORTAGES

Recent debates about whether teacher shortages exist have left policymakers unsure of what to believe, and those who would inform them have been unable to present sufficient evidence to resolve the dispute. The problem is twofold. First, there is little consensus on what constitutes useful shortage indicators or on the implications of teacher qualifications. Second, school districts have many alternatives to pursue if they do not have an adequate number of qualified teacher candidates. They may raise the salary offered for difficult-to-fill positions or offer other inducements to candidates; they may enlarge class sizes, increase teachers' course loads, or cancel certain courses; or they may fill positions with teachers with less-than-optimal qualifications. The variety of strategies available suggests the range of indicators needed to ascertain whether a labor market shortage exists.

For many shortage indicators, the source of the data is also important. For example, school districts have little incentive (and some large disincentives) to collect and report information on how many teachers are assigned to teach subjects in which they are not certified. Thus, it is not surprising that teachers' own accounts of their certification status reveal much higher levels of out-of-field teaching than do district reports.

In sum, the form in which shortage data are collected and reported affects how they are later interpreted. While one picture of the supply and demand situation may engender complacency, a closer look may create concern. Additionally, reliance on untested assumptions produces different perspectives on the current situation and different prognoses for the future.

TRENDS IN TEACHER SUPPLY AND DEMAND

Between 1972 and 1985, the number of students graduating with bachelors' degrees in education decreased by more than half. There were only half as many graduates with science education degrees and only one-fourth as many with mathematics education degrees. However, these data provide only a partial indicator of teacher supply, as they ignore those individuals who receive degrees in fields other than education but become certified to teach. One analysis, for example, suggests that in 1979, only 21 percent of the recent college graduates who were eligible to teach mathematics or science actually majored in mathematics or science education. The data also show a decline in this supply source through 1985, but information is not routinely reported by subject-matter field.

Another adjustment to supply estimates must occur at the point of labor-force entry. Only about 50 percent of recent college graduates who are trained to teach are teaching full-time one year after graduation, and entry rates are even lower for those trained in mathematics. (Comparable data are not available for science teachers.) While gross trends in supply are discernible from these data, it is difficult to quantify precisely the magnitude or adequacy of supply.

On the demand side, teacher turnover creates the single largest source of new teacher demand. Measures of teacher turnover, however, have been inconsistent and have been inconsistently applied to demand projections. Based on three different turnover rates estimated from different sources, anywhere from 1 million to 1.5 million new teachers might be needed over a five-year period. Whatever estimate is correct, other evidence suggests that the turnover rate is higher for mathematics and science teachers, particularly in those fields that have a wider range of non-teaching job options.

Data on teacher turnover also do not distinguish between more and less permanent types of turnover. Teachers who leave teaching temporarily constitute one component of the reserve pool; another major component consists of individuals who switch from other fields into teaching at mid-career or after retirement. There are no reliable national-level data on the reentrance of former teachers from the reserve pool or on the entrance of new teachers from sources other than the cohort of recent college graduates. Most perspectives on the ability to avoid teacher shortages are based on untested assumptions about the propensity of these current non-teachers to enter teaching.

TEACHER QUALIFICATIONS

Assessments of whether teacher shortages are severe also rest on judgments about the importance of teacher qualifications in determining supply. However, there is no consensus on the definition of a qualified teacher: As is true for teacher shortages, teacher qualifications must be assessed indirectly and with multiple measures.

Certification status is not a standardized measure, since requirements vary substantially from state to state, and certification rules often differ within states (sometimes in response to teacher shortages). As a measure of qualifications, certification lacks stability over time and may mean different things for different candidates in the same state. However, certification is a useful shortage indicator because states generally allow hiring of uncertified teachers only when shortages exist. While most secondary mathematics and science teachers are certified in the subject areas they teach, estimates diverge across databases. However, it appears that significantly more senior high school than junior high school mathematics and science teachers are certified.

Data on teachers' college majors indicate similar disparities: More senior high school than junior high school teachers have subject-area majors. Also, more science than mathematics teachers have majors in their subject area. However, fewer teachers have college majors in these areas than are certified to teach in them.

Teachers' preparation can also be examined by comparing course-taking data with the recommendations made by the National Council of Teachers of Mathematics and the National Science Teachers Association. This comparison shows that still fewer teachers are able to meet those recommendations.

A final, more subjective, indicator of preparation is the degree to which teachers feel prepared to provide instruction in specific subject areas. Available data show that, in general, the higher the grade taught, the more qualified the teacher feels to teach science. Most elementary teachers feel adequately prepared for teaching mathematics, but they feel particularly unprepared to teach physical sciences.

Comparison of these qualifications indicators shows that how well-prepared teachers appear to be depends on the measure of preparation one chooses. In terms of teachers' own perceptions or their certification status, most mathematics and science teachers appear to be reasonably well-prepared. In terms of college majors or professional standards for content courses, however, they appear to be less well-prepared. A common finding across all indicators is that mathematics and science teachers in the middle school grades are less well-prepared than their counterparts in the upper secondary grades. It is less easy to draw conclusions about elementary teachers, because their preparation and teaching responsibilities are different. Given this variability, the adequacy of teachers' preparation should be addressed using a wide range of indicators over a wide range of teacher types.

RESEARCH NEEDS

Existing data and analyses leave a number of questions unanswered. Key questions concerning teacher supply and demand include:

- What are the major sources of supply for precollege mathematics and science teachers? What proportion of new entrants come from each of the available supply sources?
- What are the turnover rates of mathematics and science teachers in different specialty areas? Where do these teachers go when they leave teaching, and how many subsequently return?
- What is the demand for mathematics and science teachers of different types, and how do demographic and policy factors interact in affecting demand?
- How are teacher qualifications and teaching conditions distributed across schools and students, and how do these factors affect teacher turnover and teaching quality?

Issues concerning teacher preparation include:

- How does teacher preparation vary across types of teachers?
- How do different types of preparation affect teacher effectiveness and retention?
- How does inservice coursework taken during the teaching career supplement initial teacher preparation?

Many of these questions can be partially answered with existing datasets, but others will require special studies and the collection of new data.

New data are needed to address remaining questions such as:

- What teaching practices are related to particular forms of teacher preparation?
- What factors motivate qualified individuals to enter mathematics or science teaching?
- What encourages qualified individuals to remain in or leave teaching?

Only by better understanding how talented mathematics and science teachers acquire their skills and how they react to labor market conditions can we hope to develop appropriate policies for recruiting and retraining a sufficient number of qualified teachers.

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I. INTRODUCTION

BACKGROUND

Recent national reports have pointed to the need for improvement in the quality of mathematics and science teaching in our nation's schools (National Commission on Excellence in Teacher Education, 1985; National Science Board, 1983; National Governors Association, 1986). In addition, there is increasing public concern about shortages of elementary and secondary school teachers, especially those qualified to teach mathematics and science (Shymansky and Aldridge, 1982; National Science Board, 1983; Darling-Hammond, 1984; Carnegie Forum on Education and the Economy, 1986), and about suboptimal adjustments that school districts may make to cope with supply problems, e.g., hiring uncertified teachers, assigning teachers to teach outside their fields of preparation, canceling course offerings, and expanding class sizes.

Although there is evidence that shortages of mathematics and science teachers have existed for most of the past 30 to 40 years (Levin, 1985; Kershaw and McKean, 1962), this problem has received renewed attention because of at least two aspects of the current educational reform movement. First, there is a belief that America's ability to compete in a more technological international economy depends in part on the production of a larger, better-trained scientific workforce, as well as the general education of a more scientifically literate population (National Science Board, 1983; Carnegie Forum on Education and the Economy, 1986). Second, it is increasingly assumed that further improvement in American education will depend largely on the caliber of the teaching force (Carnegie Forum on Education, 1986; Education Commission of the States, 1986; National Governors' Association, 1986). Educators and policymakers have reached substantial consensus that if teachers are not prepared to address the needs of their students and the demands of their subject areas, other reform strategies will fail. These new reform "theories" call for policies that invest in the production of an adequate supply of well-qualified mathematics and science teachers, in contrast to previous approaches, which sought to improve mathematics and science education by developing new curricula, mandating course requirements, or creating new programs.

While focusing policy attention on the character and capacity of the teaching force seems desirable to many, reaching consensus on the size, scope, and nature of problems to be remedied is more problematic. Until quite recently, little data existed that could be analyzed to confirm, refute, or characterize many of the suspected problems. Moreover, little analysis has been performed on the existing data to discern trends in the precollege mathematics and science teaching force. These shortcomings seriously impede the development of sound, targeted policies.

Nonetheless, it is possible to discern what is currently known about the nation's teaching force, and about mathematics and science teachers in particular, by gathering together the available pieces of evidence. This Note attempts to describe what is known and what should be learned about the supply of and demand for mathematics and science teachers, and about their preparation for their teaching assignments. It also examines how new and existing data might be used to address important, unanswered questions about the interrelationships among teacher supply, demand, qualifications, and teaching practices.

THE PROBLEM IN CONTEXT

The terms "scientific illiteracy" and "innumeracy" have recently been coined to describe the American public's ignorance of basic scientific and mathematical facts and the beliefs and attitudes of many about the difficulties and "irrelevance" of these fields. A recent survey by the National Science Foundation (NSF), for example, found that only 6 percent of Americans could be termed "scientifically literate," with reference to their knowledge of the process of science, their identification of scientific concepts and terms, and their understanding of the impact of science on society.

Data on trends in technical occupations support the impression of a population that is ill-prepared to meet the needs of an increasingly technological society. While occupational need in science-related fields has dramatically increased in the past decade, fewer U.S. students have been majoring in science and mathematics, especially at graduate levels (Bloch, 1986). Between 1976 and 1983, science and engineering jobs increased at three times the rate of national employment, while college enrollments in most science areas were declining (National Science Board, 1985; cited in Shavelson, McDonnell, Oakes, and Carey, 1987).

As Table 1 indicates, employment in engineering and the sciences nearly doubled between 1976 and 1986, and employment in computer science increased almost fourfold. But the number of degrees awarded by U.S. universities in the life sciences, physical sciences, and mathematics remained constant or declined during these years. Furthermore, an increasing percentage of these degrees were awarded to foreign nationals, many of whom were returning to their home countries after graduation. Increases in engineering degrees were almost entirely accounted for by foreign students (Commission on Professionals in Science and Technology, 1987).

The picture revealed by the progress of students in elementary and secondary schools is not much more promising. The most recent mathematics assessment from the National Assessment of Educational Progress (NAEP) found that "most students, even at age 17, do not possess the breadth and depth of mathematics proficiency needed for advanced study in secondary school mathematics" (Dossey, Mullis, Lindquist, and Chambers, 1988, p. 10). And the NAEP science assessment indicated that despite recent increases, science achievement scores in 1986 were still lower than they had been in 1970. The authors estimated that "only 7 percent of the nation's 17-year-olds have the prerequisite knowledge and skills thought to be needed to perform well in college-level science courses" (Mullis and Jenkins, 1988, p. 6).

