DOCUMENT RESUME

ED 272 388 SE 046 882

TITLE	Report of the Planning Conference for a Study of Statistics on Supply of and Demand for Precollege Science and Mathematics Teachers.
INSTITUTION	National Academy of Sciences - National Research Council, Washington, DC. Commission on Behavioral and Social Sciences and Education.
SPONS AGENCY	National Science Foundation, Washington, D.C.
PUB DATE	[86]
NOTE	79p.
AVAILABLE FROM	Committee on National Statistics, National Research Council, 2101 Constitution Avenue, Washington, D.C. 20418.
PUB TYPE	Collected Works - Conference Proceedings (021) -- Reports - Descriptive (141)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Data Analysis; Data Collection; Educational Research; Elementary Secondary Education; Mathematics Education; *Mathematics Teachers; Models; Preservice Teacher Education; *Research Methodology; Research Problems; Science Education; *Science Teachers; Secondary School Mathematics; Secondary School Science; *Secondary School Teachers; Statistical Data; Teacher Certification; *Teacher Shortage; *Teacher Supply and Demand

ABSTRACT

Statistical issues associated with the supply and demand of science and mathematics teachers are reviewed in this conference report of the Committee on National Statistics. The conference was held to generate a plan for a study that would make recommendations to improve the information, sources, statistics, and models used in estimating and projecting the supply and demand for precollege science and mathematics teachers. Consideration was also given to elementary and middle school conditions. Major topics addressed included: (1) concepts of a qualified teacher and related statistical problems; (2) models used by the National Center for Education; (3) data on supply and needed improvements; (4) data on demand and needed improvements; and (5) activities for a proposed study on supply and demand for precollege science and mathematics teachers. Activities selected as important were those that focused on: measurement of teacher quality; descriptions of the entry/exit/bumping system; development of teacher population profiles; assessment of existing national and state data resources on teacher supply and demand; evaluation of project models; and review of statistics from colleges of education. This report also contains listings of the conference's participants, agenda, and reference sources. (ML)

REPORT OF THE PLANNING CONFERENCE

FOR A STUDY OF STATISTICS ON

SUPPLY OF AND DEMAND FOR

PRECOLLEGE SCIENCE AND MATHEMATICS TEACHERS

Committee on National Statistics
Commission on Behavioral and Social Sciences and Education
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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The conference on which this report is based was held with support from the National Science Foundation.

Available from:
Committee on National Statistics
National Research Council
2101 Constitution Avenue
Washington, D.C. 20418

Committee on National Statistics

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FOREWORD

During the past few years much concern has been expressed about the quality of precollege science and mathematics education in the United States. Several commissions and task forces have stressed the importance of improving science and mathematics education. At the same time there appears to be a shortage of qualified mathematics and science teachers as well as evidence that there are many teachers of science and mathematics who are teaching out-of-field because of the shortages. It is difficult to assess the extent of these shortages because of the inadequacy of available information on supply of and demand for precollege science and mathematics teachers. Little is known about the reserve pool of teachers and the number who will return to teaching. The available data on new teachers in the job market are four years old, and it is not clear whether a teacher certified in both mathematics and chemistry would be counted as a mathematics teacher or a chemistry teacher.

The Committee on National Statistics held a conference August 9-10, 1984, to explore these issues. The purpose of the conference was to identify problems with the available data, or gaps in the data, to discuss problems and improvements in the models now used for estimating and projecting supply and demand, and to suggest activities that a National Research Council study group might effectively carry out. The conference was held to generate a plan for a study that would make recommendations to improve the information sources, statistics, and models used in estimating and projecting the supply of and the demand for precollege science and mathematics teachers. The proposed study would not be limited to high school science and mathematics teachers; it would consider ways to improve the existing statistics, models, and information sources relevant to teachers of mathematics and science in elementary and middle schools, as well.

The conference, held with support from the National Science Foundation, was chaired by Lincoln E. Moses, chair of the Committee on National Statistics. Dorothy M. Gilford, senior research associate to the committee, organized the meeting with the assistance of consultant Ellen Tenenbaum.

The committee extends its appreciation to the National Research Council's Committee on Indicators of Precollege Science and Mathematics Education for providing access to a prepublication copy of its report Indicators of Precollege Education in Science and Mathematics: A Preliminary Review (National Academy Press, 1985). The report provided useful background information for the conference.

PARTICIPANTS

Speakers and Discussants

LINCOLN MOSES (Chair), Department of Statistics, Stanford University

WILLIAM ALDRIDGE, National Science Teachers Association

STEPHEN M. BARRO, SMB Economic Research, Inc.

RICHARD M. BERRY, Office of Studies and Analyses, Science and Engineering Education Directorate, National Science Foundation

NANCY B. BORKOW, Congressional Research Service

ALPHONSE BUCCINO, College of Education, University of Georgia

F. JOE CROSSWHITE, Department of Education, Ohio State University and National Council of Teachers of Mathematics

EMERSON ELLIOTT Office of the Undersecretary, U.S. Department of Education

DOROTHY M. GILFORD, Committee on National Statistics, National Research Council

ALAN GINSBURG, Planning and Technical Analysis, U.S. Department of Education

GUS W. HAGGSTROM, RAND Corporation

CHARLOTTE KUH, American Telephone & Telegraph Company

ALEXANDER I. LAW, Planning, Evaluation and Research, California State Department of Education

STEPHEN LEINWAND, Connecticut State Department of Education

RICHARD MURNANE, School of Education, Harvard University

HAROLD NISSELSON, WESTAT

SALLY PANCRAZIO, Research and Statistics Section, Illinois State Office of Education

ROBERT W. PARRY, Department of Chemistry, University of Utah

VALENA WHITE PLISKO, Condition of Education, National Center for Education Statistics

PAUL SALLY, Department of Mathematics, University of Chicago

BASSAM Z. SHAKHASHIRI, Science and Engineering Education Directorates, National Science Foundation

DAVID C. SMITH, College of Education, University of Florida

AUDREY WEINBERG, National Center for Education Statistics

Other Participants

SUSAN ADLER, Education Commission of the States

JOAN BARATZ, Educational Testing Service

AUDREY CHAMPAGNE, American Association for the Advancement of Science

CHARLES H. DICKENS, National Science Foundation

WALTER L. GILLESPIE, National Science Foundation

HERMAN GOLDBERG, American Association of School Administrators

MILTON GOLDBERG, National Institute of Education

WILLIAM S. GRAYBEAL, National Education Association

RAYMOND HANNAPEL, National Science Foundation

CALVIN JONES, National Opinion Research Center

JOHN W. LAYMAN, Physics Department, University of Maryland

GWENDOLYN LEWIS, National Research Council

EUGENE MCLOONE, Department of Educational Policy, Planning and Administration, University of Maryland

BEVERLY PORTER, American Institute of Physics

SENTA RAIZEN, National Research Council

NEAL ROSENTHAL, Bureau of Labor Statistics

RICHARD L. SCHEAFFER, Department of Statistics, University of Florida

PAUL SIEGEL, Population Division, U.S. Bureau of the Census

JOYCE STERN, Office of the Undersecretary, U.S. Department of Education

JEAN VANSKI, National Science Foundation

ANDREW VERNON, American Geological Institute

WAYNE WENDLING, W. E. Upjohn Institute for Employment Research

RICHARD WILCOX, Center for Strategic and International Studies, Georgetown University

Staff, Committee on National Statistics

EDWIN D. GOLDFIELD, Executive Director

DOROTHY M. GILFORD, Senior Research Associate

ELLEN TENENBAUM, Consultant

ANNE SPRAGUE, Administrative Secretary

CONFERENCE SUMMARY

The National Science Foundation (NSF) sponsored this conference for two reasons. First, NSF needs to have a sound statistical base on which to establish and implement policies and programs to improve the quality of precollege science and mathematics education in the United States. Second, NSF has encountered a number of data problems in carrying out its responsibility to develop indicators of the condition of precollege science and mathematics education. The conferees discussed at length five topics related to statistics and models concerning the supply of and demand for precollege science and mathematics teachers:

- Concepts of a qualified teacher and related statistical problems;
- Models used by the National Center for Education Statistics;
- Available data on supply and improvements needed in the data;
- Available data on demand and improvements needed in the data; and
- Activities for a proposed study by the Committee on National Statistics on supply of and demand for precollege science and mathematics teachers.

Most of the presentations and discussions focused on high school mathematics and science teachers, although occasional statements were made about the importance of looking at the qualifications in mathematics or science of teachers in elementary and, especially, in middle schools. Education at the elementary level is particularly important in mathematics since 50-80 percent of precollege math education takes place in elementary schools. The proposed study would be concerned with teachers of science and mathematics at all three levels: elementary, middle schools, and high schools.

Although the available data cannot show it, it appears that science and mathematics teaching may be solving its supply/demand problem by adjusting downward for quality. There may not be a significant numerical shortage of science and mathematics teachers because vacancies are filled promptly with out-of-field or underqualified teachers. The data are not adequate to address this critical issue, nor to answer a number of important questions:

- How many teachers not qualified to teach science or mathematics are assigned to those subjects to fill gaps? What is the scope and the expected duration of this situation?
- Do we have an adequate number of qualified teachers (inside and outside the teaching force) of mathematics and science for the courses now taught and for courses that may be added in the near future?
- Can we predict with any degree of accuracy what the teacher supply/demand situation will be like in the future?

The conferees did not attempt to define a "qualified" teacher, but the need for more finely discriminating data on qualifications of teachers surfaced repeatedly during the conference. They proposed looking at a multivariate continuum of qualifications rather than a simple dichotomy of qualified and unqualified. It is important to collect data on a number of different dimensions and to address gradations of qualifications on these dimensions. Clearly, different criteria would be required for measuring the competence of elementary school teachers and high school teachers, since elementary school teachers are responsible for teaching all subjects while high school teachers may teach in only one field.

