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Is the Supply of Mathematics and Science Teachers Sufficient?

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This study seeks to empirically ground the debate over mathematics and science teacher shortages and evaluate the extent to which there is, or is not, sufficient supply of teachers in these fields. The authors' analyses of nationally representative data from multiple sources show that math and science are the fields most difficult to staff, but the factors behind these problems are complex. There are multiple sources of new teachers; those with education degrees are a minor source compared to those with degrees in math and science and the reserve pool. Over the past two decades, graduation requirements, student course taking, and teacher retirements have all increased for math and science, yet the new supply has more than kept pace. However, when preretirement teacher attrition is factored in, there is a much tighter balance between supply and demand. Unlike fields such as English, for math and science, there is not a large cushion of new supply relative to losses—resulting in staffing problems in schools with higher turnover.

KEYWORDS: teacher research, sociology, school/teacher effectiveness, organization theory/change

Few education issues have received more attention in the past few decades than the challenge of staffing the nation's classrooms with qualified mathematics and science teachers. Recent high-profile reports from organizations such as the John Glenn Commission (National Commission on Mathematics and Science Teaching for the 21st Century, 2000), the National Research Council (2002), and the National Academy of Sciences

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(2007) have directly tied mathematics and science teacher staffing problems to a host of educational and societal problems—to the inability to meet student achievement goals, to low U.S. educational performance compared to other nations, to the minority achievement gap, to national economic competitiveness, and even to the security of the nation.

There are a number of competing explanations concerning the sources of, and solutions to, these mathematics and science teacher staffing problems. One of the most prominent explanations focuses on teacher shortages. The primary root of the problem, in this thesis, is insufficient production of new mathematics and science teachers in the face of two demographic trends: increasing student enrollments and increasing teacher retirements. Subsequent shortages, this view continues, force many school systems to lower standards to fill teaching openings, in turn inevitably leading to high levels of underqualified mathematics and science teachers and lower student performance (e.g., Blank & Langesen, 2003; Liu, Rosenstein, Swann, & Khalil, 2008; National Commission on Teaching and America's Future, 1996, 1997; U.S. Department of Education, 2002).

Researchers and policy analysts hold, moreover, that these shortfalls affect some locations and groups more than others. Some argue that teacher shortages are geographically based, vary by region and state, and result from an uneven production of new teachers across locales (e.g., Curran, Abrahams, & Clarke, 2001; Murphy, DeArmond, & Guin, 2004; National Commission on Teaching and America's Future, 1997). Others focus on issues of equity and argue that shortages fall disproportionately on schools in high-minority and high-poverty communities and contribute to unequal educational and, ultimately, occupational outcomes (e.g., National Commission on Teaching and America's Future, 1996, 1997; Oakes, 1990; Oakes, Franke, Quartz, & Rogers, 2002; Quartz et al., 2008).

Concerns over teacher shortages, especially for mathematics and science, are not new to the education system. For example, in the 1980s, a series of highly publicized reports trumpeted a similar series of concerns (see, e.g., Darling-Hammond, 1984; National Academy of Sciences, 1987; National Commission on Excellence in Education, 1983). Indeed, teacher shortages historically have been a cyclic concern in the educational system, and references to teacher shortages have long been ubiquitous in both education research and policy (Lortie, 1975; Tyack, 1974; Weaver, 1983).

The prevailing policy response to these school staffing problems, both now and in the past, has been to attempt to increase the quantity of new teachers supplied (see Darling-Hammond, 2007; Fowler, 2008; Hirsch, Koppich, & Knapp, 2001; Liu et al., 2008; Lortie, 1975; Rice, Roellke, Sparks, & Kolbe, 2008; Theobald, 1990; Tyack, 1974). In recent decades, a wide range of initiatives has been implemented to recruit new candidates into teaching—especially targeted to the fields of mathematics and science. Among these are midcareer-change programs, such as "troops-to-teachers," alternative certification programs, overseas teacher recruiting initiatives, and financial incentives, such as scholarships, signing bonuses, student loan forgiveness, housing assistance, and tuition reimbursement.