International achievement comparisons are even more discouraging. In the Second International Science Study, U.S. 5th grade students ranked 8th among 17 countries in science achievement, and U.S. 7th grade students ranked 15th. Among 13 countries, the most advanced U.S. 12th graders ranked 9th in physics, 11th in chemistry, and 13th in

Table 1

THE SCIENTIFIC LABOR MARKET: DEGREES AND EMPLOYMENT

Earned Degree/[a] Employment[b]	Computer Sciences	Engineering	Life Sciences	Physical Sciences	Mathematics
Bachelor's					
1975	5,033	39,388	51,741	20,778	18,181
1985	38,878	77,154	38,445	23,732	15,146
(% change)	(+672%)	(+96%)	(-26%)	(+14%)	(-17%)
Master's					
1975	2,299	15,127	6,550	5,807	4,327
1985	7,101	20,926	5,059	5,796	2,882
(% change)	(+209%)	(+38%)	(-23%)	(-0%)	(-33%)
Doctorates					
1975	213	3,106	3,384	3,626	975
1985	248	3,221	3,432	3,403	699
(% change)	(+16%)	(+4%)	(+1%)	(-6%)	(-28%)
Employment[b]					
1976	116,000	1,278,300	198,200	154,900	43,800
1986	437,000	2,243,000	340,500	264,900	103,900
(% change)	(+277%)	(+76%)	(+72%)	(+71%)	(+137%)

[a]National Center for Education Statistics, *The Digest of Education Statistics, 1987*, pp. 190-192.

[b]National Science Board, *Science and Engineering Indicators, 1987*, p. 218.

biology (International Association for the Evaluation of Educational Achievement, 1988). The Second International Mathematics Study presents similar results for the 8th grade and 12th grade students tested on mathematical knowledge. Among 20 countries, 8th grade American students ranked 10th in arithmetic, 12th in algebra, 16th in geometry, and 18th in measurement. Among 15 countries, American 12th grade students ranked 12th in elementary functions/calculus, 12th in geometry, and 14th in advanced algebra (McKnight et al., 1987).

These data do not portend an immediate increase in the number of students interested in pursuing scientific fields in college, graduate school, and later life. And given the projected growth in demand for scientific workers, we can anticipate that many occupations will be competing with each other and with teaching for the dwindling supply of newly trained entrants. The problem is exacerbated by an especially severe decline in the number of college graduates in the standard secondary school subject fields, e.g., mathematics, biology, chemistry, and physics. Given the continuing wage disparities between teaching and other scientific and technical occupations (see Table 2), recruiting teachers from this pool is not a trivial task.

A vicious cycle appears to have been launched: As shortages of mathematics and science teachers have eroded the ability of American schools to adequately prepare large numbers of American students in these subjects, the pipeline of entrants into college-

Table 2

RATIO OF EXPECTED SALARIES OF COLLEGE GRADUATES IN VARIOUS FIELDS TO BEGINNING TEACHERS' SALARIES

Field	1972	1974	1976	1978	1980	1982	1984	1986	1987	1988
Teaching	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Engineering	1.52	1.43	1.54	1.66	1.72	1.86	1.73	1.61	1.55	1.52
Accounting	1.49	1.37	1.36	1.34	1.35	1.39	1.30	1.20	1.21	1.24
Sales/Marketing	1.28	1.22	1.25	1.26	1.36	1.33	1.27	1.17	1.08	1.16
Business Admin.	1.23	1.12	1.13	1.20	1.21	1.33	1.25	1.21	1.18	1.16
Liberal Arts	1.19	1.10	1.10	1.13	1.14	1.25	1.25	1.19	1.10	1.15
Chemistry	1.41	1.27	1.31	1.46	1.47	1.59	1.56	1.37	1.45	1.31
Math or Statistics	1.33	1.33	1.36	1.35	1.51	1.54	1.45	1.36	1.37	1.33
Economics/Finance	1.33	1.26	1.17	1.20	1.24	1.37	1.32	1.26	1.18	1.18
Computer Science	—	1.20	—	1.41	1.52	1.63	1.61	1.48	1.41	1.39
Others	1.33	1.28	1.30	1.38	1.50	1.51	1.49	1.51	1.18	1.34

SOURCE: American Federation of Teachers, *Survey and Analysis of Salary Trends, 1988*, Washington, D.C., July 1988, p. 47.

level study has become inadequate to meet the nation's needs for scientifically trained people. As a consequence, competition for scientifically trained graduates is keen, and schools' needs for well-trained mathematics and science teachers often lose out to the needs of business and industry. When this occurs, the cycle of inadequate preparation leading to inadequate numbers of able and interested potential scientists begins again. The extent to which such a cycle exists or can be analytically examined and portrayed is discussed in the following section.

II. THE TEACHER SHORTAGE DEBATE

Despite the fact that college placement officers have reported shortages of mathematics and science teachers in most states over the past decade (Association for School, College, and University Staffing (ASCUS), 1984, 1986), and there is some evidence that these shortages have existed for several decades (Levin, 1985; Rumberger, 1985), some debate has recently arisen about whether teacher shortages are a "myth" or a reality (Feistritzer, 1986; Hecker, 1986). This debate rests on characterizations of teacher supply that treat location- and field-specific variations very differently, define shortages in disparate ways, rely on different types of indicators, and make widely varying assumptions about human behavior and occupational trends.

The fundamentally different assumptions underlying each side's arguments are discussed below. The issues raised by this discussion are critical for understanding various perspectives on teacher supply and quality, and for placing the available evidence in context.

THE NATURE OF THE ARGUMENT

At least two-thirds of the states have reported shortages of mathematics and science teachers, especially in physics and chemistry, for a number of years (Howe and Gerlovich, 1982; ASCUS, 1986). Other data suggest that many new mathematics and science teachers are not certified to teach in their assigned fields (Shymansky and Aldridge, 1982; NCES, 1983). In what is most often viewed as a policy response to shortages, many states and districts have launched special initiatives to recruit and train mathematics and science teachers, sometimes offering a wide variety of incentives to candidates (Carey, Mittman, and Darling-Hammond, 1988).

The National Center for Education Statistics (NCES), however, has published data that appear to show negligible shortages, and some recent reports (Feistritzer, 1986; Hecker, 1986) have declared that there is no current, or prospective, shortage of teachers. A 1984 General Accounting Office (GAO) report concluded that insufficient data exist to establish the magnitude or severity of teacher shortages in science and mathematics. Policymakers do not know what to believe, and those who would inform them seem to have been unable to muster sufficient convincing evidence to resolve the dispute. While new data will soon be available, important conceptual issues remain.

The problem is twofold. First, there is a lack of agreement on what constitutes a "real" shortage of teachers, because there is little consensus on what measures are useful indicators of shortages and on whether or how qualifications enter the definition of shortage. Evidence of shortages in education is generally indirect, as classrooms do not remain empty when school starts each year. The adjustments schools make when teacher supply is low often render shortages invisible (NAS, 1987).

Second, there is little consensus on how to interpret supply and demand projections, which are based on past trends that may or may not hold in the future. In particular, assumptions about the factors influencing new supply and reentrance into the teacher market from the reserve pool have not been well tested. And until quite recently, data needed to generate key estimates for projection models have not been routinely gathered.

DEFINING SHORTAGE

The term "shortage" is, as the National Academy of Sciences (1987) points out, perhaps the most abused and overused term in the teacher supply-and-demand literature. Although "shortage" can be defined in general terms, measuring the specific factors that contribute to it is difficult. As a result, incomplete or inaccurate indicators are often used to assess teacher shortages.

According to the standard definition, a shortage exists when an inadequate number of persons with the requisite qualifications offer their services for the openings available (Rumberger, 1985). Thus, assessing the extent of the shortage of mathematics and science teachers requires accurate knowledge of the number of openings, the number of individuals willing to apply for those openings, and the qualifications of those willing to apply. Since data on each of these elements—especially the latter two—are typically unavailable, indirect indicators must be used as a proxy for shortages. These indicators, in turn, are limited in their utility for identifying the magnitude, nature, or sources of labor supply problems.

Various indicators of potential shortages, data regarding trends in teacher supply and demand, and factors that should influence projections of mathematics and science teachers are discussed below. Evidence on teacher qualifications is also examined, both as it relates to questions of general preparedness and as an indicator of labor-market shortfalls.

INDICATORS OF SHORTAGES

School districts have many alternatives to pursue if the labor market does not produce enough well-qualified candidates to fill teaching positions. They may raise the salary offered for difficult-to-fill positions or offer other inducements to candidates (e.g., recruitment bonuses, choicer assignments); they may make do with fewer candidates by enlarging class sizes, increasing the number of courses teachers must teach, or canceling certain courses; or they may fill positions with teachers having less-than-optimal qualifications. These teachers may be experienced teachers from other fields, newly hired teachers who lack one or another of the desired qualifications, or short- or long-term substitute teachers intended to fill positions temporarily until qualified candidates can be found.

The variety of strategies available reflects the range of indicators that might be needed to ascertain whether or not a labor-market shortage exists (Haggstrom, Darling-Hammond, and Grissmer, 1988). Each of the possible measures (e.g., salary hikes, changes in class sizes or teaching loads, out-of-field teaching assignments) has its own utility and shortcomings, since a variety of factors could offset or engender changes in any one of them. For example, because all teachers are paid on a single salary schedule, localized shortages of teachers might not result in salary hikes unless they become quite severe or more widely generalized. Similarly, unfilled vacancies could be a signal of poor school-district planning as much as labor-market shortages, while an absence of vacancies might be no cause for complacency if positions are quickly filled with unqualified candidates. Out-of-field assignments of teachers could be used to prevent reductions in force during times of declining enrollments, just as they appear during times of high demand and inadequate supply. Changes in class size or course offerings can reflect budgetary ups and downs and state or local policies as well as labor-market forces. Thus, establishing the existence and nature of a labor-market shortage requires the use of multiple indicators in the context of additional information that allows them to be correctly interpreted.

INTERPRETATION OF SHORTAGE DATA

The most timely and regular data on teacher supply relative to demand by teaching field have come in recent years from ASCUS. These data are based upon an opinion survey of teacher placement officers in institutions of higher education; thus, they do not provide precise or quantifiable information. Nonetheless, they are a useful indicator of perceived employment opportunities for prospective teachers.

Table 3

RELATIVE TEACHER DEMAND, BY TEACHING AREA AND YEAR, IN THE CONTINENTAL UNITED STATES

(5 = greatest demand; 1 = least demand)

Field	1986	1985	1984	1983	1982	1981	1976
Teaching Fields with Considerable Teacher Shortages (5.00–4.25)							
Mathematics	4.55	4.71	4.78	4.75	4.81	4.79	3.86
Science–Physics	4.44	4.57	4.45	4.46	4.41	4.56	4.04
Science–Chemistry	4.40	4.42	4.25	4.30	4.13	4.42	3.72
Bilingual education	4.27	4.12	4.04	3.83	4.13	4.10	—
Special education–Mult. handi.	4.25	3.94	3.77	3.82	3.93	4.13	—
Special education–MR	4.25	3.76	3.55	3.71	3.84	4.14	2.87
Teaching Fields with Some Teacher Shortages (4.24–3.45)							
Special education–LD	4.23	3.95	3.98	4.09	4.20	4.47	4.00
Computer science	4.22	4.37	4.34	—	—	—	—
Special education–ED/PSA	4.20	4.02	3.84	4.08	3.98	4.22	3.42
Speech pathology/audio.	4.09	4.01	3.83	3.62	3.95	4.27	3.68
Data processing	3.97	4.30	4.18	4.36	3.86	—	—
Special education–gifted	3.91	3.85	3.74	3.80	3.81	4.10	3.85
Science–Earth	3.86	3.79	3.70	3.80	3.89	4.08	3.44
Science–General	3.82	3.65	3.65	—	—	—	—
Science–Biology	3.65	3.58	3.40	4.10	3.66	3.98	2.97
Modern language–Spanish	3.64	3.43	3.18	2.77	2.68	2.95	2.47
Special education–reading	3.46	3.39	3.48	3.39	3.73	4.21	3.96

SOURCE: Association for School, College, and University Staff, Tenth Annual Teacher Supply/Demand Survey, January 1986.