Three factors are expected to exacerbate the shortage of qualified high school science and math teachers: the age distribution of teachers, which implies that 40 percent of the current teachers will retire by 1995; the demographics, which indicate that by the mid-1980s there will be an increase in enrollment in elementary schools and in the ear , 1990s in the secondary schools; and the increase in science and mathematics requirements for high school graduation. Discussion of teacher supply covered a wide range of data needed on current teachers, new teachers, and those in training, as well as the reserve pool of potential teachers who have certificates but are not teaching. Almost no data exist on the reserve pool, yet such data are essential to projecting future supply and demand.

Data on teacher demand are equally problematic. Current demand studies do not attempt to estimate separate equations for the demand for and the supply of high school science or mathematics teachers. Instead, they estimate such variables as vacancies or shortages that reflect both demand and supply effects. Nor do current studies adjust for differences in demand in relation to teacher quality or price. Specific refinements needed in demand data are geographic disaggregation, subject areas within science or mathematics, consistency of measurement techniques over time, and science and mathematics data in the context of all fields.

The conferees discussed the need for a variety of models for use in policy analysis and the data needed for some specific policy purposes, stressing that in most cases the data do not now exist. It would be desirable for the proposed study to focus on likely trends and changes in the supply situation for the short run and through the early 1990s. The study could gear its discussions of particular data problems and recommendations to these time frames. One central point is that there is time and opportunity now to obtain needed data and to test policy incentives that aim to produce the number of high-quality science and mathematics teachers that will be needed in the 1990s, when high school enrollment is projected to increase. In the long run it will be necessary to look at supply and demand functions (rather than numbers) or a supply/demand response model.

While the conference was in session, the President signed the mathematics and science teaching bill (P.L. 97-388). The bill provides block grants to the states to conduct an evaluation of teacher supply and demand and teacher qualifications in mathematics, science, and computers. The conferees urged that the proposed study provide guidance for possible use by states by describing procedures and content for state studies and by working through some of the problems with definitions currently in use.

On the basis of the discussions at the conference, the most important activities for the proposed study appear to be:

(1) To take a first step toward measuring teacher quality in elementary, middle, and secondary schools by drawing on the research literature to identify information (beyond teacher certification) that is associated with qualification (e.g., the extent of training to teach, a teacher's preparation to teach in this field, the adequacy of a teacher's background in the subject matter to offer the advanced placement version of the subject, textbooks used in college) that would increase understanding of the character of the teaching force.

(2) To review the entry and exit of math and science teachers (including teachers in elementary and middle schools) in the system, including intrasystem bumping. This would entail visits to a sample of schools (or districts) and preparation of a case study of each school (or district) that would describe the teachers there (qualifications, experience, seniority, preparation, courses taught, and class size) as well as the teachers who were there last year but not this year, the procedures for hiring, the recent hiring history, and the rules governing intrasystem bumping. Drawing on the background developed in the case studies, the study would make recommendations on statistics that should be collected to describe the entry/exit/bumping system in a manner that will focus attention on teacher qualifications.

(3) To attempt to develop profiles of the populations of elementary, middle, and secondary school teachers of science and mathematics in the United States, drawin on existing data and information from the case studies. If that is not feasible, the study would recommend steps that must be taken in baseline data collection to produce a national profile of these populations.

(4) To review data resources related to teacher supply and demand at national and state levels and make recommendations that would provide the data required to profile the current status of supply and demand, including attention to its distribution nationwide

(5) To evaluate projection models being used at national and state levels and recommend changes in the models or assumptions used that could be expected to improve them.

(6) To review the available statistics on colleges of education that are pertinent to teacher supply and make recommendations concerning data

that should be collected to shed light on the characteristics of teacher training programs that would be useful in estimating the size and qualifications of the supply of teachers.

REPORT OF THE MEETING

INTRODUCTORY REMARKS

Lincoln Moses opened the conference, and, after the welcoming and introduction of the participants, turned to Richard M. Berry of the National Science Foundation (NSF) to explain its interest in sponsoring the planning conference. The Office of Studies and Analyses of NSF's Science and Engineering Education Directorate is responsible for developing indicators of the condition of precollege science and mathematics education. The statistics that provide the basis for such indicators are inadequate in many ways. Existing statistics, though they may be valid and serviceable in their own right, are not detailed enough, especially in disaggregation by fields, for NSF to use in its analyses related particularly to science and mathematics teachers. Those statistics that do focus on high school science and mathematics teachers tend to be opinion surveys that are limited in scope, have been discontinued, or are marred by problems of nonresponse or unreliability of response. Berry cited the March 1984 report of the General Accounting Office (New Directions for Federal Programs to Aid Mathematics and Science Teaching) which found "the data documenting the shortages of mathematics and science teachers . . . to be very weak and [believed] teacher shortages to be basically undocumented to date." The goal of the planning group was therefore to help NSF and the National Research Council plan a study that would recommend steps to improve the statistics on the supply of and demand for science and mathematics teachers.

B.Z. Shakhashiri, NSF's assistant director for science and engineering education, who had been invited to discuss national needs for data on qualified teachers, stressed the absolute necessity for teachers to be highly competent in the subject they teach, knowledgeable well beyond the textbook. A critical problem today appears to be that many teachers are not sufficiently knowledgeable about the subject matter to teach science and mathematics courses to which they are assigned. Reports of shortage, misassignment, and use of emergency credentials abound, but there are no reliable data to document the extent of this problem.

The unanswered questions, from the perspective of NSF, are:

- How many teachers not qualified to teach science or mathematics are assigned to those subjects to fill gaps? What is the scope and the expected duration of this situation?
- Is there an adequate number of qualified teachers of mathematics and science for the courses now taught and for courses that may be added in the near future?
- Can we predict with any degree of accuracy what the teacher supply/demand situation will be like in the future?
- If problems exist with the supply of teachers qualified to teach science and mathematics, what immediate steps should be taken to correct the situation?

When NSF looks to the existing data for answers to these questions, weaknesses in the data become apparent, Shakhashiri noted. On the supply side, there are weaknesses in the counts of actual numbers of high school teachers currently teaching science and mathematics. It is not known how many inactive teachers return each year to fill vacancies. No current national data are available on how many teachers of mathematics and science are fully certified to teach these subjects. Because of these gaps in data, NSF is unable to anticipate the effects of various initiatives now being considered to draw people to the teaching profession. One of the most important issues is what effect raising teachers' salaries will have on increasing the supply of qualified teachers in science and mathematics. Data should be collected about some of the natural experiments going on in several states.

On the demand side, no national statistics exist on the number of teacher vacancies in mathematics or science that are filled with tenured teachers from other fields. We also need to know how many new teachers are being certified in the vacancy areas and where they are being placed. Other data required are the incidence of emergency certification and the incidence of retraining or becoming certified once assigned to the subject. To what extent are new technologies being used in the classroom, and what is the impact on the demand for teachers? What effect will upgrading science and mathematics courses have on teacher demand? Data systems should be put in place to monitor the effects of these changes as they are implemented.

The toughest question is that of teacher quality. The only standard now used is certification, and we know that certification is only a poor approximation of competence. Even national data on certification are out of date. We need to know more about what constitutes adequate academic preparation for teachers and the suitability of courses in math and science at the college level for education majors. Questions remain about the proper balance between the training of prospective teachers in pedagogical techniques and in knowledge of the subject matter they teach. There is a paucity of data on the qualifications of teachers now teaching science and mathematics. We do not know how many who are teaching are not really qualified. In short, the data need extensive improvement for NSF to have a sound statistical base on which to establish and implement policies and programs to improve the quality of precollege science and mathematics education in the United States.

CONCEPTS OF A QUALIFIED SCIENCE OR MATHEMATICS TEACHER AND RELATED STATISTICAL PROBLEMS

The concepts and statistical problems of teacher quality may be divided, for purposes of this discussion, into two general problem areas: (1) the qualifications of newly assigned teachers and (2) the effectiveness of a teacher in terms of output or student achievement.

David Smith, dean of the College of Education at the University of Florida, spoke first about the problems of new teacher graduates and their training institutions--that is, problems of one part of the total supply of teachers. In the past decade the number of new teacher graduates has decreased by 50 percent, while the number of colleges preparing teachers has increased in number by approximately 100.

There is an unevenness of quality among colleges of education and the students enrolled in them--an unevenness that is largely unaddressed. In 34 states, tests are required for graduates of teacher preparation programs to be certified for teaching. There does not appear to be a study that assembles the relative rates of success among those institutions. Among Florida's 26 institutions, the success rates of graduates from these programs range from about 28 to about 93 percent. A study showing relative success rates for all 34 states would help us begin to identify the factors behind the uneven quality of teacher training programs--assuming that high scores on the tests are correlated with effective teaching.

In addressing the supply of new teachers, it is important tc look at teacher quality as well as quantity. New knowledge requirements in . ience and mathematics make it imperative to upgrade the substantive preparation of science and mathematics teachers. Smith considers this to be essential if we are to remain leaders economically and technologically. Yet in some states, certification requirements have not been revised for 20 years. He expressed particular concern that the average SAT scores for students who are going into teaching programs are lower than those for other college students. Because many older teachers will soon retire, and as many states raise high school graduation requirements, concern over the qualifications of new teacher graduates becomes more urgent. For example, if teacher training institutions were to raise the minimum SAT levels of entrants, how many teacher candidates would the institution lose?

Smith expressed serious concern with the very real but largely undocumented incidence of certified teachers who are teaching only one course out-of-field. How many high school science and mathematics classes in the United States are taught by such out-of-field teachers? What is the incidence of teaching on temporary or emergency certificates? What science or math courses did these people have at the undergraduate level? He noted that, in a number of states, a substitute teaching certificate can be earned with a high school diploma without even a college degree. How long can a substitute teacher teach? What are the actual certification requirements of the various states?

He stressed the importance of understanding the attrition rate for teachers. Who leaves teaching and who stays? What is the attrition rate and what lies behind it? What are the differential characteristics of teachers who leave and teachers who stay? There may have been disproportionate entries to teaching in the 1950s and 1960s, when the baby boom cohort was attending school. Will there be disproportionate exits in the late 1980s and the 1990s?