Research on the Adequacy of Teacher Supply

>Despite the long-standing prominence of this issue as a national policy concern, empirical research on the adequacy of the quantity of the supply of teachers has been surprisingly limited—in data, methods, and measures. There are few sources of comprehensive data, especially at a nationally representative level, on the new supply of qualified teachers. The most readily available data focus on perhaps the most obvious source of new hires: the "pipeline" of college students who have recently completed a teacher preparation program in a school of education and obtained an education degree and teaching certificate (e.g., Darling-Hammond, 1984; Grissmer & Kirby, 1997; National Commission on Teaching and America's Future, 1997). But data are less readily available on several other important sources of new hires in schools, such as those entering teaching with noneducation degrees and those entering through alternative, midcareer, and nontraditional routes. In addition to those in these pipelines of newly qualified candidates, there is the "reserve pool" of those who completed teacher preparation in prior years but delayed teaching, as well as former teachers who left teaching to later return. Finally, a third and large source of new entrants to particular schools is, of course, other schools—those who are already employed as teachers who move from one school to another. Accurately assessing the quantity of teacher supply requires data on all of the major sources of new hires.

Related to these data limits have been limitations of measures and methods. Empirically measuring inadequacies and shortfalls in teacher supply is difficult (see Behrstock, 2009, for a detailed review). One possible indicator used to assess the extent of shortages is the vacancy rate, that is, unfilled teaching positions in schools (e.g., Blank & Langesen, 2003; U.S. Department of Education, 2009). But national data have long shown that in any given school year, there are very few teaching openings left vacant or withdrawn because suitable candidates could not be found (Ingersoll, 1999). In reality, for legal reasons, schools often simply cannot, and do not, leave teaching positions unstaffed, regardless of the quantity and quality of supply.

An alternative indicator used to assess shortages is the number of positions filled by underqualified teachers (e.g., Blank & Langesen, 2003; National Academy of Sciences, 2007; National Center for Education Statistics, 1997; National Commission on Teaching and America's Future, 1996, 1997; Rumberger, 1987; U.S. Department of Education, 2009). However, the problem of underqualified and out-of-field teaching has multiple sources, and is often tied to the management of teachers in schools independent of supply shortages (Ingersoll, 2004). Shortages, for instance, cannot explain high levels of underqualified and out-of-field teaching that exist in fields such as social studies and English, long held to have surpluses (Ingersoll, 1999).

Another commonly used empirical measure to assess shortages focuses on teacher recruitment and hiring difficulties (e.g., American Association for Employment in Education, 2008; National Academy of Sciences, 2007; National Center for Education Statistics, 1997; National Commission on Teaching and America's Future, 1996, 1997). Data from school administrators on the degree of difficulty they encounter filling their teaching job openings are probably the most grounded and accurate measures available of the extent of actual staffing problems at the school level. But data on hiring difficulties themselves do not indicate the sources of these difficulties, and they do not themselves allow us to evaluate the magnitude, or sufficiency, of the quantity of supply.

Because of these data limitations, much of the research and policy commentary on teacher shortages have not been empirically well grounded. Researchers have rarely specified how to empirically evaluate whether teacher supply and demand are, or are not, in balance and how to empirically determine at what point the new supply of teachers is, or is not, sufficient to meet the demand for new teachers. It is difficult to find any research, especially with representative data, that empirically tests either of the two main claims of the teacher shortage thesis: that the production of new teachers has not kept pace either with student enrollment increases or with teacher losses from retirement. Addressing these gaps is the objective of this study.

The Study

This study builds on our prior research on teacher supply and demand. In this earlier work, we have offered an alternative hypothesis and perspective to the contemporary teacher shortage thesis to explain the staffing problems encountered by many schools (see Figure 1; for summaries, see Ingersoll, 2001, 2003). Our analyses revealed that preretirement teacher turnover—the departure of teachers from their schools—is a significant factor behind the need for new hires and the accompanying difficulties that schools encounter staffing classrooms with qualified teachers. In turn, we documented that teacher turnover varies greatly between different kinds of schools serving different student populations and is closely tied to the organizational characteristics and working conditions of those schools. Unlike research on employee turnover in other industries, until recently, there has been little empirical investigation of the types and amounts of costs and benefits, advantages, and disadvantages of teacher turnover.[1] Our alternative perspective revealed that one negative consequence of teacher turnover is its connection to the larger staffing problems that plague the educational system. Hence, from a policy perspective, the data suggest that improving teacher retention could be an important antidote to school staffing problems.