The ASCUS surveys from 1976 to 1986 indicate that mathematics and science have been consistently in the group of teaching fields showing "some" to "considerable" teacher shortages (see Table 3). Mathematics has led the list in recent years, followed closely by physics and chemistry. All of these fields showed fairly substantial jumps in their shortage index between 1976 and 1981. Computer science has shown a high and stable level of shortage for the three years in which it has been on the list. Shortage levels are somewhat lower for earth science, general science, and biology, but these too have increased slightly since 1984.

While these survey data are informative, they are limited, due to their qualitative nature. They cannot tell us, for example, how many teachers we need to solve a teacher shortage of "4.55," or how concerned we should be with a shortage index of "3.70." Other sources of quantitative data are clearly necessary to answer such questions, but the remarkable consistency with which mathematics and science have appeared on the surveys over the years strongly suggests labor-market shortages that are tenacious and real, rather than imaginary.

Though the desire to quantify shortages is understandable, this goal can never be completely met. As noted earlier, unfilled positions rarely appear in the data, since a variety of adjustments to schedules, class sizes, and hiring standards are used to meet staffing exigencies (Haggstrom, Darling-Hammond, and Grissmer, 1988). Neither can a count of "supply" be compared to an estimate of "demand" to produce a positive or negative balance. As a National Academy of Sciences panel on teacher supply and demand pointed out, supply and demand are both slippery concepts; they refer to relationships (between districts' and candidates' preferences and a variety of conditions and constraints surrounding hiring), not to numbers. And these conditions may produce imbalances between the numbers of teachers hired and real demand, as well as between both of these and supply (NAS, 1987).

The NCES reports of shortages as measured by unfilled vacancies illustrate the problem of developing valid shortage indicators using quantitative data (i.e., counts of supply relative to demand). Data collected from school district administrators in 1979 and 1983 revealed little evidence of shortages (see Table 4).

In 1983, there were only 1.6 unfilled vacancies per thousand currently employed teachers; the figures were only slightly higher for science and mathematics teachers (1.7 and 1.8 per thousand, respectively). This does not appear to represent a crisis situation. Paradoxically, in 1979, when teacher layoffs were reported—and far exceeded shortages—levels of unfilled vacancies in mathematics and science were much higher.

These data, however, do not reveal a great deal about labor-market shortages. First of all, levels of vacancy are not used as a benchmark for measuring success in filling vacancies. Because the unfilled vacancies are reported *as a proportion of all current teachers*, the data do not reveal the extent to which new teachers were sought or found. Varying demand or hiring rates from year to year are not taken into account; thus the degree to which current posted positions were adequately filled cannot be calculated. Additional calculations from the 1983 data indicate that, *as a proportion of all vacancies*, 19 vacancies per thousand were not filled—a figure that suggests a level of shortage substantially greater than the reported 1.6 per thousand.

A greater vacancy level may also explain why shortages appeared so much larger in 1979, when teacher surpluses and layoffs were generally thought to be widespread: If more hiring occurred during 1979, relatively higher levels of unfilled vacancies would be expected, even if labor-market shortages were not comparatively more pronounced.

Table 4

UNFILLED VACANCIES AND UNCERTIFIED TEACHERS, 1979 AND 1983

	1979		1983	
Teaching Field	Unfilled Vacancies (per 1000 teachers)	Layoffs (per 1000 teachers)	Unfilled Vacancies (per 1000 teachers)	Percent Not Certified
All fields	11,300 (4.4)	23,900 (9.4)	3,965 (1.6)	3.5
Science fields	900 (6.9)	1100 (8.4)	225 (1.7)	4.1
Biology	100 (3.3)	300 (10.0)	49 (1.7)	3.8
Chemistry	NA	NA	27 (1.9)	4.1
Physics	600 (24.0)	100 (4.0)	39 (4.5)	5.6
Other sciences	200[a] (2.6)	700[a] (9.2)	111 (1.4)	4.0
Mathematics	900 (6.0)	1,100 (7.3)	263 (1.8)	4.1

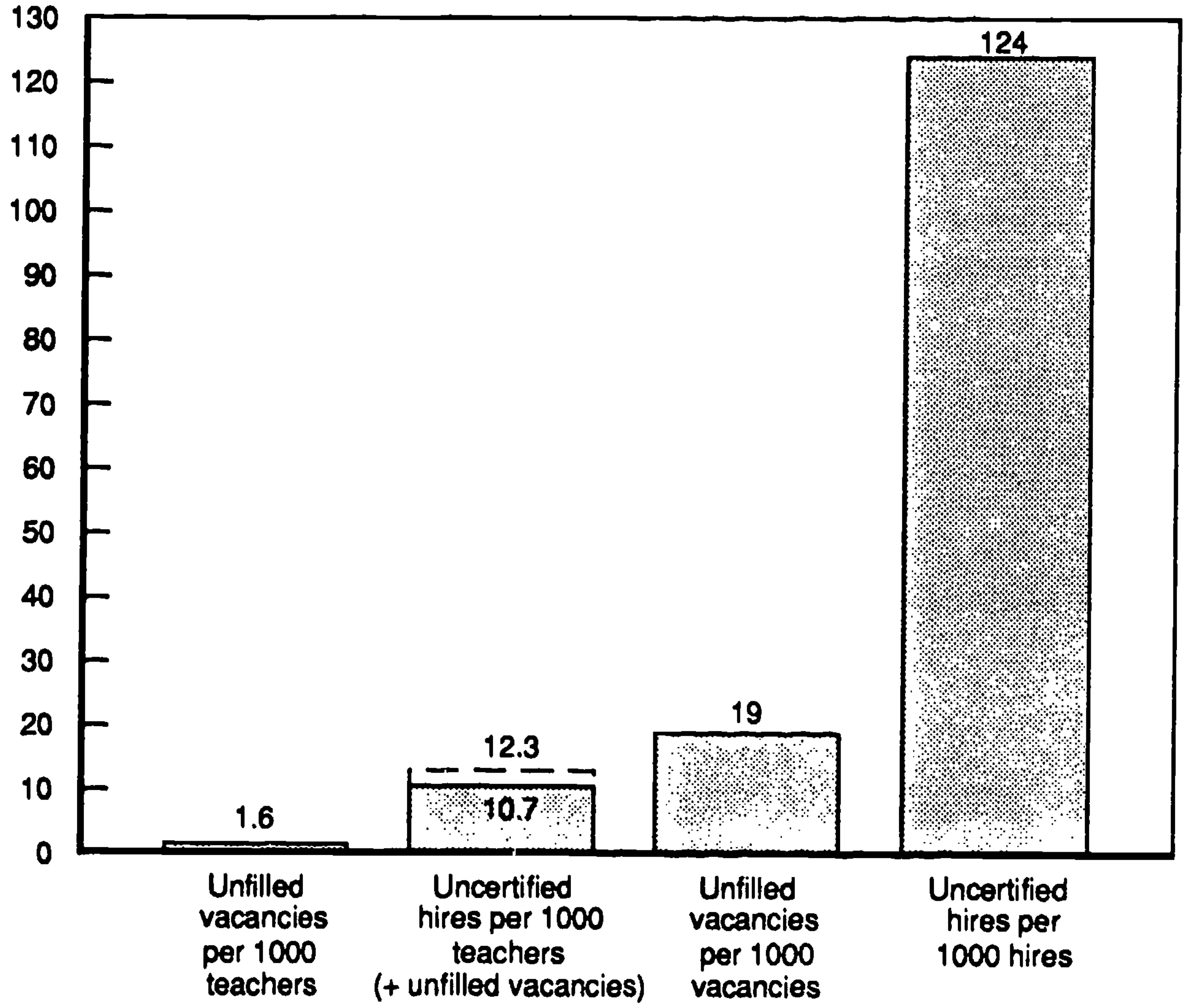
SOURCE: National Center for Education Statistics, "Survey of Teacher Demand and Shortage," 1979 and 1983, reported in *Condition of Education, 1982*, Washington, D.C., 1982, and *Condition of Education, 1985*, Washington, D.C., 1985.

[a]Data are for "general science"; chemistry and other sciences were not reported separately in 1979.

Alternatively, the differences between the two years may be due to the fact that the NCES changed its definition of shortage slightly between the two surveys. Finally, levels of unfilled vacancies really may have been relatively higher in 1979 than in 1983. However, since there were more layoffs than unfilled vacancies for mathematics and science teachers in 1979, the absolute levels of shortage were probably not greater in 1979; rather, labor-market volatility and geographical imbalances may have contributed to a greater disequilibrium between supply and demand.

Another problem with using unfilled vacancies as a proxy for shortages is that leaving vacancies unfilled is generally the last of the many options districts use in response to a labor-market shortage. Combining this shortage indicator with another, such as the percent of new hires who are uncertified, provides a more accurate indication of shortages. Unfortunately, although the NCES reported district officials' estimates of uncertified teachers by field in 1983 (see Table 4), comparable field-specific data on the certification status of new hires were not collected. Thus, while we know that districts counted 3.5 percent of all teachers (and 4.1 percent of all mathematics and science teachers) as uncertified in the field to which they were assigned, the survey did not report how many newly hired mathematics and science teachers were uncertified for their assignments.

Overall, 12.4 percent of newly hired teachers in 1983 were reported as not certified for the field to which they were assigned. If these were added to the counts of unfilled vacancies as evidence of shortage, the number of shortages would skyrocket from 19 per thousand vacancies to over 120 (see Fig. 1). And the estimates would be still higher for mathematics and science, given the larger number of unfilled vacancies and uncertified teachers reported for these fields.



SOURCE: Haggstrom, Darling-Hammond, and Grissmer, (1988).

Fig. 1—Alternative indicators of shortage

Data on uncertified new hires by field *are* available from two other sources: The National Science Teachers Association found in a 1981-82 survey of school principals that half of the newly employed mathematics and science teachers in that year were not certified to teach in their assigned fields (Shymansky and Aldridge, 1982); and a more recent survey of 29 state departments of education by the Council of Chief State School Officers (CCSSO) found somewhat lower but still substantial estimates of the numbers of uncertified newly hired mathematics and science teachers in 1985 (Capper, 1987). As Table 5 shows, these estimates range from a low of 9 percent for biology to highs of 20 percent for physics and 21 percent for earth science. These estimates are higher than those of the NCES but lower than those based on surveys of teachers or principals. The discrepancies are undoubtedly due in part to the particular sample of states responding to the CCSSO survey (which did not include the largest states) and the fact that state departments have less accurate information about out-of-field teaching than do school principals or teachers themselves.