With respect to the second general area, Smith called for a system of measuring or evaluating teacher effectiveness, and in particular the relationship of teacher performance to student performance. As a minimum, Smith argued that teachers must possess mastery of the subject they are teaching at a level well beyond their most advanced students; this is a necessary but not sufficient condition, in his view. In addition to inadequacies in teacher education in subject matter content, there are inadequacies in pedagogic content.

He called attention to a recently growing body of knowledge that relates student performance at the early elementary level to teacher behaviors and characteristics. That research, referred to as process-product research, has not found its way into colleges of education to the degree that it should have. A major redesign of teacher preparation programs was called for, to include well-researched methods of evaluating teacher performance. Process-product research should be a part of teacher preparation programs. If we are to prepare professional teachers for the twenty-first century, we must teach them a more sophisticated, more demanding body of knowledge in pedagogy, and it cannot be done at the expense of subject matter. The individual who enters a college of education and plans to teach at the secondary level should have earned a B.A. in the substantive field to be taught.

In conclusion, Smith urged that any study the National Research Council may undertake on this subject include science and mathematics teaching at the middle-school and elementary levels, where foundations of knowledge are laid. He also felt that the proposed study should serve as a model for all subject areas, for the problems we are studying pertain to other fields as well.

Robert W. Parry, distinguished professor of chemistry, at the University of Utah, mentioned that the National Science Board's recommendation on qualification for a science or mathematics teacher was to have a major in the discipline being taught. He also cautioned that, if efforts are made to attract people from industry to teaching, care should be taken not to get the dregs from industry, especially since there may be no way to drop them from the education system.

Alexander Law's comments concerned information problems relating to the qualifications of teachers and were illustrated with an example. In planning a program to improve the quality of education in California, the state superintendent of public instruction recently requested a profile for each school giving quality indicators related to the various state goals. One of the indicators was number of students enrolled in an advanced placement program. This appeared to be a reasonable indicator, since a high school offering an advanced placement program would have several elements of quality: faculty motivated to teach the course, an administrator motivated to offer the program, parents sufficiently interested to support the program, and students with the ability to take the program. In California there were only 836 students enrolled in advanced placement chemistry courses. The state superintendent imposed a new requirement to double the number of advanced placement chemistry students, but there was a shortage of teachers qualified to give the courses. Similarly, while there were many teachers in physics and in mathematics who thought advanced placement was an excellent course, they did not feel competent to teach the advanced placement course in their field.

Law confirmed the problem of large numbers of teachers of high school science and math courses who either lack certification in the given field or come under California's old, general, secondary credential, valid for teaching any field, that applied until 1972. Law urged that the planning group, or the proposed study, agree on a set of basic assumptions. Six studies were done in California, but they disagreed because they were based on different assumptions--for example, assumptions about the level(s) of science (remedial, basic, advanced placement, etc.), class size (30:1 or 26:1), and others. He also noted that shortages of qualified teachers are regional within the state. San Francisco, for example, has no problem getting well-qualified teachers; areas such as Fresno have serious problems doing so. There are also large differences in trends in the size of the student population in different areas.

He mentioned the importance of the attrition rate in projecting demand. Some people say attrition is 8 percent, but the National Center for Education Statistics uses 6 percent. It is important to know the characteristics that differentiate those who leave from those who stay.

Paul Sally strongly endorsed Shakhashiri's criterion that a qualified teacher must be thoroughly competent in the subject matter. Sally stressed also the importance of the maintenance of competence and of improving the effectiveness of current teachers. He suggested doing this by requiring that every science or mathematics teacher master certain literature in the field and by having an ongoing 40-year plan for maintaining competence--a plan approved by the school system in which he or she teaches. Sally also addressed the importance of teachers reading professional journals, e.g., a mathematics teacher should read mathematics journals such as the American Mathematical Monthly and Mathematics Magazine.

He stressed that we should define more precisely what we expect mathematics teachers to know. He described the requirements for competency to teach mathematics at the secondary level in terms of knowledge of certain topics and mastery of specific books on those topics. At the elementary level teachers certainly need more knowledge of mathematics than is currently required. Elementary school teachers should have a working knowledge of elementary number theory, elementary geometry, computer science, and statistics. Arithmetic should not be the only math topic in elementary school. These are goals we should strive for and define more precisely.

Joe Crosswhite, president of the National Council of Teachers of Mathematics, focused on the need for more finely discriminating data on the qualifications of teachers. There is a continuum of qualifications--not a simple dichotomy of qualified and unqualified. He illustrated how misleading some of the statistics may be. Ohio has no reported shortage of qualified science or mathematics teachers, but only because their credentials are so general that they can teach almost any subject. Certification may be one of the worst measures of qualification. Thus it is important to collect data on a number of different dimensions and to address gradations of qualifications on these dimensions. Data on actual courses taught should specify the types or levels of science and math, i.e., remedial, basic, or advanced. A system of data collection should also capture the physical education teacher who fills in the remainder of the day with one mathematics class. Crosswhite would prefer to use the term "teachers of science and mathematics" rather than "science and mathematics teachers." To what extent are science and mathematics teachers asked to teach other fill-in courses? On what schedule? In short, it should be known how many of exactly what courses teachers teach, their level of qualifications in each, and the context behind any unusual circumstances. Similar information is needed for elementary teachers who routinely teach many subjects and for middle school teachers.

Formal certification is neither necessary nor sufficient to determine an effective teacher. Certification and effectiveness may have virtually no relationship. In fact, to be qualified and to be certified are not the same, according to the consensus of the group.

Stephen Leinwand, mathematics consultant with the Connecticut Department of Education, commented that the key issue is competency, not credentialing. When trying to find teachers, credentialing can prevent the school from hiring the most qualified individual. For example, many of the best applicants for the presidential award for the best science and math teachers were not graduates of any teacher training program. Many actually graduated in majors other than mathematics or the sciences, and many of them went to NSF summer institutes--a commitment to quality. Leinwand pointed out the serious underlying problems involved in measuring qualified teachers rather than certified teachers. Edwin Goldfield identified a problem if "qualified" is interpreted to mean "competent": How can you get a count of competent teachers?

Crosswhite stressed the importance of looking at the qualifications in mathematics of teachers in elementary and especially in middle schools. In mathematics, 50-80 percent of the precollege education takes place in elementary schools. The difference in mathematics achievement in the United States and in other developed countries is evident by the fourth grade, and continues in the fifth through eighth grades. Haggstrom voiced concern about the low position of this country relative to others in the international assessment of educational attainment.

Haggstrom also expressed the opinion that ultimately we should look at outcome data on students, although little is known about the connections between teacher qualifications and student test scores. It was the opinion of Lincoln Moses and David Smith that sooner or later we must be able to measure the effectiveness of teachers by output in terms of student performance. But others, including Paul Siegel of the Census Bureau, believed this to be too difficult at present, given, for instance, that a student's performance represents the cumulative influence of so many factors and so many teachers.

Bill Aldridge of the National Science Teachers Association stressed the importance of recognizing reality: many teachers must teach in more than one field although they may be certified in only one field. Half the secondary schools in the United States have fewer than 830 students and offer only two physics courses. It follows that physics teachers must do some out-of-field teaching or that physics must be taught by an out-of-field teacher. Mathematics is a convenient fill-in assignment for a physics (or chemistry) teacher.

Murnane posed the question, "Are test scores related to something that we can do something about, something that will affect the decisions people make about entering teaching or staying in teaching?" For example, what about paying for better teaching? During the period from 1973-1974 to 1980-1981, when the National Assessment of Educational Progress showed a decline in science attainment, there was a marked decline in the ratio of entering salaries of education graduates to entering salaries for physical scientists. If we are to understand the occupational choices that people make, who goes into teaching, and how talented they are, we will have to pay attention to the alternatives available. To model supply and demand we need to think about estimating responses to salaries.

Dickens mentioned the importance of determining what fraction of students are taught by "qualified" teachers (as a first cut, qualified might be defined as certified to teach in the field in which teaching) and what would be required to increase that proportion from 50 to 60, or 75 percent? How many teachers would have to be changed t affect a given proportion of the pupils being taught?

Rosenthal mentioned that in supply/demand studies in many fields, such as engineering or nursing, there is always a problem of measuring quality, and it cannot be studied in a survey. He stressed the importance of trend data for supply/demand studies and the need for consistency over time in data collection series.

The proposed study, noted Crosswhite, could list a number of standards or qualifications, some in the form of gradations. Using an array of measurable standards of a qualified teacher, one could begin to approach a statistical profile of teacher quality. Aldridge suggested that standards for qualification could be derived from the National Science Teachers Association's new list of requirements to be used to grant special certification for individual science teachers. The new criteria are said to exceed any state's criteria for certifying teachers in science or mathematics fields.

THE NATIONAL CENTER FOR EDUCATION STATISTICS

TEACHER PROJECTIONS MODEL

Valena White Plisko and Audrey C. Weinberg of the National Center for Education Statistics (NCES) prepared a paper for the conference that described the model used by NCES to project teacher supply and demand in the United States. Because of the central role of projections in this conference and because the NCES projections are the official federal projections of teacher supply and demand, an abbreviated version of the paper presented by Plisko follows.

The projections program at NCES was begun in 1964 and was formally mandated by the Education Amendments of 1974, which required NCES to submit "a statistical report on the condition of education in the United States during the two preceding fiscal years and a projection, for the three succeeding fiscal years, of estimated statistics related to education in the United States . . . ." The original 1964 projections of the teaching force forecast the number of teachers, staffing ratios, and the demand for new certified teachers. The 1978 edition of The Condition of Education was the first to show projections of the supply of new teacher graduates.