However, this earlier work did not include any analysis, or evaluation, of the quantity of the supply of teachers and did not investigate field-to-field differences in the adequacy of supply. Teacher turnover may be a significant

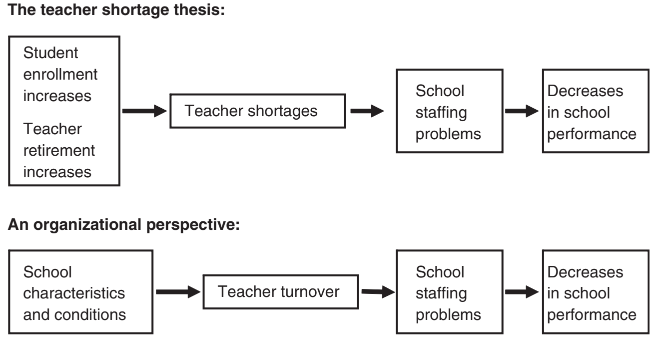

Figure 1. **Two perspectives on the causes and consequences of school staffing problems.**

factor, but remaining empirically unaddressed is the question of the extent to which particular fields, such as mathematics and science, do indeed suffer from an insufficient supply in the production of new teachers. In this new study, we build on this previous work by combining, analyzing, and comparing comprehensive national data on the actual quantity of qualified teachers supplied from different sources, the quantity of student enrollment, and the quantities of teacher retirement, attrition, and migration. We also build on this prior work by disaggregating the data and comparing different fields. Specifically, we focus on and compare the data for mathematics and science, considered shortage fields, with the data for other kinds of teachers, especially English, typically considered a surplus field. The objectives of this new study are to empirically ground the debate over mathematics and science teacher shortages; to evaluate the extent to which there is, or is not, sufficient supply of teachers in these fields; and to test our alternative perspective for the fields of mathematics and science and English.

Research Questions

There are four sets of specific research questions we seek to address:

1. What is the magnitude of demand for new teacher hires and the magnitude of school staffing problems? Have student enrollments and teacher retirements increased? Has teacher hiring increased? To what extent do schools suffer from teacher hiring difficulties, especially for mathematics and science, in comparison with English?
2. Is the new supply of teachers sufficient? What are the main supply sources of new teacher hires for mathematics, science, and English? What are the magnitudes of these sources? Has the new supply of qualified teachers kept pace with student enrollments and with teacher retirements? What portion of the new supply of qualified teachers is willing to teach?

3. Do school staffing problems vary by location? Are school staffing problems geographically based or concentrated in particular states, districts, or locales?
4. What is the role of teacher turnover in school staffing problems? What portion of the need for new mathematics and science teachers is accounted for by teachers moving between schools or leaving teaching altogether?

The theoretical perspective we adopt in our research is drawn from organizational theory and the sociology of organizations, occupations, and work. Our operating premise is that in order to fully understand the causes and consequences of school staffing problems, it is necessary to "put the organization back" into the analysis (cf. Stolzenberg, 1978) and to examine these issues from the perspective of the schools and districts where these processes happen and within which teachers work. Employee supply, demand, and turnover are central issues in organizational theory and research (e.g., Hom & Griffeth, 1995; Price 1977, 1989). However, there have been few efforts to apply this theoretical perspective to understanding staffing problems in education. By adopting this perspective, we seek to discover the extent to which staffing problems in schools can be usefully reframed from macrolevel issues, involving inexorable societal demographic trends, to organizational-level issues, involving policy-amenable aspects of particular districts and schools.

In the next section, we describe our data sources and define key terms and measures. In the following sections of this article, we present our results sequentially for each of our four research questions. We then conclude by discussing the implications of these findings for understanding and addressing the math and science staffing problems of schools.

Data and Methods

Data

To try to provide a more complete and comprehensive understanding of teacher supply, demand, and staffing problems, this study utilizes three different nationally representative data sets. All three are based on surveys undertaken by the National Center for Education Statistics (NCES), the statistical arm of the U.S. Department of Education. Fortuitously, these three databases were collected during the same year, allowing us to utilize them in conjunction and, hence, to gain a more comprehensive portrait of teacher supply and demand.

The first source of data for this study is the Schools and Staffing Survey (SASS) and its supplement, the Teacher Follow-Up Survey (TFS), collected by the Census Bureau for NCES. SASS/TFS is the largest and most comprehensive data source available on teacher staffing in elementary and secondary schools. SASS administers questionnaires to a random sample of about 50,000 teachers, 12,000 principals, and 4,500 districts, representing all types of teachers, schools, districts, and all 50 states. NCES has administered SASS on a regular basis; to date, six cycles have been completed: 1987–1988, 1990–1991, 1993–1994, 1999–2000, 2003–2004, and 2007–2008 (see NCES, 2005). We analyze the SASS data items on the numbers of students; the sources, numbers, ages, and qualifications of the teaching force; and the degree of difficulty school administrators report when filling teaching job openings. Our analysis uses data from all cycles of SASS, but we focus in particular on the 1999–2000 SASS. Our data represent all teachers for grades prekindergarten through 12, working part-time and full-time, and from all types of schools, including public, charter, and private.