For many shortage indicators, the source of the data is important. School districts have little incentive—and a large disincentive—to collect and report information on how many teachers are assigned in fields for which they are not certified. Favorable certification data enhance a district's reputation with its clientele; moreover, the practice of assigning teachers out of field is illegal in a number of states. Thus, it is not surprising that teachers' own accounts of their certification status reveal much higher levels of out-of-field teaching than do district reports. A 1980-81 NEA survey of teachers indicated that 16 percent of all teachers teach some classes outside their field of preparation, and 9 percent spend most of

Table 5

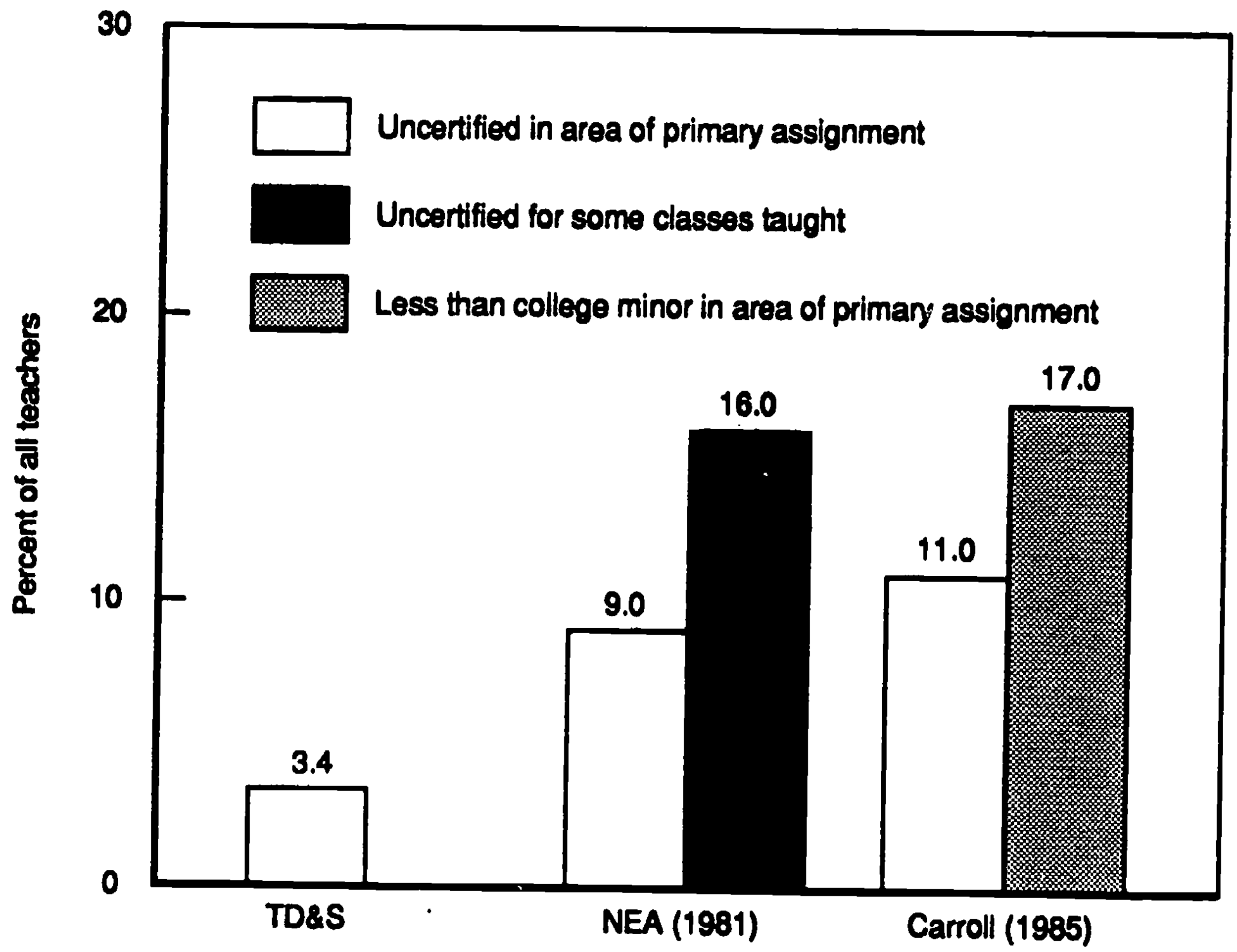
PERCENTAGE OF TEACHERS UNCERTIFIED IN SUBJECT HIRED TO TEACH

Subject	Number of Uncertified New Hires	Percent of Uncertified New Hires	Percent of Uncertified Teachers
Biology	90	9	6
Chemistry	63	13	10
Earth Science	76	21	17
General Science	184	16	18
Physics	60	20	15
Mathematics	478	12	8

SOURCE: Joanne Capper, *A Study of Certified Teacher Availability in the States*, Council of Chief State School Officers, Washington, D.C., February, 1987.

their time teaching out-of-field (NEA, 1981). The High School and Beyond (HSB) special survey of 10,000 teachers indicated that 11 percent of high school teachers teach primarily outside their area of state certification and 17 percent have less than a college minor in the field they most frequently teach (Carroll, 1985) (see Fig. 2).

These examples demonstrate that the form in which data are collected and reported affects the way they are later interpreted. While one picture of the supply and demand situation may engender complacency, a closer look may indicate cause for concern. Additionally, reliance on untested assumptions about supply and demand trends produces different perspectives on the current situation and different prognoses for the future.



SOURCE: Haggstrom, Darling-Hammond, and Grissmer (1988).

Fig. 2—Alternative indicators of misassignment

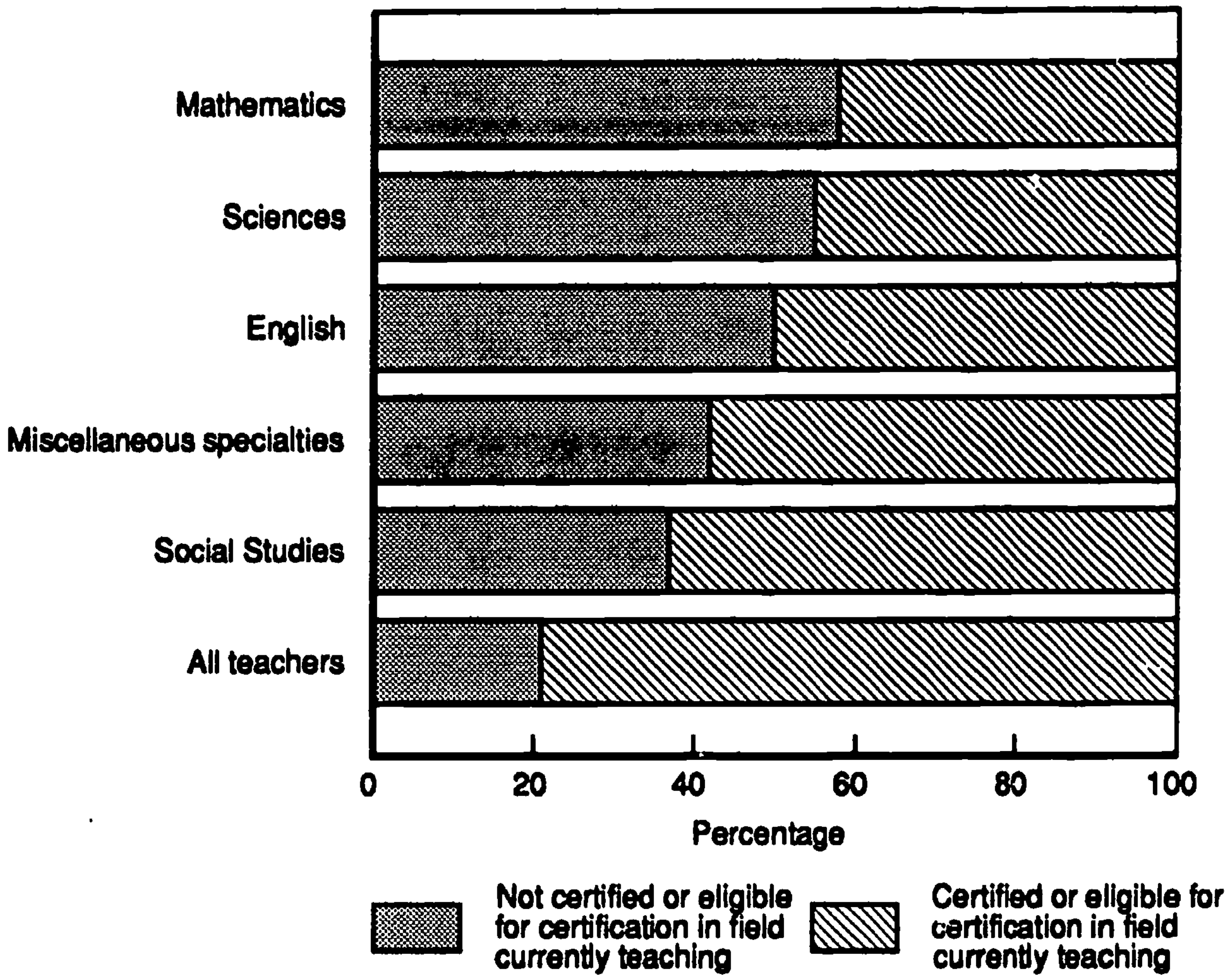
TRENDS IN TEACHER SUPPLY

From the 1970s through the mid-1980s, the supply of newly prepared entrants into teaching—especially mathematics and science teaching—declined sharply. The most reliable information on trends in teacher supply comes from the data on earned degrees collected by the NCES. These data show that between 1972 and 1985 the number of students graduating with four- or five-year bachelor's degrees in education dropped by more than half, from 194,229 to 88,161 (NCES, 1987). Graduates with degrees in mathematics education dropped from 2,217 to 629 between 1971 and 1982, and graduates in science education dropped from 891 to 558 (NCES, 1982, 1986).

Since then, increased demand, coupled with salary hikes and recruitment incentives, has boosted enrollments in mathematics and science education programs. In 1985-86, a total of 1,259 degrees were earned in mathematics education—a fair increase, but still well below levels of a decade earlier. Earned degrees in science education rose to 1,052 (NCES, 1988).

These data are only a partial indicator of teacher supply, since they do not take account of the students who receive degrees in other fields but become certified to teach. Unfortunately, the only source of national data on this pool of potential teachers—the Center for Statistics' Recent College Graduates Surveys (RCGS)—does not routinely report information by subject-matter field. One analysis of these data, though, suggests that of the 1979-80 college graduates who reported that they were certified or eligible for certification in mathematics and science, only 21 percent actually majored in mathematics or science education (Rumberger, 1985). This would suggest that the actual numbers of recent graduates prepared to teach might exceed the estimates of supply indicated by the earned-degrees data by as much as 400 percent.

Nonetheless, the RCGS survey data show that fewer than half of those newly hired to teach mathematics or science full-time in 1981 were certified or certifiable in these fields (see Fig. 3). This is probably partly because demand exceeded even the more generous estimate of available supply and partly because many newly prepared teachers do not go on to teach. Time-series data from the RCGS show that, of a declining pool of graduates prepared to teach between 1978 and 1985, only about 60 percent were teaching full- or part-time a year after graduation (see Table 6). The proportion teaching full-time was about 50 percent in each of these years. NCES data for mathematics teachers in 1978 and 1981 show that these prospective teachers were less likely than others to seek a teaching job after graduation or to be teaching. Sample sizes were too small to provide comparable data for science teachers.