The forecasting model developed at NCES does not purport to be an economic model that would describe the balance of total supply and total demand of the entire teaching force. Rather, the model is data-driven, in that it is formulated on the basis of the limited amount of data available. Specifically, supply in this model refers to newly qualified teacher graduates who constitute only a part of the total supply. The remaining segment is the reserve pool of teachers, defined as former teacher graduates who are currently not employed as teachers. These qualified individuals may be employed elsewhere, unemployed but seeking jobs in or out of teaching, or not actively seeking employment. Very limited or no data exist on these groups. Consequently, when the projected results indicate that the demand for additional teachers exceeds the supply of new teacher graduates, a shortage of teachers cannot be conclusively deduced, since many positions may be filled by members of the reserve pool of teachers. Some of the newly qualified teacher graduates, however, do not seek teaching positions.

Overall, NCES's model generates national projections for 10 years in the future. Three alternative projections--low, intermediate, and high--are produced under varying assumptions. The model does not produce information at a regional or state level, nor does it provide forecasts for any specific field of instruction. Nevertheless, the model does provide general information on the employment prospects for those considering the teaching field. As an example, the Bureau of Labor Statistics uses NCES projections in its Occupational Outlook Handbook to inform students and counselors about job opportunities in teaching.

Classroom Teachers and Additional Demand

A. Data used and estimation methods

The source for the annual number of public elementary/secondary school teachers is the NCES Common Core of Data collected each year from the states. Because NCES no longer collects data on teachers by elementary/secondary level, the distribution of elementary and secondary teachers is obtained from the National Education Association (NEA) and then used to prorate the NCES total into elementary or secondary.

Projections of classroom teachers in elementary and secondary schools are based on the enrollment projections by organizational level and the alternative projections of teacher-pupil ratios. Again, NEA estimates are used to prorate NCES enrollment counts into elementary or secondary. Since the 1982 edition of Projections, teachers-per-1,000- pupil ratios have been used instead of pupil-teacher ratios. The projections of classroom teachers represent the total demand. The demand for additional teachers represents the number needed to replace teachers who leave the profession and to provide for changes in enrollment and staffing patterns.

Estimates and projections of the demand for additional teachers are computed as a sum of the following components: (1) the number of additional teachers needed for teacher-pupil ratio changes (which is computed as the difference between the total teacher demand in a given year, less the estimated total teacher demand in the same year had the teacher-pupil ratio in the previous year remained constant); (2) the number of additional teachers needed for enrollment changes (which is computed as the difference between the total teacher demand in a given year and the total teacher demand in the previous year, less the computed number needed for teacher-pupil ratio changes in the given year); and (3) the number of additional teachers needed in a given year to replace those leaving teaching either temporarily or permanently (computed as an estimated percentage of the total number of teachers employed in the previous year). The replacement rate, currently estimated at 6 percent, was chosen to reflect tighter job market conditions in the 1970s and 1980s than those that prevailed in the 1960s when the rate was recorded at 8 percent.

The last time data on replacement were collected was in the sixties. Yet this turnover rate is the single largest determinant in the model projecting demand for additional teachers.

B. Problems with the model and data

In 1983 the projections staff conducted a systematic evaluation of the accuracy and consistency in the projection series. Projections of total demand and supply were evaluated, but demand for additional teachers was not evaluated because the entire series was estimated, there being no empirical data for comparison. The evaluation showed that projections of classroom teachers in public schools have been fairly accurate, with about 1 percent error for 1-year-out projections, growing to about 5 percent errors for lead times of 6-10 years. These figures are somewhat misleading because the projections being evaluated include the effect of errors in enrollment projections. In the 1970s, teacher projections were accurate but for some of the wrong reasons, since the projections were based on enrollment projections that were too high and projections of staffing patterns that were too low. When adjusted for the error in enrollment projections, that is, when actual enrollment data were used in the model, the projections of classroom teachers were somewhat less accurate, although with relatively low mean absolute percent errors of from 1 percent, growing to 8 percent for longer lead times. In addition, decomposition of the mean square error showed that most of the error was due to problems with the model, even for short lead times.

There are other problems in projecting demand. While basic elementary/secondary enrollment trends may be quite accurate, several factors that conceivably should figure in the demand model have no empirical basis and are not well understood. For example, demand in the current model cannot register changes in staffing needs brought on by the introduction of new technologies or by recent changes in high school graduation requirements.

Supply of New Teacher Graduates

A. Data used and estimation methods

Data used to project the supply of new teacher graduates include (1) bachelor's degrees from the NCES Higher Education General Information Survey (Earned Degrees Conferred by Institutions of Higher Education) and (2) new teacher graduates from the National Education Association (Teacher Supply and Demand in Public Schools). From these two sources, historical data are used to calculate new teacher graduates as a percentage of bachelor's degrees. This percentage is then projected under various assumptions and multiplied by projections of bachelor's degrees to forecast the number of new teacher graduates.

B. Problems with the model and data

Projections of the supply of new teacher graduates have only been included in the Projections publication since 1978. It does appear that projection errors are large, with a 14 percent error for even one lead year. And since most of the error appears to be due to problems with the model, the development of new forecasting models in this area is currently being examined.

Projection Model Results

When comparing the estimated supply of new teacher graduates to the estimated demand for additional teachers, the most recent analysis showed a surplus of new teacher graduates through 1981-1982 followed by relative equilibrium of supply and demand into 1984-1985. Again, the supply and demand being compared here are not those of the total teacher work force, but only the supply of new teacher graduates and the demand for additional teachers. Furthermore, this is a national picture and is not disaggregated to portray regional conditions or situations in particular fields.

The intermediate alternative projections show supply falling short of demand starting in fall 1985 as enrollments in the lower grades begin increasing. Supply is projected to represent 92 percent of demand in fall 1985, declining to 66 percent in fall 1992. Approximately two-thirds of this demand is expected to be at the elementary school level. Increased demand for secondary school teachers is projected to begin after 1990, stimulated by enrollment growth. These intermediate projections assume relative stability in the proportion of recent bachelor's degree recipients qualified to teach.

Current NCES Activities Related to Teacher Supply/Demand

NCES has several projects under way to improve the current model and the data on teachers.

A. Development of alternative models to project teacher supply and demand

Starting in August 1984, NCES contracted with the operations research department of Case Western Reserve University to develop alternative projection models of teacher supply and demand. The contractors--Burton V. Dean and Arnold Reisman--along with Edward Rattner of the Department of Education, conducted a similar study in 1971, developing projections models on "Supply and Demand of Teachers and Supply and Demand of Ph.D's." When NCES staff evaluated their own projections and examined the results of others, they found that the Dean, Reisman, and Rattner projections of Ph.Ds were particularly accurate. The approach of Dean, Reisman, and Rattner included using a Delphi method, which may have contributed to their success. This method allowed for a formal procedure to use the judgment of a group of experts to provide alternative values for the model. Under the 1984 contract with NCES, Dean and Reisman will review alternative models and develop projection models that incorporate the Delphi method.

B. Survey of Demand and Shortage

The 1983-1984 Survey of Demand and Shortage is the third NCES survey in recent years to deal with the teacher shortage question. The last data collection of this kind was in 1980, when the concern was more over layoffs than shortages. Other changes from the previous survey, described in the agenda book for the conference, include (1) a clarification of the definition of shortages and (2) the reporting of full-time equivalents by field. The 1983-1984 survey defines a shortage as a teaching position that was vacant, withdrawn, or transferred to another field because a candidate could not be found, including one filled by a temporary substitute. So if, for example, an opening in math was filled by an English teacher because a math teacher could not be found, the position would still be recorded as a shortage in math. The reporting in full-time equivalents will refine the data collection and consequently the analysis by disaggregating teaching time by field. As an example, for those teachers who teach both three classes of physical education and one class of physics, the survey will be able to register the quarter-time assignments and whether the teachers are certified in both fields. In the previous survey, head counts were reported only in the principal field of assignment, thus missing those fractions of time (which may add up) spent teaching in other fields. Results of the survey can be expected in the fall of this year.

C. Public School Survey

NCES is also initiating a public school sample survey that in 1985 will collect baseline data on current teachers. By sampling schools and teachers, the survey will obtain basic information from teachers within their various school settings. Teachers' backgrounds, training, and experience will be described in relation to current teaching assignments. This survey will produce estimates, by field of assignment, of the number certified to teach in that particular field, the age and years of experience of teachers, and the salaries, incentives, and outside employment of teachers. From the Public School Survey, it will be possible to gauge to what extent science and math teachers are trained in their field of assignment, at what time in the future most will reach retirement age, and what incentives are currently being offered to retain them. Public use tapes from this survey should be available by fall 1985.

D. Recent College Graduate Survey

A survey of Recent College Graduates is planned for 1985. This will be the fourth in a somewhat periodic series of surveys of recently graduated bachelor's and master's degree recipients. The last data collection was in 1981. The major emphasis of this survey is on graduates certified to teach and those who teach in the year following graduation. The 1985 survey, with its expanded sample of some 18,000 graduates, will permit a more detailed analysis of field of specialization than was possible in earlier surveys. Specifically, the analysis will focus on graduates certified to teach in the fields of special education, mathematics, and sciences and those teaching these subjects in the year following graduation. The employment and education experience of graduates who were trained in these fields but did not teach following graduation will also be analyzed. Public use data tapes are expected to be available in the winter of 1986.

In summary, this presentation of NCES's fairly simple model of teacher supply and demand was intended to clarify some of the rather shaky assumptions on which it rests and to show the need for additional data.

Gus Haggstrom of RAND drew a striking similarity in the discussion that followed between supply/demand resolution in the military and the apparent supply/demand resolution in many of today's secondary schools with respect to science and mathematics teachers. In the military, supply always equals demand--adjustments for quality bring them into balance. If there is a personnel shortage, qualifications are lowered until the gap is filled. Similarly, statistics on the science/mathematics teacher shortage may not show a shortage, to the extent that the needed positions are being filled--with underqualified personnel. This situation in secondary schools may last for the next several years, until the 1990s or beyond bring new waves of college graduates into the job market. But for the near future, the "market" solution is a serious problem. The market does not clear itself, because information about the market is not available to students. Incentives must be created to change the pipeline for teachers, to update teachers' knowledge, and to professionalize the teaching profession. Programs are needed to stimulate the supply of science and math teachers. These real imbalances are only partially suggested by the existing data used in the NCES model.