In addition, all those teachers in the SASS sample who departed from their schools in the year subsequent to the administration of the initial survey questionnaire were contacted to obtain information on their departures. This nationally representative supplemental sample, the TFS, contains about 7,000 teachers. The TFS distinguishes between two general types of turnover. The first, often (and hereafter) called *teacher attrition*, refers to those who leave teaching altogether. The second type, often (and hereafter) called *teacher migration*, refers to those who transfer or move to different teaching jobs in other schools. We analyze TFS data items on the rates and magnitude of teacher movements between schools and of attrition from teaching altogether. Our analysis uses data from all cycles of the TFS available, but we focus in particular on the 2000–2001 TFS.

The SASS/TFS data are useful for understanding the existing teaching force; however, these data sources do not provide much information on the new supply of teachers. To obtain data on the latter, we utilize two additional NCES databases. One of these is the Integrated Postsecondary Educational Data System (IPEDS). IPEDS is a comprehensive source of data collected annually from the universe of postsecondary education providers (see NCES, 2003). For our purposes, we focus on the IPEDS data on those who complete both undergraduate and graduate degrees in education (e.g., mathematics education, biology education). We utilize data from the 1999–2000 IPEDS cycle to coincide with data from the 1999–2000 SASS data.

Data on recipients of noneducation degrees (e.g., mathematics, engineering, biology, English) in the teacher supply pipeline come from our final data source, the 2000–2001 Baccalaureate and Beyond Survey (B&B). This survey collected data from a nationally representative sample of 10,030 new recipients of undergraduate bachelor's degrees who graduated during or at the end of the 1999–2000 academic year (see NCES, 2004). This cohort sample was interviewed at the end of senior year in college and a year later, in July 2001. We utilize data from this source to examine new recipients of noneducation undergraduate degrees who entered the teacher supply pipeline to become teachers within 1 year after their graduation. We count these degree completers as being in the pipeline if they met one or more of the following criteria: (a) They obtained a teaching certificate during their senior year or immediately after their graduation; (b) within a year of graduation, they took a national or state teacher certification exam; (c) within a year of graduation, they applied for a teaching job; or (d) within a year of graduation, they actually began teaching.

From the SASS, TFS, and B&B databases, we used data weighted to compensate for the over- and undersampling of the complex stratified design of the surveys. To obtain unbiased estimates of the national population of schools, students, and teachers in the year of the survey, we weighted observations by the inverse of their probability of selection.

Methods and Measures

As indicated, our emphasis in this study is on the comparison between mathematics, science, and English teachers. We define a teacher as qualified in a given field if he or she holds an undergraduate or graduate degree in that or a related field. We define *qualified mathematics teachers* as those who indicated they had completed an undergraduate or graduate major in mathematics, statistics, mathematics education, or engineering. We define *qualified science teachers* as those who indicated they had completed an undergraduate or graduate major in science education, biology, physics, chemistry, geology, or another natural science. We define *qualified English teachers* as those who indicated they had completed an undergraduate or graduate major in English literature, English composition, English education, or language arts education.

The theory of supply and demand defines the labor supply as the number of individuals both able and willing to offer their services in a particular line of work, depending on wages and conditions. In this study, we attempt to distinguish and quantify the main sources of teacher supply. We focus in particular on the *new supply of teachers*, which we define as the pool of those qualified individuals who had not taught the previous year and from which schools can draw potential new hires. The new supply includes two components: first, the pipeline of newly qualified candidates or those actively seeking to be qualified who have not had prior teaching experience; and second, the reserve pool, which includes delayed entrants, who completed their preparation in a prior year but have not previously held regular teaching jobs, and reentrants, who taught previously, stopped for a while, and then returned. We also attempt to examine both those able to teach and those willing to teach, separately and together, by examining both those who are qualified, as defined above, and those qualified who actually seek employment as teachers. This distinction is useful to discern different sources of staffing problems; for instance, is the problem an insufficient quantity of qualified candidates produced or an insufficient quantity of qualified candidates willing to teach?

From the perspective of the teacher shortage thesis, the term *shortage* is typically assumed to be a result of insufficient production of new teachers in the face of increasing student enrollments and teacher retirements (Figure 1). This is a narrower definition than typically used in supply-and-demand theory, which defines a shortage as any imbalance where the quantity of labor demanded is greater than the quantity supplied given the prevailing wages and conditions. In supply-and-demand theory, such imbalances can result from a variety of factors, including those hypothesized by both perspectives in Figure 1. Here we use the term in the context of examining the teacher shortage thesis. Our focus is on empirically distinguishing and evaluating the magnitude and sources of staffing problems underlying the labels and terms used. From our data sources, we have been able to create several indicators and criteria to empirically evaluate the extent to which the new supply of teachers is, or is not, sufficient.