SOURCE: Darling-Hammond (1984).

Fig. 3—Qualifications of new teachers for the field they are currently teaching: 1981

Table 6

ELEMENTARY/SECONDARY TEACHING STATUS OF RECENT BACHELOR'S DEGREE RECIPIENTS NEWLY QUALIFIED TO TEACH

Teaching Status	1978	1981	1985
Recent bachelor's degree recipients			
newly qualified to teach	171,100	132,200	98,658
(Mathematics)	4,800	4,900	NA
Percent applying to teach	77	85	74
(Mathematics)	(78)	(73)	NA
Percent teaching full- or part-time	60	64	58
(Mathematics)	(58)	(59)	NA

SOURCE: National Center for Education Statistics, *The Condition of Education, 1983*; unpublished tabulations from the *Survey of Recent College Graduates, 1985*, National Center for Education Statistics.

That qualified mathematics and science teachers might be less likely than other candidates to enter teaching is not surprising, since the wage discrepancies between teaching and alternative careers are much greater in these fields than others. Yet, like candidates in other fields, mathematics and science graduates seem to be responding to the recent large wage hikes in teaching. Enrollments in mathematics and science education programs began to increase after states and local districts had taken actions that raised teacher salaries by 40 percent between 1981 and 1986 (Darling-Hammond and Berry, 1988).

We noted earlier that real wage hikes are one of the most useful economic indicators of a tight labor market. This appears to have been the case in teaching in recent years. However, increases in teacher salaries began to flatten out in 1989 without closing the wage gaps with other occupations, so the extent to which supply will increase to meet demand is still a major question.

TRENDS IN TEACHER DEMAND

According to NCES projections, overall demand for teachers will rise through most of the coming decade as enrollments grow and teacher retirements increase (see Table 7). If demand for mathematics and science teachers remains a constant share of overall demand during these years, an estimated 20,000 teachers will be needed annually over much of the next decade (Carey, Mittman, and Darling-Hammond, 1988). As a very rough point of comparison, if the pool of newly prepared entrants is assumed to comprise five times the number of mathematics and science education graduates, the current "new supply" would amount to approximately 11,000 annually. Though these very rough estimates suggest a gap, we cannot rush to a judgment about whether shortages will exist and how large they might be.

Assumptions about teacher turnover rates and the size of the reserve pool of prospective teachers have produced contradictory views of teacher supply and shortages. Ultimately, whether the number of new entrants to teaching will be adequate in any given year or period of years is largely a function of teacher turnover, on the demand side, and how many additional entrants from the reserve pool are available to fill those positions, on the supply side. At present, we have little data with which to assess either of these major factors.

As Table 7 shows, teacher turnover is the single largest cause for new teacher demand. Measures of teacher turnover, however, have been inconsistent, and they have been inconsistently applied to demand projections. Until 1989, the NCES used an annual turnover rate of 6 percent, based on a downward adjustment made to the 8 percent turnover

Table 7

PRO.;ECTED DEMAND FOR NEW HIRING OF CLASSROOM TEACHERS IN PUBLIC ELEMENTARY AND SECONDARY SCHOOLS IN 50 STATES AND D.C., FALL 1988 TO FALL 1997

		Demand for New-Hire Teachers			
			Due to		
Year	Total Teachers	Total	Turnover	Enrollment Changes	Other Factors
1988	2,313	155	118	–1	38
1989	2,333	140	120	–1	21
1990	2,355	143	121	21	2
1991	2,381	149	122	32	–5
1992	2,419	161	124	35	2
1993	2,459	166	126	35	5
1994	2,500	169	128	37	4
1995	2,544	174	130	28	16
1996	2,585	174	132	22	20
1997	2,622	171	134	13	24

SOURCE: National Center for Education Statistics, *Projections of Education Statistics to 1997-98*, 1988.

rate estimated in 1969. Using these old data, the NCES projected that the nation will need to hire about 1,080,000 new teachers between 1987 and 1992 (NCES, 1985). However, more recent data from the Census Bureau's Current Population Surveys placed the teacher turnover rate in 1984 at slightly more than 9 percent. If this estimate is correct, more than 1.5 million new teachers will be needed over this period. On the other hand, the most recent NCES projections use rates developed by the Bureau of Labor Statistics, which estimated elementary teacher turnover in 1983-84 at 4.9 percent, and secondary teacher turnover at 5.6 percent. These estimates yield a demand in 1987-92 of about 1 million. Since attrition was at a historic low in 1983 due to a preponderance of mid-career teachers in the teaching force, this figure will undoubtedly increase with pending retirements (Grissmer and Kirby, 1987). The disparities in these estimates and projections indicate serious problems in both the measurement of teacher turnover and the use of available measures in projection models (NAS, 1987; Haggstrom, Darling-Hammond, and Grissmer, 1988).

Whatever estimate one uses for overall teacher turnover, the same figure is not applicable to mathematics and science teachers. Teachers in these subject areas tend to have a wider range of non-teaching job options, most of which pay much better than teaching, so they are more likely to leave teaching. For example, Murnane and Olsen (forthcoming (a,b)) found that physics and chemistry teachers in Michigan and in North Carolina leave teaching sooner than teachers of other subjects.

Data on teacher turnover must also distinguish between more and less permanent types of turnover (e.g., retirement versus temporary leaves of . :nce). Teachers who leave temporarily constitute one major component of the reserve pool. The other major component consists of individuals who are switching from other fields into teaching at mid-career or after retirement. There are no reliable national-level data on the reentrance rates of former teachers from the reserve pool, and only a few small studies of field-switching into education (see Darling-Hammond, Hudson, and Kirby, 1989). Most of the conclusions made about the prospects of shortages are based on untested assumptions about the propensity of these current non-teachers to enter the teaching workforce.

Feistritzer (1986) and Hecker (1986) have expressed doubt that shortages exist or are imminent, but these conclusions are based on unfounded assumptions about reserve pool availability. Feistritzer assumes that all of the individuals certified to teach since 1970 but not currently teaching are available members of the reserve pool. Hecker assumes—without supporting data—that greater openings and current education reforms will produce sufficient newly trained entrants and returnees from the reserve pool to fill the demand gap.

While the plausibility of these assumptions may be increased by new initiatives to increase the supply of mathematics and science teachers (see Carey, Mittman, and Darling-Hammond, 1988), existing data do not support the view that large numbers of individuals in the scientific and technical labor force will leave their jobs to enter elementary or secondary school teaching. The National Science Foundation (NSF) Longitudinal Surveys of Scientists and Engineers, for example, show that of the 21,423 respondents employed in scientific and technical occupations in 1970, no more than 121 (about 0.5 percent) ever switched to jobs in precollege teaching during the decade. And most of those who switched did not stay in teaching for more than 1 or 2 years. Of the 1980 sample of scientific and technical workers, less than 0.2 percent entered precollege teaching in 1982 or 1984 (Darling-Hammond, Hudson, and Kirby, 1989).

Assumptions about turnover rates and reserve pool availability are key to any assessment of whether shortages will continue. Assessments of the severity of current shortages rest on judgments about the importance of teacher qualifications as a measure of supply. However, there is no consensus on the definition of a qualified teacher, and some measures of supply and shortage ignore teacher qualifications altogether. With changes in certification and hiring standards, the supply of teachers can be altered at will so that, based on body counts at least, supply can always equal demand. Essentially, the competing claims about teacher shortages are arguments over the degree to which qualifications are an important indicator of supply.

In the following sections, we examine the available data on the qualifications of mathematics and science teachers and identify additional studies that would be needed to resolve the debate over teacher shortages.

III. TEACHER PREPARATION

Teachers' qualifications are typically defined only by reference to certification status; thus the definition varies substantially from state to state. Part of the reason for this inconsistency is the lack of agreement about what teachers need to know in order to teach well. The complexity and scope of instructional practice make this determination difficult. A teacher must understand not only the content of the material to be taught, but also how to best deliver this instruction, how to modify and adapt instructional practice to individual student needs, and how to diagnose and evaluate those needs. Further, education has multiple, and frequently changing, instructional goals. For example, many of the "direct instruction" behaviors that seem to increase achievement in standardized tests of rudimentary skills are dissimilar, indeed nearly opposite, from those "indirect" teaching activities that seem to increase complex cognitive learning, problem-solving ability, and creativity (McKeachie and Kulik, 1975; Peterson, 1979; Soar, 1977; Soar and Soar, 1976). Moreover, desirable affective outcomes of education—independence, curiosity, and positive attitudes toward school, teacher, and self—seem to result from teaching behaviors that are different from those prescribed for increasing student achievement on standardized tests (Horwitz, 1979; McKeachie and Kulick, 1975; Peterson, 1979; Traub et al., 1973). Teachers also handle multiple clients simultaneously, and these clients typically benefit in different ways from different types and levels of instruction. For example, a student-structured approach to teaching and learning has been found to improve males' attitudes toward science, while females' attitudes seem to be enhanced by a teacher-structured approach (Abhyankar, 1977). In the face of these complexities, both new and experienced teachers note the importance of methods courses that link theory to practice, "internship" opportunities, and training in understanding student motivation and behavior to effective performance in the classroom (Darling-Hammond, Hudson, and Kirby, 1989).

In sum, teaching is a highly complex activity requiring extensive knowledge and a wide repertoire of skills, flexibility, versatility, and commitment. One might expect that to effectively engage in such an activity would require substantial formal preparation.

A variety of teacher preparation and qualification measures have been examined to ascertain their relationship to student learning. These include teachers' years of education, recency of educational enrichment, years of teaching experience, and subject-matter knowledge (e.g., Andrews, Blackman, & McKey, 1980; Ayers and Qualls, 1979; Druva and

Anderson, 1983; Murnane and Phillips, 1981; Penick and Yager, 1983; Summers and Wolfe, 1975). These analyses have had equivocal results, however, primarily because of (1) an inability to specify the effects of the many variables that mediate between teacher preparation and student performance, and (2) the lack of student-attainment measures that reflect a wide range of content and modes of performance. Under these conditions, measures of association are likely to be weak if they appear at all; thus, we should be encouraged by *any* detectable relationships in the existing research literature.

In general, effective teaching requires knowledge of what to teach (subject matter) and knowledge of how to teach (teaching methods). There is some support for the assumption that a teacher with better subject-matter knowledge is a better teacher, although the findings are not always strong or consistent. Studies of teachers' scores on the National Teacher Examinations have found no consistent relationship between subject-matter knowledge and teacher performance, as measured by either student outcomes or supervisory ratings (Andrews, Blackmon, and Mackey, 1980; Ayers and Qualls, 1979; Quirk, Witten, and Weinberg, 1973; Summers and Wolfe, 1975). However, Byrne (1983) summarized the results of 30 studies relating teachers' subject knowledge to student achievement and found that 17 studies showed a positive relationship. And many of those showing no relationship had such little variability in the teacher knowledge measure that insignificant findings were almost inevitable.