Haggstrom concurred with the weaknesses that Plisko noted in the NCES model, and he emphasized that one main limitation was its reliance on its own earlier feeder projections. The demand projections depend heavily on the turnover rates. The data particularly in need of prompt improvement are data relating to turnover. He believed 6 percent to be an underestimate.

In any study undertaken, he emphasized, it is crucial to obtain enough reliable data to describe, estimate, and project turnover.

He also expressed concern about supply projections that depend on projections of new teacher graduates because of assumptions, questionable in his opinion, that are made in projecting new teacher graduates as a percentage of bachelor's degrees. The intermediate alternative assumes the 1982 percentage will hold for the next 10 years and the high alternative assumes a reversal of the decreasing trend experienced in the past 12 years.

Charlotte Kuh of AT&T concurred with Haggstrom's technical analysis of the NCES projections and amplified the importance of a turnover rate more reflective of reality. Historical context can help explain a low or high turnover rate. In the late 1960s, for example, one could get a military deferment for teaching; a policy that might explain, in part, the low turnover rate of 6 percent noted in 1968.

The turnover rate by number of years in teaching is an important statistic, in Kuh's opinion. To what extent do science or mathematics teachers leave in the first three years? After 15 years? Not until retirement? The substantive problems of shortage and quality would be different for the different ranges of teaching experience. Moreover, one would want data on where those who quit go--to teach elsewhere, in another school, at another grade level, or to leave teaching? Such information should be obtainable rather easily. What was learned in the follow-up of graduates after a year's experience?

Responding to Haggstrom's description of the supply/demand similarity in the military and in teaching, Kuh pointed out that quality adjustment to disequilibrium--downward <u>or</u> upward--is not a long-term adjustment but one that can be made relatively quickly. She was confident that one can get higher-quality people into science and mathematics teaching at a time when they will assuredly be needed--in the 1990s. There is time now to build and refine the models, to find out how great the problem is and to set forth appropriate policies. There is lead time to do something useful, she affirmed.

Kuh commented on the need for a variety of models for use in policy analysis and expressed the hope that the proposed study would develop such models. She discussed data needed for some specific policy purposes, stressing that in most cases the data simply do not exist. For example, some alternative policies or policy preferences currently include:

- merit pay, salary increases, summer supplements,
- improving working conditions, summer institutes, seminars,
- relaxing certification requirements, bringing in qualified non-teachers as teachers, borrowing teachers from industry, and
- more substitution of capital for labor, e.g., use of computers and computer software to help teach.

There are almost no data to uphold or discredit any of these policies. From such issues can be generated specific data needs and plans for the collection of data. Working from policy questions to specific data needs, one can then decide to add certain data to the NCES system, or add to state or district systems, or to design new data sets.

Going back to the models, the policy issues help suggest what could be done to make the NCES projections a bit richer. For example, a variable for female labor force participation rate could be added to the supply model to account for the fact that education faces increasing competition from other segments of the labor market for the female labor force. Or the demand model could introduce a variable for substitution of capital for labor, e.g., some refinement of computers/student. (To date computers have been used as an extra mode of teaching rather than as a substitution of capital for labor, but this may change.)

Building on the proposed policies to increase salaries, Kuh stressed the importance of targeting such policies and of obtaining data on how the target groups in the reserve pool of teachers (people certified to teach but not teaching) might respond to the policies. She suggested obtaining data for three groups of the pool who might respond differently to incentives: (1) those not teaching but who are employed in science- or mathematics-related work; (2) those not teaching but who are employed in other jobs, not related to science or mathematics; and (3) those not employed. These groups probably have very different characteristics and would respond differently to salary policies and incentive programs. She stressed the importance of the data from a policy viewpoint; without data more money can be directed to a problem than needed, or a program can be established with no response at all.

Because of the regional variation in teacher shortages mentioned earlier, Kuh also suggested more district-level or state-level projections and that different socioeconomic variables be taken into account. Many of the shortage problems are local or regional in nature and would respond best to tailored incentives, e.g., fellowships tied to teaching in areas with understaffed schools.

She pointed out that, although the NCES collects teacher data for states and school districts, such data suffer from the problem that the teachers leaving the education system cannot be differentiated from those moving to a school in another state or district. Kuh suggested further the desirability of a longitudinal study of certified teacher graduates for a fuller picture of their teaching positions, career incentives/disincentives, and turnover. It should be possible to identify the certified teacher graduates and sample them. Buccino and Smith added that it is important to study nonteaching college graduates as well, including those who might have gone into teaching were it not for more attractive alternatives. Haggstrom suggested narrowing the question to how more talented graduates can be drawn into teaching. The "sorting out" problem is very complex. To answer this important question, better longitudinal data are needed on graduates. Crosswhite mentioned that it would be important to ascertain how fully we are using the trained science and mathematics teachers in the system today. Are they underutilized?

Richard Murnane commented that a high turnover incidence among science and mathematics teachers, with people entering and leaving teaching for spans of a few years, is not new and is not necessarily a problem. It is important to know the circumstances behind a teacher's leaving, and the circumstances that spur a nonteacher to enter teaching, if only for a few years. For policy purposes, in the short term, it may be important to know how to get bright people into teaching for a few years. Special on-the-job training might be required, and it could be costly. It may be possible that an external factor, such as a very strong retirement plan, may have the unintended effect of keeping teachers in teaching longer than desired, perhaps dulling their enthusiasm and effectiveness over the years. Turnover and length of teaching thus need to be reexamined, but first new data must be collected.

DATA ON SUPPLY AND NEEDED IMPROVEMENTS

Nancy Borkow of the Congressional Research Service discussed three broad categories of supply data pertaining to the total pool of teachers prepared to teach: current teachers, prospective teachers and new recruits, and the reserve pool composed of former teachers and graduates who have never taught.

Current Teachers.

Borkow cited data derived by the National Science Teachers Association (NSTA) from a survey of 2,000 principals to estimate that there may be about 107,000 mathematics teachers and 92,000 science teachers of the secondary level in 1982-1983. Of the total, the association estimates that 60,000 were underqualified (insufficiently trained, misassigned, or using emergency certificates). The data cited, however, are unreliable as a basis for national policy making because of the low response rate to the survey.

NCES reports that 40 percent of the pool of first-year teachers of science and math in May 1981 were not certified in the field in which they were teaching and 13 percent were not certified in any field. One reason for the high proportion of misassigned teachers is that many states have low certification standards. In half the states a teacher certified to teach a specific science is allowed to teach any science. In 14 states any certified teacher can be assigned to teach mathematics or science.

She cited the Howe and Gerlovich survey of science supervisors in 50 states in 1982 in which teacher shortages were reported in mathematics and all fields of science except biology. Borkow cited three factors that are expected to exacerbate the shortage of qualified science and math teachers:

the age distribution of teachers, which implies that 40 percent of the current teachers will retire by 1995; the demographics, which mean that by the mid-1980s there will be an increase in enrollment in elementary schools and in the early 1990s in the secondary schools; and the increase in science and mathematics requirements for high school graduation.

Among the data needs on current teachers, Borkow called for:

a. More information on the pool of misassigned teachers--information on their background in the subject they teach, any upgrading of skills in which they are engaged, whether they are working toward certification in the field in which they are teaching, and more accurate estimating of the size of the problem at the district, state, and national levels;

b. More state-level and district-level data about the math and science teacher shortage--more reliable data than those obtained from opinion surveys, information on whether the shortage is more serious at the elementary level or at the secondary level and how this might change over time; and

c. More information on the actual preparation of the reportedly "adequately trained" teachers of the various science subjects.

New Teachers

Borkow described NSTA data from a 1981-1982 survey showing declines in the number and quality of teacher candidates from 1971-1981. She noted that the number of people ages 19-25 will also decline in the near future, and this is the age group that constitutes the pool of potential new teacher training graduates. NCES reports that in 1981, 25 percent of those certified to teach mathematics did not apply for teaching jobs. Selected state data show similar trends; for example, in North Carolina, 50 percent of those trained to teach in math or science in 1980 did not go on to teach.

She called for follow-up information on new graduates newly hired. Why do some leave teaching after one or two years? Data are needed that would help design new incentives to attract the best qualified science and mathematics teachers into the profession.

The Reserve Pool.

Borkow pointed out the extremely limited information that exists on the pool of potential teachers who have certificates but are not now teaching. In 1970 NCES reported an estimated 30,000 unemployed experienced teachers (at the time of the teacher surplus). In 1980 NEA estimated 660,000 former teachers not currently in the labor market.

Data needs on the reserve pool are almost all-inclusive, Borkow suggested. How many certificated individuals are employed in nonteaching jobs? How many of them were certified in math or science? How many of them reenter the labor market or the classroom each year? How many never sought teaching positions, and why? Timely data of comprehensive scope are needed, in Borkow's view. Without these data we cannot even begin to project accurately the future supply and demand estimates.

The discussion that followed was related to data on the three broad groups of the teaching supply. The consensus of the discussion relating to current teachers was that more data are urgently needed on the qualifications of current science and mathematics teachers. The problem is not one of quantity. In schools a shortage of science teachers can be filled immediately by underqualified individuals--uncertified, temporarily certified, or even formally certified but under such low standards that virtually anyone can teach the given science or mathematics course. In the interest of keeping jobs, districts and unions can help teachers fill vacancies within the district. In fact, a less-qualified current teacher can often move laterally to fill a science vacancy, beating out a new college graduate majoring in that discipline who applies for the first time to that school district. And, according to Bill Aldridge, many underqualified teachers and their administrators believe they are quite qualified because the teachers meet state certification requirements. Thus, it is imperative to gather data on the qualifications of the present stock of current teachers. Such data should be finely tuned or should show gradations in qualifications, as suggested by Crosswhite. The purpose of collecting such data is not to belittle teachers, but to point up weaknesses in the systems of certification; in systems of hiring, transferring teachers, and judging qualifications; and in systems of requirements for in-service training. The standards used in these systems may be very low, and that is what new data collection could ascertain. It also is important to identify the underqualified teachers and to provide retraining programs for them.

With regard to new entrants to teaching, the standards each state requires for certification to teach science or mathematics should be collected and compared. Data are needed state by state, preferably in the same level-of-gradation form as suggested above.

Information on supply and characteristics of new B.A.s should be supplemented extensively with salary and qualifications data to permit carrying out sensitivity analyses. What would be the supply response to changes in salary, in nonsalary benefits (i.e., retirement benefits), and changes in qualifications or certification requirements? Scheaffer anticipates some dramatic curriculum changes in mathematics in the next five years and stressed the importance of studying the effect on supply and demand in this dynamic system over the next five years.

"New" teachers who fill vacancies should be distinguished as to whether they are (a) new hires to the system just graduated from a teacher training institution, (b) new hires to the system who were certified years ago but did not teach until now, (c) reassigned from within the system or district. If data collection focuses in part on the new teaching graduates and how they fare in their job search, these other groups constitute their competition for vacancies, and information on their job and career paths should be gathered in this context.

On data relating to the reserve pool, it was the consensus that most relevant information about this vast pool could be gained through experimenting with various incentives concerning salaries and certification and their likely effects on would-be teachers. Efforts should be made to capture data in states that are taking such initiatives in response to the apparent shortage of qualified science and math teachers.

DATA ON DEMAND AND NEEDED IMPROVEMENTS

Alan Ginsburg, director of planning and technical analysis at the Department of Education, spoke on the topic of data on demand for precollege science and mathematics teachers. He pointed out that the current sources of data relating to demand really do not address demand, but by selecting the right "demand study" one could prove shortage, surplus, or balance. These differences in results matter greatly to the question of whether the nation should try harder to attract more high school science and mathematics teachers relative to other types of teachers.

Current demand studies do not attempt to estimate separate equations for the demand for and the supply of science or mathematics teachers. Instead, they estimate such variables as vacancies or shortages that reflect both demand and supply effects; nor do current studies adjust for differences in demand in relation to teacher quality or price.

The different results across studies reflect differences in methodology. Ginsburg distributed a description of five current demand studies (Table 1) and three studies that attempt to address quality (Table 2).

Demand Studies

In commenting on Table 1 Ginsburg made the following points concerning specific studies:

o Opinion data (see nos. 1 and 2) of "experts" (i.e., university teacher placement officials or state science supervisors) show severe shortages of math/science teachers. In actuality, these highly publicized findings are difficult to interpret, because opinions do not translate into quantitative numbers of shortages and represent individual perceptions that lack uniform definitions.

o Head count information (see nos. 3 and 4) on the number of unfilled positions indicates that shortages in math/science fields are not severe. Unfilled positions tend to amount to less than 2 percent of total positions. However, the head count data do not speak to the qualifications

TABLE 1 Math and Science Teachers: A Sampling of Current Demand Studies

Title	Methodology	Findings	Problems
1. Teacher Supply/Demand by Field and Region, James Akin, Kansas State University, 1984.	1983 opinion survey of 60 university teacher placement officials representing all regions of the country. Placement officials are asked whether there is a considerable shortage, slight shortage, balanced, slight surplus, or considerable surplus of teachers in various subject areas.	Math, physics, and chemistry received ratings of "Considerable teacher shortage"; earth and general science received ratings of "Slight teacher shortage."	It is not possible to translate opinions into quantitative data on the magnitude of shortage. Individual perceptions of "shortage" may or may not include issues of quality, teacher turnover, or filling math and science vacancies with teachers from other assignment areas.
2. National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers, 1980-1982, Howe and Gerlovich.	A survey of all state science supervisors was conducted in 1980, 1981, and 1982. Supervisors ranked their estimate of the available supply relative to demand of biology, chemistry, physics, general science, earth science, and mathematics teachers in their respective states. The rating key was: 1 = surplus; 2 = slight surplus; 3 = adequate; 4 = shortage; 5 = critical shortage.	1982 mean shortages were: biology 2.81; chemistry 4.16; physical science 4.43; general science 3.17; earth science 3.82; math 4.37	Survey has been discontinued. See no. 1 above.

TABLE 1 (Continued)

Title	Methodology	Findings	Problems
3. Survey of Teacher Demand and Shortage: School Year 1979-1980, NCES.	Nationally representative survey of 1,448 Local Education Agency public school district administrators and 875 administrators of other units, such as private schools. Figures are based on head counts (not full-time equivalents) of full-time and part-time teachers.	Opinion Data: Administrators were asked their opinions as to whether the demand for teachers was expected to increase or decrease over the next 5 years. The data are not published. Head Count Data: Total shortage for teachers in all fields was .4%. Out of a math teaching force of 15,000 there were 900 shortages (defined as number of openings for which teachers were sought but not hired for the 1979-1980 school year) nationwide (.6%) in elementary and secondary schools combined. Out of a secondary biology teaching force of 30,000, there were 100 shortages nationwide (.3%). Out of a secondary physical sciences teaching force of 25,000, there were 600 shortages nationwide (2.4%).	Data subject to individual interpretation of the term "demand"; individual perceptions of demand may may not include issues of quality, class size, awareness of teacher turnover factors, etc. "Position Openings" by assignment were indicated to their existence, but actual numbers were not reported. Definition of "shortage" m or may not omit those positions that were filled by teachers in other assignment areas rather th by new hires. Districts may have eliminated unfilled positions. Full-time equivalent's not used in reporting. Persons teaching in more than one field are reporte in the field in which they spent most of their teachi time. While "numbers of teachers laid off" are reported, other factors relevant to teacher turnover are not addressed.

TABLE 1 (Continued)

Title	Methodology	Findings	Problems
4. Survey of Teacher Demand and Shortage, School Year 1983-1984, NCES.	See no. 3 above except that full-time equivalent's are indicated.	Head Count Data (full-time equivalent): Unpublished preliminary data findings based on 50% of completed returned questionnaires; percentages are weighted to represent the entire sample. All shortages (defined as "positions vacant, abolished, or transferred to another field because candidate was unable to be found) are less than 1%; physics shortage is one of the higher percentages, but still less that 1%.	"Shortage" definition is fairly rigorous, and several respondents indicated by telephone that they would have preferred to include certified teachers who are less-than-qualified in the shortage definition. Teacher turnover not addressed.

Title	Methodology	Findings	Problems
5. Teacher Supply and Demand in Public School, 1981-1982, NEA.	Opinion survey of college placement officers in 1981. Placement officers provided opinions on extent of teacher shortage on rating key: 5 = considerable shortages; 4 = slight shortages; 3 = balanced; 2 = slight surplus; 1 = considerable surplus.	Opinion Data: College placement officers rated shortage by field of assignment on a scale of 1-5. Result presented as "Average rating of supply versus demand as percent of rating used to denote balance between supply and demand": math 62.4 natural and physical sciences (total) 68.0-82.0	Subject to individual interpretations of "shortage"; math or scienc vacancies filled by teache from other assignment area may or may not be perceive as shortage. Note variation between opinion and supply and demand estimation presente below.
	Study statistics provide estimates derived mostly from other data bases such as NCES and Census. The demand for each assignment is estimated by apportioning the total demand for the level in which the assignment is classified; this is done on the basis of the percentage distribution of the number of beginning teachers among these assignments reported by nine states last year.	Demand and Supply Estimation: Supply as percent of demand for secondary public school in fall, 1981: math 82.2 natural and physical sciences 149.1	Report discontinued Findings do not indicate demand for math and scienc in particular; findings ar based on aggregate numbers from different sources.

TABLE 2 Math and Science Teachers: A Sampling of Studies Addressing Quality

Title	Methodology	Findings	Problems
1. Survey of Principals on the Status of Science/Math Teaching in the United States grades 7-12, 1981, James Shymansky.	A one-page questionnaire was mailed to 2,000 principals (sample from the U.S. Registry).	For the school year 1981-1982, among newly employed science and math teachers, 50% were unqualified to teach science or math.	Only newly employed science and math teachers were considered. No comparisons are made wit teachers in other field-. (The Condition of Education 1983 edition reports that for May 1981, approximately 50% of English Language Art teachers are uncertified in the field they are currentl teaching.) Nonresponse was a major problem (e.g., 60 percent nonresponse rate).

TABLE 2 (Continued)

Title	Methodology	Findings	Problems
2. Survey of Teacher Demand and Shortage: School Year 1983-1984, NCES.	See no. 1 above.	Unpublished preliminary data. Findings based on 50% of completed returned questionnaires; percentages are weighted to represent the entire sample. 2.41% of biological and physical sciences teachers are uncertified to teach in those areas. 2.24% of mathematics teachers are uncertified to teach in the field. Percentages are higher for bilingual education (10-21%), computer science (4.22%), vocational education (4.12%), and special education, (3.40%), for example.	Certification requirements vary widely from state to state, and they do not necessarily reflect competence.

TABLE 2 (Continued)

Title	Methodology	Findings	Problems
3. Public School Survey of Administrators and Teachers, 1985, NCES.	Survey conducted in February 1985, with a nationwide sample of 2,800 public elementary and secondary schools.	Unpublished preliminary data. Findings based on 50% of completed returned questionnaries; percentages are weighted to represent the entire sample. When completed, findings will include detailed data on teachers college training (credit hours by subject), major, certification, teaching experience, subjects taught, training and retraining received, and subjects taught (including math and physical sciences) without accompanying regular or state certification.	Only 4 teachers per school will be surveyed; math and science teachers may or ma not be surveyed. It will not be possible to draw reliable national conclusions.

of existing teacher force or adjust for the possibility that districts have eliminated unfilled positions.

o NCES estimates of demand and shortage (see no. 4) show shortages in all fields are less than 1 percent (note: this contradicts no. 1). A serious limitation of the estimates is that they are not reliable with respect to math and science in particular. Demand estimates may also reflect supply considerations (i.e., class size).