Comparisons of teachers having degrees in education with those having subject-matter degrees often show no relation between the type of degree held and teacher performance. This may result from certification standards that result in teachers with different degrees having very similar backgrounds (Murnane, 1985). However, Druva and Anderson (1983), in a meta-analytic study of teacher characteristics and behaviors, found consistently positive relationships between student achievement in science and teacher background in education, biology (for biology teachers), and science. Also, Casserly found that girls perform relatively better in mathematics when taught by teachers with a background in science, mathematics, or engineering (cited in Kolata, 1980).

Teachers' pedagogical skill may interact with subject-matter knowledge to bolster or reduce teacher performance. Glaser's (1983) work suggests that *how* one teaches mathematics or science (i.e., knowing how to teach problem-solving, reasoning from evidence, checking one's procedures, and checking for understanding) is as important as *what* one teaches. Also, Begle (1979) found, from the National Longitudinal Study of Mathematical Abilities, that the aspect of preparation that had the greatest effect on student performance was the number of credits a teacher had taken in mathematics *methods* courses.

Teachers' educational level and recency of educational enrichment have also been used as proxy measures for teacher knowledge. Penick and Yager (1983) found that teachers in exemplary science programs not only had more years of education, but also had more recent educational experiences than the average science teacher. Hanushek (1970) found that the recency of *voluntary* educational experience is also related to teacher performance. These findings suggest that not only is the knowledge acquired with a higher degree important, the enthusiasm for learning that leads the teacher to *seek* new knowledge is also a major factor in teacher performance (Murnane, 1985).

In sum, the kinds of teacher knowledge that seem to promote student learning include pedagogical as well as subject-matter knowledge, and particular benefits appear to result from continuing coursework or inservice training.

HOW WELL PREPARED ARE MATHEMATICS AND SCIENCE TEACHERS?

Like teacher shortages, teachers' qualifications can be assessed only indirectly, because no absolute measures of qualification or preparation exist. Current databases provide some potential indicators of teachers' preparation, including certification status, college major, courses taken, and teachers' own perceptions of their qualifications. These indicators are derived from the following recent national surveys of teachers:

- High School and Beyond (HSB): A supplemental survey of 11,000 public and private secondary school teachers drawn from HSB sample schools, conducted in 1984.
- National Survey of Science and Mathematics Education (NSSME): A survey of 1,383 elementary teachers, 1,239 secondary mathematics teachers, and 1,708 secondary science teachers, all in public or private schools, conducted in 1985-86.
- National Assessment of Educational Progress (NAEP) Science Assessment: A survey of 774 3rd grade teachers, 325 7th grade science teachers, and 289 11th grade science teachers in public and private schools, conducted in 1986.

In addition, transcript analyses of college graduates in the Southern Regional Education Board (SREB) states provide detailed information on the coursework background of the pool of teacher candidates in one region of the country.

CERTIFICATION

Most state governments require that all public school teachers be certified before they enter the classroom. In practice, individuals who do not fully meet certification requirements are often hired when qualified applicants are unavailable, to minimize the cancellation of courses or unacceptable increases in class sizes, alternatives that are typically viewed as even less desirable than the hiring of marginally qualified teachers. Because schools must usually hire certified candidates when they are available, the proportion of uncertified teachers hired provides an informal measure of labor-market shortages.

Certification has a number of advantages as an indicator of teacher preparation or qualification. First, certification statistics are relatively easy to collect, at least in comparison with measures such as college coursework and grades (which are more susceptible to errors in recall and reporting biases, or which must be obtained through the difficult and expensive procedure of transcript analysis). Also, certification standards are a richer indicator of preparation than, for example, coursework counts, since they typically rely on a number of relevant domains of knowledge (e.g., basic-skills knowledge, subject-matter knowledge, pedagogical knowledge, student-teaching experience).

The primary disadvantage of certification status as an indicator is that certification standards are highly variable. In years of shortage, states often permit hiring under "provisional" or "alternative" certification (Darling-Hammond and Berry, 1988). And the meaning of certification status varies substantially from one state to another, limiting cross-state comparisons. Finally, practicing teachers are usually grandfathered into full certification when standards are raised for entering teachers. This also limits comparability, since two teachers within a single state with the same certification status may have met very different preparation requirements.

Problems in comparability are evident in the data from the three national surveys that collect and report information on teacher certification (see Table 8). While most secondary mathematics and science teachers are certified in the subject areas they teach, estimates diverge across databases and by level and field. It appears, however, that significantly more senior high school than junior high school science and mathematics teachers are certified. Roughly 80 to 90 percent of high school teachers are reported to be certified for their subjects, as compared with 65 to 75 percent of junior high school teachers. The worst-case estimate appears in the NAEP Science Assessment, which finds that 37 percent of 7th grade students are taught by teachers who are not certified in science. The best-case estimate, from the HSB survey, shows 91 percent of senior high mathematics teachers certified.

Probably neither of these extremes paints an entirely accurate picture. Many 7th grade science teachers may have received full certification in K-8 elementary education when that was the normal area of licensure. On the other hand, the high school mathematics teachers responding to the HSB survey were those whose *primary teaching assignment* is mathematics. Many out-of-field teachers teach only one or two courses of the subject for which they are less well-qualified. Those for whom mathematics or science was a secondary assignment area would not have responded to this question.

The data in Table 8 represent teachers who have regular, provisional, alternative, or in some cases, emergency certification in mathematics or science. Most surveys include a *separate* item that asks what kind of certification the teacher has without specifying the subject area of the certificate, thus obviating analysis of certification type by field taught. Since the definitions of certification types are highly variable, such an analysis would not permit comparisons in any event. "Provisional" certification, for example, is equivalent to emergency certification in some states, but in others, it is equivalent to full certification for a beginning teacher (who does not become "fully" certified until he or she completes a year or more of regular classroom teaching). In some states, alternative routes lead to full certification, while in others they do not.

Table 8

PERCENTAGE OF SECONDARY LEVEL MATHEMATICS OR SCIENCE TEACHERS WHO ARE CERTIFIED FOR THE COURSES THEY TEACH

Survey	Percent of Mathematics Teachers	Percent of Science Teachers
High School and Beyond[a]	91	87
NSSME: Grades 7–9[b]	65	76
NSSME: Grades 10–12	85	91
NAEP Science: Grade 7[c]	—	63
NAEP Science: Grade 11	—	80

SOURCES: *High School and Beyond Tabulation: Background Characteristics of High School Teachers* (Carroll, 1985); *Report of the 1985-86 National Survey of Science and Mathematics Education* (Weiss, 1987, figures adjusted for nonresponse); *The Science Report Card: Elements of Risk and Recovery* (Mullis and Jenkins, 1988).

[a]These data represent the percent of teachers with mathematics or science as their primary teaching assignment who are certified for the courses they teach.

[b]These data represent the percent of mathematics or science teachers who are certified in those fields.

[c]These data represent the percent of students taught mathematics or science by teachers certified in those fields.

COLLEGE MAJOR

Most measures of teacher preparation focus on teachers' subject-area knowledge. This focus addresses not only the college courses prospective teachers choose to take, but also the out-of-field assignment of teachers when qualified candidates are unavailable.

One general measure of subject-area knowledge is a teacher's college major. There is a growing belief that secondary teachers should have a major (or its equivalent) in the subject they teach. Some states have had such a requirement for many years, and many teacher education reform proposals have recommended it, which has led to its recent adoption in several states.

This indicator has important policy relevance, but it also has some limitations. First, teachers who did not major in a subject field may nonetheless have taken as much coursework in the area as those who did receive a major. Second, a subject-area major (as opposed to a specialized education major) addresses only one part of the preparation issue. It does not address how well prepared the teacher is to translate subject knowledge into instruction that is appropriate, informative, and interesting to students.

The one national survey that includes data on college major, the NSSME, reports both the proportion of teachers who majored in mathematics or science and the proportion who majored in mathematics or science education (see Table 9).

As in the case of certification, a greater degree of preparation is found among senior high school teachers than among middle or junior high school teachers. For example, 84 percent of senior high school science teachers majored in science or science education, compared with only 68 percent of junior high school science teachers. Also, although mathematics teachers appear to be more likely than science teachers to have a subject-specific education major, they appear to be less likely than science majors to have either a subject-area major or a subject-area major combined with an education major.

COLLEGE COURSEWORK

Another measure of teachers' academic preparation is the number of courses they have taken in relevant subject areas. The available analyses tend to concentrate on subject-area coursework, with only the NSSME reporting data on teachers' education coursework. According to the HSB data, secondary mathematics teachers have generally taken fewer courses in their subject area than either science teachers or teachers in other fields (see Table 10). The data indicate that science teachers take the most courses in their discipline—89 percent of them have taken at least seven courses in their subject area. This compares with 81 percent of mathematics teachers and 83 percent of other area teachers.

Table 9

PERCENTAGE OF TEACHERS WITH MAJOR IN GIVEN FIELD (NSSME)

Major	Grades 7–9	Grades 10–12
Mathematics teachers		
Mathematics	30	52
Mathematics education	18	24
Either or both majors	48	76
Science teachers		
Science	59	76
Science education	9	8
Either or both majors	68	84

SOURCE: Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education*, 1987.

Table 10

PERCENTAGE OF TEACHERS WHO HAVE TAKEN A GIVEN NUMBER OF COLLEGE COURSES IN THEIR PRIMARY ASSIGNMENT FIELD

Primary Assignment Field	Number of Subject-Area Courses			
	0	1–6	7–12	13+
Mathematics	1	18	27	54
Science	1	10	30	59
All other areas	2	15	22	61

SOURCE: Carroll, *High School and Beyond Tabulation: Background Characteristics of High School Teachers*, 1985.

The NSSME provides the most detailed information on teachers' subject-area and pedagogical preparation. Weiss (1987, 1988) examined these data separately for elementary teachers, junior high school mathematics and science teachers, and senior high school mathematics and science teachers. Transcript data on 6,000 graduates at 17 major universities in states belonging to the SREB also provide detailed coursework data on *prospective* mathematics and science teachers (i.e., graduates meeting all teacher certification requirements in their state) (Galambos, 1985; Galambos, Cornett, and Spitler, 1985). Although the SREB data do not necessarily reflect the course backgrounds of practicing teachers, they do provide insight into teacher preparation in one region of the country.

In the following, the coursework findings from the NSSME and the SREB studies are compared with the recommendations for certification of the two professional teacher organizations that have developed coursework standards for mathematics and science teachers—the National Council of Teachers of Mathematics (NCTM) and the National Science Teachers Association (NSTA).

The NSTA guidelines for K-12 science teachers (see Table 11) are designed as the core requirement for a national certification program. This program is intended, among other things, to identify the most highly qualified science teachers for advancement opportunities within the teaching profession. An important feature of the NSTA program is that dual certification is recommended for secondary-level teachers. This recommendation stems from the NSTA research finding that most secondary-level science teachers have assignments in more than one area of science: 65 percent of physics teachers' assignments, 52 percent of chemistry teachers' assignments, and 37 percent of biology teachers' assignments are in other areas (predominantly other sciences) (Aldridge, 1986).

The NCTM established a set of revised guidelines for the preparation of mathematics teachers in 1981. The guidelines "present the minimal standards for programs for the preparation of teachers of mathematics," as well as a "minimal list of competencies that . . . teachers in mathematics should meet" (NCTM, 1981, p. v). The courses recommended for teachers of mathematics are listed in Table 12.