Studies Addressing Quality

Studies of teacher quality are generally limited to using state certification requirements as the criterion of quality. However, certification requirements vary widely from state to state and they do not necessarily reflect teacher competence.

Data on newly employed science and math teachers (see Table 2, no. 1) show that in 1981-1982 50 percent or more of these teachers were employed outside their field of certification. However, the interpretation of these data is not straightforward for two reasons: (1) NCES data for 1981 for other fields, such as English, also show a percentage of newly employed teachers not certified in the field they are teaching that approaches 50 percent and (2) NCES 1983 preliminary findings on total number of uncertified teachers, not just new hires, show that only about 2 percent of all math/science teachers lack certification in their primary field of teaching.

Some suggested improvements in the data offered by Ginsburg were:

o Opinion data: The opinion data seem to have seriously misrepresented the nature and magnitude of the math/science problem. Although these data have their place as a relative barometer of expert views, they should not be used in isolation from information based on clear definitions.

o Teaching position openings: No survey currently collects data on the number of teaching positions that opened in math/science during the past school year. These data come closest to yielding head counts on teacher demand.

o The real problem is teacher quality, not quantity, but quality is not easily measured. Using certification as a sole measure of teacher quality poses a serious concern due to large differences in requirements. Furthermore, certification does not ensure successful teachers. Future research should focus on the definition and measurement of attributes of successful teaching in math and science.

According to Ginsburg, major issues of modeling demand that must be addressed include:

o Assuming available qualified applicants, can districts hire them? For example, to what extent must districts fill math/science vacancies with on-board teachers from other fields?

o Are districts willing to make trade-offs (i.e., increase class size while upgrading salary levels) to hire qualified math/science teachers? Note: Japan has a pupil/teacher ratio of about 45:1, compared with the U.S. ratio of 26-30:1.

o What are the ways in which districts are willing to relax certification requirements, and what effect does this have on the quality of applicants? For example, New York City reported an increase in applicants (for all fields) after temporarily delaying school certification requirements.

o What effects will increased graduation requirements have on future demand? Note that high school students are already taking more math than previously, but it is believed that this increase reflects remedial course work. How do the formal mandated increases actually translate at the district/school level?

Ginsburg suggested a need for much refining of data related to demand for science and mathematics teachers. At the same time, similar data on all other major teaching fields should be included for a more accurate general picture. Some specific data needs for studying or modeling demand are:

o Geographic disaggregation: Most studies fail to present any detailed breakouts on how demand might differ by geographic area. This is unfortunate because changes in enrollment patterns differ considerably among regions and states, as well as by size of district.

o Subject area divisions within science or mathematics: Demand estimates may fail to discern a shortage in certain subject areas because of their aggregation into broader curriculum areas. For instance, the demand for teachers of higher-order math subjects may grow rapidly, but this trend would not be observed in highly aggregated statistics.

o In the context of all fields, not just science and math: Data on the magnitude of the math/science teacher problem are much more informative if they are placed in the context of the same type of information for teachers in other fields. Hence, where funds permit, surveys should not focus solely on the math/science teacher problem.

o Consistency: A good barometer of the demand for math and science teachers must reflect consistency of measurement techniques used over time. Unfortunately, such information is extremely limited because ongoing surveys have been terminated and radical changes in instrumentation for continuing surveys occur frequently. Future efforts should attempt to correct these shortcomings.

In the discussion that followed, Crosswhite pointed out the need to be keenly aware of the interests served and the purposes for which various data are used. The data presented (or collected) can differ markedly depending on one's audience and policy purpose. For example, the 1983 edition of The Condition of Education notes that for May 1981 approximately 50 percent of English/language arts teachers were uncertified in their field. But when a state applies for certain funding, such data would not be cited, or even collected or compiled in such a way.

Sally Pancrazio, manager of research and statistics for the Illinois State Office of Education, stressed the need for data and models to center on the state level, and be aggregated from there. State policies--on high school graduation requirements, course offerings, salaries, certification changes, class size--have significant impacts on teacher supply and demand. These policies vary significantly among states, and local requirements are often higher than state requirements. Illinois, like some other states, has a model of current teacher supply and demand, and state experience could guide a national modeling effort. Illinois is 1 of 11 states that conducts an annual survey of teacher supply and demand. With regard to earlier discussions on replacement rates: in 1983-1984 in Illinois the replacement rate for science and mathematics teachers was 5.5 percent and for all other teachers was 7 percent. In 1983-1984 there were no unfilled vacancies in science or math.

Pancrazio offered additional advice on demand modeling:

- o Data should be added annually, for continuity and comparability over time.
- o A model should apply to all major teaching subjects.
- o Better quantitative information is required to compare number of peo' e being trained to teach in relation to the number of available jobs. For example, in Illinois these ratios are 5:1 for elementary teachers, 2:1 for science teachers, and 1:1 for math teachers.
- o Better quantitative definitions of critical shortage, moderate shortage, and slight shortage are needed.

Harold Nisselson of WESTAT disagreed with those who called for state-level data. It is difficult to get good subnational data to use in conjunction with state education data. Improvements are needed in phrasing questions on the NCES Public School Survey, and much better coordination among federal and state data collection agencies is needed, for example to standardize definitions. But with such coordination and refinement of particular questionnaire items, it is possible to use national data as a basis and from there to disaggregate. He believed that although the NCES model has serious limitations that marginal improvements might not overcome, the national estimates can serve as a good basis. Nisselson called for models with a finer structure, acknowledging the plans to refine the NCES models. He called for longitudinal surveys of teachers witn linkages to longitudinal surveys of the labor force, such as the Parnes survey. Special studies are needed on the determinants of demand.

He also stressed the importance of addressing the statistical implications of including "need" in the concept of "demand," when need is defined to be the precollege education in science and mathematics recommended by experts in those fields as desirable if we are to have a scientifically literate population in the United States.

Relating to the quality of teaching and the problems of the three studies outlined by Ginsburg, Bill Aldridge reported on NSTA's current project aiming to identify those teachers who are teaching two or more subjects (i.e., biology and chemistry; biology, chemistry, and physics). Such incidence suggests that the teacher is teaching at least one subject out-of-field.

David Smith seconded the importance of knowing the context behind data on the incidence of out-of-field teaching and teaching on temporary certificates. Crosswhite illustrated the importance of context by pointing out that to become certified to teach physics, one might have to take enough mathematics units to be certified in mathematics as well as in physics. One teacher could easily be multiply certified.

There was consensus on the need for data on vacancies and detailed data on the resolution of vacancies. These needs seem to argue for a state/local level for certain data collection and aggregating to the national level from there. Jean Vanski of NSF suggested that to avoid the cumbersomeness of a model with a 50-state disaggregation, the major states with the better data should form the basis of the modeling effort.

If there is to be a state-based effort, funding should be given to the states to support it, noted Al Buccino, since some states could not supply data without special surveys. Ginsburg noted that this is a time of opportunity--funding is likely to be available to the states. House Bill 1310, as amended by the Senate and signed into law August 11, 1984 (P.L. 98-377), aims explicitly at improving the quality of mathematics and science teaching in the United States. It provides funds to states for surveys of supply and demand of science and math teachers. Among other measures, it encourages school-corporation exchanges in which teachers can gain science-related work experience and industry specialists can teach. It also provides an incentive program of scholarships for undergraduates who intend to become science or mathematics teachers.

ACTIVITIES FOR THE PROPOSED STUDY

Richard Murnane of the Harvard School of Education opened the discussion of activities appropriate for a National Research Council study by discussing work that could be done to improve the quality of the models. He pointed out those statistics he considered most important to estimate.

Three activities on which the proposed study could focus, relating to the supply/demand models, are: (1) improving the mechanics and the data components of the model; (2) modeling factors that affect the career choices of prospective teachers; and (3) including in the model policies and their effects.

(1) Murnane suggested three ways NCES could improve the model now used:

a. A better estimate of turnover (turnover is part of both supply and demand). If the experience distribution of the stock of teachers and, for each range of years of experience, their attrition rates were known, we would have a better idea of turnover. Some states already have such information (Illinois, New York, Michigan, and California, for example), which NCES could obtain and use in an attempt to produce national turnover estimates.

b. On the supply side, more informative data on qualified versus less-qualified teachers. NCES could try to distinguish between being formally certified and being substantively qualified. For example, how many hours of course credits did a given teacher take in each subject taught? In other words, there are some measures of quality on which data could be collected.

c. On the demand side, include any increased high school graduation requirements and try to assess their net effects on staffing and course needs. What percentage of students in particular states already fulfill the increased requirements?

(2) It would be desirable to try to model what factors affect career choices of prospective or potential teachers. Include women's labor force participation rates, as Charlotte Kuh suggested. Though difficult, Murnane thought this would be a step toward making the model more realistic and less mechanical.

(3) Another difficult but worthwhile effort is to structure the model so that policies and their likely effects can be studied. For example, one should have the capability of seeing what effect an x percent increase in salary would have on attracting people to teaching (as opposed to alternative, comparable private-sector careers).

Stephen Barro emphasized the importance of thinking of supply and demand as functions rather than numbers. If our supply and demand estimates are going to be useful for any kinds of policy purposes, we must look at supply and demand functions as a supply/demand response model. If we are interested either in prediction or in evaluating impacts of proposed policies, what we need are not fixed estimates of numbers of people who are or will be teachers, but conditional estimates that can be connected to specific assumptions about the policies themselves or about external conditions. To be more concrete, given the policies that are currently debated, demand functions are needed that relate the numbers of high school science and math teachers wanted by school systems to levels of funding (overall and for science and math) and curriculum requirements. Thus, salaries, or what it costs districts to hire science and math teachers, have a place on the demand side of the model. Barro would not take for granted a great deal of price sensitivity on the demand side.

Supply functions are needed that relate the numbers of people who present themselves to teach science or math to the attributes we require of them (i.e., math and science background and preparation) and to certification and hiring rules. How do we define eligible teachers, where can we find them, and what does it take to draw them in? Salary and other dimensions of compensation are important supply side elements. These other dimensions of compensation, or working conditions, include hours of work required, fringe benefits, and retirement provisions. The latter have an obvious connection to retention rates. To address policies pertaining to such variables, we need to think in terms of supply/demand estimates or models and the supporting data collection that will let us put together supply/demand functions and to create response models that deal with reactions to changes in these variables.

On the demand side, estimating aggregate demand for science and math teachers is relatively manageable, as long as one stays away from including the "quality" variable. This may sound defeatist, Barro said, but it must be kept in mind that we are starting with NCES-type models that give only fixed estimates based on implicit, fixed assumptions about the world; we cannot manipulate them to ask how demand might respond even to gross changes such as a large increase in funding for science and math. If we can improve these models on quantitative grounds, we would be doing well.

Barro also cautioned that it is manageable if we work on aggregate demand, as opposed to net demand, which would require us to estimate retention rates. Such estimation would belong to the supply side, in his view. To estimate aggregate demand, data collection is for the most part feasible. Data could be collected from states or samples of school districts on numbers of teachers (or the teacher input into science and math teaching measured, for example, in hours). Corresponding data would be needed from the same states or school districts on enrollment, composition of enrollment, curriculum requirements, and certain dimensions of finance. With these we can construct at least cross-sectional regression models of the kind that have already appeared in the literature relating numbers of teachers per pupil to the above kinds of variables. Such models would certainly be better than mechanical time trend projections. We should be able to deal with at least gross variables and their effects on demand for science and math teachers.

If such data could be collected for more than a year, we could further look at increments in teaching employment over time and we could focus the model better on response to changes. All this and more complex models are feasible, if one starts without "quality" and considers aggregate demand, at least for the short term. Improved projection and policy analysis demand models seem to be well within the current state of the art with respect to both data collection and modeling.

At present, the development of a "quality" variable is still in a conceptual stage. In the short run Barro is pessimistic about producing a policy-usable teacher demand model that includes both quantity and quality dimensions. Data on quality would have to be at a teacher level and very complex, including numbers of teachers who have different quality-related attributes and the salaries they receive. There would be problems of collection, burden, uniformity, and validation. Even apart from the data complexities, when we talk about models that purport to explain both quantity demanded and quality demanded, they would have to model supply and demand in combination. One must model not only quantity-quality trade-offs, but quality-quality trade-offs. (How are districts going to trade off lower-quality teachers for higher-quality teachers?) To get at these longer-term issues of modeling quality, one route would be microstudies of single states or small sets of districts within them. We have no conceptual basis, much less existing analytical tools, for dealing with this issue.

But in the short term, useful work on the demand side omitting "quality" can certainly be done, as Barro outlined above.

The supply side is harder to model, in Barro's view, for one obvious reason. The actors or units of analysis include the far more inclusive group of nonteachers whose identities and behavior patterns are unknown and not easily observed. One needs supply functions that include all those who would teach if certain incentives were applied. Incentives would include merit pay, differential pay, elimination of certain certification standards, and the like. Such incentives affect retention/turnover rates; thus Barro would view turnover and retention rates as part of the supply side of the model. He urged use of a model that portrays a nonstatic view: How much (and how long) would it take for policy x, y, and/or z to bring in this number, or that number, of people into science and mathematics teaching?

He considers that focusing on the production of newly certificated college graduates as the main item of interest on the supply side is an overly narrow view that neglects the behavior of the existing teaching force and also neglects people outside the system.

In connection with modeling supply, Barro considered it necessary to work separately with four components of supply: (1) those who are now science or mathematics teachers, (2) those who are now teaching, but not science or mathematics, (3) new teacher graduates and those in the training pipeline, and (4) the pool of people in other occupations. (This group is not limited to people certified to teach--it is bigger than the reserve pool discussed earlier.) He reviewed the key data requirements for a supply model for each of the components:

(1) The key statistic required for current teachers is their retention rate. Barro concurred with Richard Murnane's suggestions for better estimates of turnover. He underscored the importance of collecting descriptive information on retention rates of various cohorts in various types of places. If such data were available it would be feasible to model activity to try to explain variations in retention rates in different cohorts among places as a function of policy-relevant variables such as salary level, salary schedule over years, and retirement provisions.

(2) For those now teaching, but not in science and mathematics, one would try to model a transfer or conversion probability that presumably would depend on the additional education required to qualify as a science or

math teacher. Detailed microdata on those kinds of ·fts in fields of teaching would be required--a forbidding data collection requirement. The modeling required is also forbidding because of the many district-specific staffing circumstances.

(3) NCES already has a good deal of information on new teacher graduates. Needed is a way to relate the key parameter in the NCES-type models, the ratio of new teachers to all B.A.s, to policy incentives. It can be done, but individual panel data more concerned with teaching, teaching by field, etc., than existing panel data are needed. More aggregate (national level) modeling could be done with a few gross policy variables, but observable variation in salary or certification rules among places would be lost.

(4) The problem of the pool of people in other occupations is that one cannot estimate responses to behavior that has not been observed. The number of people working in other occupations who apply to teach science or math may be very small and certification may not be possible in many instances. To find out, survey work on new hires would be required. It does seem that in the next several years, some significant new science/math teacher supply must come from people now in other occupations, especially if increased curriculum requirements are real and take effect soon. States may be forced to allow lateral hiring from other occupations and if so, we may have the opportunity of "natural" experimental data.

Emerson Elliott, director of issue analysis in the Office of the Undersecretary of Education, commented that the timing of the conference and the planned study was extremely propitious because of the mathematics and science teaching bill (P.L. 97-388), which provides block grants to the states to conduct an evaluation of teacher supply and demand and teacher qualifications in mathematics, science, and computers. Elliott expressed the opinion that one excellent possibility for the proposed study would be to suggest ways in which the state studies might be carried out. It is unlikely that the federal government will prescribe how the studies are to be done. In Elliott's opinion, the proposed study could well describe the procedures and content for state studies and probably would have substantial influence on what some states do. The study might also help work through some of the questions of definition that have been of recent concern to the Council of Chief State School Officers.

He mentioned that the legislative requirement for the state studies will generate much-needed data. To enhance the comparability and reliability of those data, the proposed study could recommend to the states methods for obtaining reliable data and for surveying efficiently.

He concluded by remarking that this is not the time for a new monumental national data effort. NCES's data can be the cornerstone; states can supply data. When we have so many questions about clarifying definitions in use and in defining quality, case studies of states or school districts are strongly recommended for obtaining greater depth. Emerson Elliott also reflected that given the real need to consider quality, beyond just questions of quantity or supply, perhaps the proposed study should be titled "The Status of Science and Mathematics Teachers."

In the discussion that followed, Gus Haggstrom emphasized that the basic purpose of modeling is to inform users of the real problem. The simpler the model can be and still do the basic job, the better. Only a few data elements are really needed, and a national model can be used--it is not necessary for every state to be modeled. Projections are political instruments, and generally response is inversely proportional to the model's complexity. Charlotte Kuh reaffirmed that the model need not be complicated or laden with detailed data to be useful.

It was the general consensus that the National Research Council study would not actually build a model, although a good model that can simulate policy responses is needed. Rather, such a group would carry out some in-depth case studies of schools or school districts to provide a better understanding of teacher flow through the education system and the factors affecting that flow. The case studies would provide background for making recommendations that NCES and the states could consider in standardizing definitions, collecting data, in making their own models, or in creating profiles of the science/mathematics teaching situation.

PLANNING CONFERENCE

for a

STUDY OF STATISTICS ON SUPPLY OF AND DEMAND FOR

PRECOLLEGE SCIENC_ AND MATHEMATICS TEACHERS

National Academy of Sciences, Board Room
2101 Constitution Avenue, N. W.
Washington, D. C. 20418

August 9, 1984 1:00 p.m.-5:30 p.m.
August 10, 1984 9:00 a.m.-3:00 p.m.

AGENDA

August 9, 1984

1:00 p.m.	I.	Opening Remarks	Linc ln Moses, Chair
		Welcome	Edwin D. Goldfield
1:20 p.m.		Background for th. Conference	Richard M. Berry
1:30 p.m.		National Needs for Data on Qualified Teachers	Bassam Z. Shakashiri
2:00 p.m.	II.	Concepts of a **Qualified** Science or Mathematics Teacher and Related Statistical Problems	David C. Smith
2:20 p.m.		Invited Discussants	Robert W. Parry Alexander I. Law Paul Sally F. Joe Crosswhite
3:20 p.m.		Roundtable Discussion	Lincoln Moses
4:00 p.m.	III.	Models Used by the National Center for Education Statistics to Estimate and to Project Teacher Supply and Demand	Valena Plisko Audrey Weinberg
4:30 p.m.		Invited Discussants	Gus W. Haggstrom Charlotte Kuh
5:00 p.m.		Roundtable Discussion	Lincoln Moses
5:30 p.m.		Adjourn	
5:45 pm-6:45pm		Reception in the Rotunda of the National Academy of Sciences	

<u>August 10, 1984</u>

9:00 a.m.	IV.	Available Data on Supply of Precollege Science and Mathematics Teachers and Improvements Needed in the Data	Nancy B. Borkow
9:20 a.m.		Invited Discussants	Alphonse Buccino Bill G. Aldridge Steven Leinwand
9:50 a.m.		Roundtable Discussion	Lincoln Moses
10:30 a.m.	V.	Available Data on Demand for Precollege Science and Math Teachers and Improvements Needed in the Data	Alan Ginsburg
10:50 a.m.		Invited Discussants	Sally Pancrazio Harold Nisselson
11:10 a.m.		Roundtable Discussion	Lincoln Moses
12:00 noon		Luncheon in the Lecture Room	
1:00 p.m.	VI.	Activities for a Study on Supply of and Demand for Precollege Science and Mathematics Teachers	Richard Murnane Stephen M. Barro Emerson Elliott
1:45 p.m.		Roundtable Discussion	Lincoln Moses
2:50 p.m.	VII.	Concluding Remarks	Dorothy M. Gilford
3:00 p.m.		Adjourn	

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