Science Teachers

The NSTA recommends that elementary teachers have a minimum of 12 semester hours of science, including one course each in biological science, physical science, and earth science, plus a science methods course. The SREB and Weiss studies found that elementary teachers (and prospective elementary teachers) do take an average of 12 science course credits. However, they tend to concentrate heavily in the biological and life sciences, with far fewer courses in the physical and earth sciences. Thus, only 34 percent of all elementary teachers meet the full course standards. More specifically, 85 percent of all elementary teachers meet the biology course requirement and 72 percent meet the physical science standard, but only 53 percent meet the earth science standard. Further, while most elementary teachers have taken an elementary science methods class, over 10 percent have *not* taken such a course.

Table 11

NATIONAL SCIENCE TEACHERS ASSOCIATION STANDARDS

ELEMENTARY LEVEL

1. Minimum 12 semester hours in laboratory or field-oriented science, including courses in biological, physical, and earth sciences. Course content should be applicable to elementary classrooms.
2. Minimum of one course in elementary science methods.
3. Field experence in teaching science to elementary students.

MIDDLE/JUNIOR HIGH SCHOOL LEVEL

1. Minimum 36 semester hours of science with at least 9 hours in each of biological science, physical science, and earth/space science. Remaining 9 hours should be science electives.
2. Minimum of 9 semester hours of mathematics and computer science.
3. A science methods course designed for the middle school level.
4. Observation and field experience with early adolescent science classes.

SECONDARY LEVEL

General Standards for all Science Specialization Areas

1. Minimum 50 semester hours in one or more sciences, plus study in mathematics, statistics, and computer applications.
2. 3–5 semester hour course in science methods and curriculum.
3. Field experiences in secondary science classrooms at more than one grade level or more than one science area.

Specialized Standards

1. Biology: minimum 32 semester hours of biology plus 16 semester hours in other sciences.
2. Chemistry: minimum 32 semester hours of chemistry plus 16 semester hours in other sciences.
3. Earth/space science: minimum 32 semester hours of earth/space science, specializing in one area plus 16 semester hours in other sciences.
4. General science: eight semester hours each in biology, chemistry, physics, and earth/space science, and applications to society. Twelve hours in one area, plus mathematics to at least the precalculus level.
5. Physical science: 24 semester hours in chemistry and physics and applications to society, plus 24 semester hours in earth/space science; also an introductory biology course.
6. Physics: 32 semester hours in physics plus 16 in other sciences.

Table 12

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS GUIDELINES

EARLY ELEMENTARY SCHOOL

The following three courses, *each of which presumes a prerequisite of two years of high school algebra and one year of geometry.*

1. number systems
2. informal geometry
3. mathematics teaching methods

UPPER ELEMENTARY AND MIDDLE SCHOOLS

The following four courses, *each of which presumes a prerequisite of two years of high school algebra and one year of geometry.*

1. number systems
2. informal geometry
3. topics in mathematics (including real number system, probability and statistics, coordinate geometry, and number theory)
4. mathematics methods

JUNIOR HIGH SCHOOL

The following seven courses, *each presuming a prerequisite of 3–4 years of high school mathematics, beginning with algebra and including trigonometry.*

1. calculus
2. geometry
3. computer science
4. abstract algebra
5. mathematics applications
6. probability and statistics
7. mathematics methods

SENIOR HIGH SCHOOL

The following 13 courses, which constitute an undergraduate major in mathematics, *each presuming a prerequisite of 3–4 years of high school mathematics, beginning with algebra and including trigonometry.*

1–3. three semesters of calculus
4. computer science
5–6. linear and abstract algebra (one course in each)
7. geometry
8. probability and statistics
9–12. one course each in: mathematics methods, mathematics applications, selected topics, and the history of mathematics
13. at least one additional mathematics elective course

The NSTA recommends that middle-school-level teachers take 36 semester hours in the three science areas (12 hours in each area), a science methods course, and at least 9 semester hours in mathematics and computer science. For secondary-level teachers, the NSTA recommends a minimum of 50 semester hours in science. The SREB study reveals that prospective secondary-level science teachers take an average of 49.4 hours of science courses, roughly comparable the NSTA recommendation, but that only 31 percent of this coursework is at the upper level.

Weiss (1988) examined data on teachers of grades 7 through 9. Sixty-seven percent of those studied met the NSTA standards for the overall number of science courses, but only 22 percent met the standards for the number of courses in each area. Those teaching earth science were the least well-prepared. While only 10 percent of biology teachers and 10 percent of physical science teachers had taken fewer than three courses in the *specific* science subject they teach, 52 percent of earth science teachers had taken fewer than three earth science courses and 22 percent had taken no college courses in earth science. About 20 percent of the sample lacked a science methods course, and two-thirds lacked a computer programming course.

A similar pattern emerged in the data on secondary-level (grades 10 through 12) teachers. Only 56 percent of these teachers met the NSTA standard of at least 50 semester hours in the sciences (based on an assumed 3.5 semester hours per course). The NSTA standards also recommend that secondary science teachers take at least 32 semester hours in their specialty area. In the NSSME analyses, "specialty areas" cannot be determined, as teachers were categorized by whether they taught a specific subject or not, rather than by specialty area. Using this classification, the survey found that 59 percent of science teachers teach biology, 33 percent teach chemistry, and 24 percent teach physics. If we examine the degree to which these teachers meet the NSTA standards, we can determine how often actual science teaching assignments in each area are filled by teachers who meet the NSTA "specialist" criteria. Table 13 presents these proportions for biology, chemistry, and physics teachers. Biology teachers are clearly more likely than physical science teachers to meet the NSTA recommendations for a science specialist; only about half of all chemistry or physics teachers have taken 32 semester hours in their subject area, compared with 80 percent of biology teachers. On the other hand, a relatively stable 82 to 84 percent have taken a science methods course.

Table 13

PERCENTAGE OF HIGH SCHOOL SCIENCE TEACHERS MEETING NSTA STANDARDS, BY STANDARD AND TYPE OF SCIENCE TEACHER

	Type of Science Teacher			
NSTA Standard	Biology	Chemistry	Physics	All
50 semester hours in science	—	—	—	56
32 semester hours in science specialty	80	53	41	64
Methods course	83	84	82	83
All science course requirements plus methods course	29	31	12	26

SOURCE: Weiss, *Course Background Preparation of Science and Mathematics Teachers in the United States*, 1988.

Mathematics Teachers

The NCTM recommends a minimum of two mathematics courses for lower-grade elementary school teachers, and three for upper-grade teachers; prerequisites of two years of high school algebra and one year of geometry, as well as a mathematics methods course, are specified for all elementary teachers. The SREB found that prospective elementary teachers do take an average of about two and one-half mathematics courses, but that many of these courses do not meet the NCTM's prerequisites. Weiss's data also show that only 18 percent of elementary teachers meet the NCTM recommendations for specific courses. However, most are missing only one recommended course, usually geometry. Like science teachers, about 90 percent of elementary school teachers have taken a mathematics methods course.

The NCTM recommends that junior high school mathematics teachers take five college mathematics courses, in separate subspecialty areas, plus a computer science course and a methods course. Weiss found that only 10 percent of junior high school mathematics teachers meet all of the NCTM standards: 83 percent are missing courses in one or more of the mathematics areas outlined in the NCTM standards (most often in applications of mathematics), 52 percent lack a computer programming course, and 14 percent have not had a methods class.

Recommendations for high school mathematics teachers are similar, but they include 10 mathematics courses. The SREB found that prospective secondary mathematics teachers take an average of 11 courses in mathematics, about 45 percent being at the upper level.

Weiss found that only 12 percent of high school mathematics teachers had taken all of the NCTM recommended courses, although about 50 percent either met or came very close to meeting the complete standards. The mathematics courses these teachers were most likely to be missing were applications of mathematics, history of mathematics, and "other upper division mathematics." On the other hand, 12 percent of them had taken *fewer* than five of the ten recommended mathematics courses. Thirty-six percent had not had a computer programming course, and 15 percent had not had a mathematics methods course.

Summary

In terms of the overall *number* of courses taken, most teachers meet the NCTM and NSTA standards. However, fewer are able to meet the recommendations pertaining to specific course content and level. For example, most elementary science teachers take too few courses in the earth sciences, while middle and secondary teachers rarely have the recommended depth in all areas of science concentration. Middle school teachers are particularly lacking in earth science coursework, while those at the upper high school level lack physical science coursework. Few mathematics teachers take as many upper-level mathematics courses as the NCTM recommends, and few have the recommended courses in applications of mathematics, history of mathematics, and/or computer programming.

To some extent, these findings may reflect inadequacies in the courses available to prospective teachers, rather than in the choices prospective teachers make. Few colleges, for example, offer a wide range of courses in the earth sciences or in mathematics history and applications. However, the findings are also indicative of an underlying tension in teacher preparation. On one hand, the professional standards suggest that teacher preparation should be academically rigorous, including a broad range of relevant courses, but on the other hand, the topics that are most important for teachers to know well are those that they will be teaching within the elementary and secondary curriculum. Filling a limited college schedule with courses in calculus or analytical chemistry, for example, may seem inappropriate to the prospective elementary teacher who feels that courses in finite numbers or animal behavior, while possibly of "lower level" or lacking in "breadth," are more relevant areas in which he or she should be well prepared to teach.

The data on teachers' pedagogical preparation clearly show that elementary teachers are better prepared for this aspect of teaching than are middle school or high school teachers. While 90 percent of elementary teachers have had a science methods course and 90 percent have had a mathematics methods course, only 80 to 85 percent of middle and secondary school teachers have had such courses.

PERCEPTIONS OF QUALIFICATIONS

A final potential indicator of adequate preparation is whether teachers *feel* adequately prepared to provide instruction in specific subject areas. We do not know the relationship between this subjective measure and the more commonly used measures of teacher preparation. Biases could affect this subjective measure in either direction. For example, teachers may be reluctant to admit that they are inadequately prepared, so their reports might overestimate the true level of preparedness. On the other hand, some may tend to feel that there is always more they could know or do for their students, leading them to overreport a lack of preparation. In either case, though, any tendency for teachers to report feelings of unpreparedness is cause for concern, and to the degree that responses on this measure mirror those on other indicators of preparation, they help construct a consistent picture of the level of preparation of mathematics and science teachers.

Data on self-perceptions of preparedness are available from the NAEP Science Assessment and the NSSME. The NAEP data show that while the teachers of virtually all 7th and 11th grade students feel "adequately prepared" to teach science (95 and 97 percent, respectively), only 80 percent of teachers of 3rd grade students feel adequately prepared (Mullis and Jenkins, 1988).

Tables 14 and 15 show a similar pattern of teacher responses to the NSSME: The higher the grade level, the more likely teachers are to feel adequately prepared to teach science. Table 14 also shows that, as the coursework data would imply, elementary teachers feel more qualified to teach life sciences than physical sciences; almost one-fourth of all

Table 14

PERCENTAGE OF ELEMENTARY TEACHERS WHO FEEL ADEQUATELY QUALIFIED TO TEACH A SUBJECT, BY SUBJECT AREA

Subject Area	Percent Feeling Adequately Qualified
Mathematics	99
Life science	89
Physical science	76
Earth/space sciences	77
Social studies	96
Reading	99

SOURCE: Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education*, 1987.

Table 15

PERCENTAGE OF SECONDARY TEACHERS WHO FEEL ADEQUATELY QUALIFIED TO TEACH ALL THEIR COURSES

Grade	Mathematics Teachers	Science Teachers
7–9	91	88
10–12	95	93

SOURCE: Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education*, 1987.

elementary teachers do *not* feel adequately qualified to provide instruction in the physical and earth sciences. Elementary teachers report feeling less prepared to teach the physical sciences than any other academic subject, although virtually all feel prepared for teaching mathematics. Table 15 also shows that secondary mathematics teachers are slightly more likelv to feel prepared for their courses than are secondary science teachers.

COMPARISON OF PREPARATION INDICATORS

Is there any consistency among the indicators of teachers' preparation? Yes and no. As Table 16 uemonstrates, the level of preparation found depends on the measure one chooses to use. If the measure is teachers' own perceptions or their pedagogical coursework, most mathematics and science teachers appear to be reasonably well-prepared. If the measure is professional standards for content courses, these same teachers appear to be less well-prepared.

The data consistently show tha' junior high school mathematics and science teachers are less well-prepared than their high school counterparts. It is less easy to draw conclusions about elementary teachers' preparation relative to that of teachers at other levels because their preparation and teaching responsibilities are different. The indicators consistently suggest, though, that elementary teachers are least well-prepared and comfortable with teaching the physical and earth sciences.

In sum, there is no single reliable standard for measuring preparation that is valid for all purposes, and the few proxy measures that are available—none of which is very satisfactory—paint very different pictures. Until there is some agreement on what a well-prepared mathematics or science teacher should know, the best approach to examining this issue is one that is similar to the multitrait, multimethod matrix approach for examining

Table 16

PERCENTAGE OF TEACHERS MEETING EACH PREPARATION STANDARD

Preparation Standard	Percent of Those Teaching Mathematics K–6	7–9	10–12	Percent of Those Teaching Science K–6	7–9	10–12
Certified in subject (includes all forms of certification)	—	65	85	—	76	91
College major in subject area (including mathematics or science education)	—	48	76	—	68	84
Meet NSTA/NCTM standards	18	10	12	34	22	26
Methods course taken	90	85	85	90	80	83
Feel prepared in subject	99	91	95	89/77[a]	88	93

SOURCE: Weiss, *Report of the 1985-86 National Survey of Science and Mathematics Education*, 1987, and Weiss, *Course Background Preparation of Science and Mathematics Teachers in the United States*, 1988.

[a]Eighty-nine percent feel prepared to teach biology; 76 to 77 percent feel qualified to teach the physical and earth sciences.

construct validity. That is, a broad range of preparation indicators should be examined and compared for teachers of different subjects (e.g., mathematics, science, English, foreign language). At present, there are no databases with which to conduct such extensive analyses. The NSSME is the only source of data on a wide range of preparation indicators, but because it surveys only mathematics and science teachers, it does not permit comparative analyses with teachers in other subject fields.

IV. RESEARCH NEEDS

Some of the needed research on the quality, supply of, and demand for precollege science and mathematics teachers can be performed with existing or soon-to-be-created databases at the NCES. Other kinds of research will require different approaches and new data collection. The overall findings should inform the nation not only about the levels of teacher supply, shortage, and qualifications, but also about supply or quality problems and, hence, about the prospects of alternative means of addressing them. The key research questions that we believe should be addressed are listed below, along with several avenues for research.

RESEARCH ISSUES

Several key questions relating to teacher supply and demand should be addressed:

- What are the major sources of supply for precollege mathematics and science teachers? How many of the new entrants each year are recent graduates of teacher education programs, recent graduates of other bachelor's or master's degree programs, entrants from other occupational fields (e.g., mid-career switchers or retirees starting other careers), immigrants from other fields of teaching, or re-entrants into teaching who left the teaching force for some period of time?
- What routes into teaching are taken by different types of teachers (e.g., traditional undergraduate teacher education programs, graduate-level programs, alternative certification programs, retraining programs)? What are the qualifications of these different pools of teachers? How well-prepared do the teachers feel to teach different subject areas?
- What are the turnover rates of mathematics and science teachers? How are these rates affected by teaching field, age, sex, family status, source of entry, qualifications level, and salary? Where do these teachers go when they leave teaching? How many return to teaching? What policies would be most effective for raising the rates of retention and return to teaching?

- What is the demand for mathematics and science teachers of different types, and how is it likely to change as a result of demographic trends and policy initiatives?
- How are teacher qualifications and teaching conditions distributed across schools, students, and courses of different types? How do these distributional differences influence teacher turnover and teaching quality?
- Where are the greatest imbalances between the supply of and demand for mathematics and science teachers, by field, level, sector, and geographic location? What factors contribute to these imbalances? How do these imbalances affect the qualifications of individuals hired to teach mathematics or science? What policies seem to be successful in ameliorating shortages while maintaining quality?

We still know little about how mathematics and science teachers are prepared; the very few studies that exist have serious biases (e.g., nonrepresentative samples, possibility of response bias from self-report data). Some of the questions that need to be answered are:

- How does teacher preparation vary, by field, level, sector, source of entry, type of certification, and type of students taught? Also, what preparation do teachers feel is most useful or necessary and how do these perceptions relate to more objective measures of preparation and quality?
- How does pedagogical preparation interact with subject-area preparation to influence teacher effectiveness? How are teaching methods and content knowledge best integrated within a preparation program?
- What are the effects of different types of preparation on teacher effectiveness and retention? To what degree do teacher candidates differ because of their previous academic training, selection or self-selection into preparation programs, previous occupational experience, pedagogical training and field experience prior to teaching, and instructional support (e.g., mentoring) during the initial teaching year?
- How does teacher preparation relate to teaching practice—that is, what types of preparation seem to encourage the teaching practices that are most desired or most strongly related to student outcomes?

- How does inservice coursework taken during the teaching career supplement initial teacher preparation? What types of additional training or preparation do mathematics and science teachers need after they are in teaching? Under what circumstances? Do they receive enough of such training? How can teaching be better structured to allow teachers the time and opportunity for additional training?

SOURCES OF DATA

Analyses of NCES Databases

The NCES has recently revised its previously fielded surveys of teacher demand and shortage and of public and private school teachers and administrators. The earlier surveys of teacher demand and shortage were not designed to enable field-specific estimates of new teacher supply or qualifications, and the public and private school teacher and administrator surveys did not focus on supply and demand issues. However, the teacher surveys did collect useful and relevant data on teacher qualifications, assignments, and mobility, which have not yet been analyzed. Furthermore, mathematics and science teachers were oversampled for these surveys in 1985 and 1986, providing an adequate sample size for many analyses of interest. Such analyses would provide valuable information about who is teaching science and mathematics in elementary and secondary schools nationwide, and how these teachers are distributed.

The new NCES surveys called the Schools and Staffing Surveys (SASS) were first fielded in 1988 and will be repeated biannually starting in 1991. They provide an integrated database that will yield more complete data on teacher supply, demand, turnover, shortage, and qualifications that can be analyzed by teaching field. The survey set links the former district-level surveys of teacher demand and shortage with surveys of schools and teachers, correcting many of their previous shortcomings and extending their capacity for assessing issues of supply and quality.

The much larger samples of teachers and the design of the instruments to capture field-specific aspects of teacher hiring, assignment, qualifications, and distribution will help to determine what kinds of individuals, with what kinds of training and experience, are teaching what kinds of science and mathematics classes to what kinds of students. Furthermore, the surveys will allow analyses of attrition, mobility, turnover, reasons for leaving, destinations, reentry from the reserve pool, sources of teacher supply, extent of shortages, and school-level strategies for handling shortfalls of qualified teachers. If continued funding is available to field these surveys on an ongoing basis and the proper analyses are then performed, many of the missing pieces in the supply and demand puzzle can be filled in.

Other existing NCES databases can be further plumbed to find needed information about the supply and qualifications of science and mathematics teachers. The National Longitudinal Study (NLS) special teacher supplement, conducted as part of the fifth followup of the high school class of 1972, includes all members of the cohort sample who ever taught, plus a sample of students who majored in mathematics or science but did not enter teaching, thus enabling examination of career paths and decisions. These data can be used to address questions related to teacher attrition and the reserve pool, but the sample of science and mathematics teachers is likely to be too small for many analyses of interest. Findings will also be limited to the single cohort of individuals in that sample.

The periodic Surveys of Recent College Graduates also suffer from small samples of science and mathematics teachers, but analyses that aggregate these teachers into one or two groups (e.g., all science teachers or all mathematics teachers) can nonetheless reveal patterns of entry into teaching and—equally important—losses of prospective teachers to other occupations. Longitudinal followups of these graduates could also provide insights into reserve pool behavior.

Other Sources of Data

State personnel files contain extensive data about the movement of teachers into and out of state teacher labor markets, and can sometimes be linked to certification files, which describe teacher preparation in at least general terms. These data can then be used to examine patterns of mobility and turnover; supplemented by surveys, they can permit analyses of reserve pool entry and exit behavior for particular types of teachers. The RAND Corporation is currently conducting such a study using state files supplemented by surveys of new teachers in Indiana.

The NSF-sponsored 1985-86 NSSME provides extensive data on teacher preparation, qualifications, and assignments, and on how teachers are distributed across schools and students of different types. The dataset enables varied analyses of the linkages between teacher preparation, source of entry and certification status, teaching practices, and teaching conditions. Some analyses have already been done (e.g., Weiss, 1987, 1988), and more are possible.

Finally, supplements to ongoing large-scale national surveys are a potentially fruitful source of data. For example, the NSF's longitudinal surveys of scientists and engineers have not, in the past, sampled precollege teachers. However, if the sample were expanded, these surveys would be an ideal source of information about labor force behavior and job characteristics for mathematics and science teachers, for comparison with scientifically trained personnel in other occupations. A National Academy of Sciences panel is considering such an expansion, among other proposals for rendering the dataset more useful.

SPECIAL STUDIES

A number of important questions warrant special studies. The relationship of teaching practices to particular forms of teacher preparation is critical to determining what kinds of preparation—either preservice or inservice—should be encouraged. Although some analyses can be performed using large-scale datasets like the NAEP (in particular, the supplemental teacher surveys for the mathematics and science assessments), more controlled and carefully designed case studies of teaching practices would provide richer data about the factors influencing teaching, including teaching conditions and assignments.

It would be useful to examine in depth the outcomes of alternative certification and other nontraditional preparation programs for mathematics and science teachers, not only in terms of teacher supply and retention, but also in terms of teacher effectiveness. Several small-scale studies have been conducted, but they have relied on record data and surveys of cross-sectional samples; none have tracked these "nontraditional" recruits over time or directly examined their experiences in teaching. Equally important, none have compared the nature and outcomes of these programs with those of traditional teacher preparation and certification programs.

Finally, a great deal more needs to be learned about what motivates qualified individuals to go into mathematics and science teaching and what dissuades others from doing so. Obviously, the same kind of information is needed about what encourages some highly qualified individuals to remain in teaching and what convinces others to leave. This includes information about early career choices in college as well as labor-market choices thereafter at various career points. Until we know what matters most to the talented individuals we would like to attract and keep in teaching, we can do little to develop policies to achieve these goals.

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