The first of our indicators, *trends in the pupil-teacher ratio*, examines changes over time in the number of qualified and employed teachers compared to changes in the number of students enrolled, by field. This addresses the question, Has the quantity of qualified math and science teachers employed kept pace with increases in student enrollments?

Our second criterion is the *replacement rate*, the ratio of the quantity of new supply of teachers to the quantity of those leaving teaching, for instance, because of retirement. This addresses the question, Has the new supply of qualified math and science teachers been sufficient to replace losses due to retirement and other factors?

A third indicator we use is the *employment rate*, the proportion of new qualified candidates in the pipeline who seek teaching jobs and enter employment as teachers. This addresses the question, How much of the new supply has been willing to teach and has been successful in finding a teaching job?

Limitations of Data and Measures

Our objective is to empirically test the two main tenets of the teacher shortage thesis: whether the quantity of new supply has been sufficient to keep up with student enrollment and with teacher retirement increases. But we do not address the question of whether the quantity of teacher supply is ideal or optimal or whether it is sufficient to meet an ideal or optimal level of demand. Determining these would entail first defining desired class sizes, desired teacher-pupil ratios, desired graduation requirements, and so on. In this study, we define demand in a typical sense as schools' need for teachers, based on the number of teachers actually hired and employed.

This study also does not focus on, or distinguish, the quality, character, fit, effectiveness, or performance of teachers. Our data cannot indicate whether there is, or is not, a sufficient supply of highly effective or high-quality math and science teachers. Nor do the data indicate whether there are, or are not, sufficient numbers of qualified math and science teachers who have the unique characteristics to be effective in particular settings, such as urban schools or private religiously oriented schools. All of the latter are, of course, crucial issues from both a practical and a policy perspective. But parallel to most analyses of labor supply and demand, we focus on the quantity of qualified and willing candidates.

It is unclear whether our data sources (IPEDS, B&B, and SASS) allow us to reliably estimate the numbers of qualified teachers for each of the separate disciplines within the multidisciplinary field of science. This limitation is especially pertinent for physics, because the latter is a numerically smaller discipline than either biology or chemistry and is often cited as having the most severe shortages (e.g., National Academy of Sciences, 2007; U.S. Department of Education. 2009). Some of those who prepare to become science teachers obtain a degree in science education. Often, these degrees require recipients to concentrate or major in one or two of the several specific science disciplines. However, our data sources (IPEDS, B&B, and SASS) do not indicate in which of the science discipline(s) these science education degree holders were qualified.

As mentioned, because of the necessity of utilizing three data sources in conjunction, we focus on the 1999–2000 school year because our databases were all, fortuitously, collected during that year. But this raises the question of whether such data are outdated and no longer relevant. For several reasons, we do not think this is a problem. Teacher shortages, especially for mathematics and science, are not new, and indeed, almost identical concerns have been voiced periodically for decades. Moreover, as we will show, the 1999–2000 data are especially useful for testing the teacher shortage thesis because the data reveal that the 1999–2000 school year was the high point in the proportion of secondary schools that reported hiring difficulties in mathematics or science over the 20-year period from the late 1980s to 2008. In addition, one of the major factors driving demand—the growth rate of student enrollments—was fastest in the late 1990s, slowing since 1999–2000—again, making that year especially useful for testing the teacher shortage thesis.

Finally, it is important to clarify that for several reasons, our data on the new supply of teachers are biased downward and provide underestimates. Our B&B and IPEDS data on the qualified pipeline do not include those who, while they did not have a major in a field, are qualified because they had passed a subject area test, held a teaching certificate, or had taught in a field. Our pipeline data do not include new recipients of noneducation degrees at the graduate level who entered the pipeline to become teachers. Our pipeline data do not include most midcareer switchers who came into teaching through nondegree, nontraditional routes. In addition, and most importantly, we do not have data on the number of qualified and willing candidates in the reserve pool of delayed entrants and former teachers. In our analyses, we use data from SASS on the number of teachers actually hired from the reserve pool—most likely an underestimate of the total number of those in the reserve pool who are qualified and willing to teach. The implications of this overall downward bias, however, will differ according to what we find in our analyses to follow. Given our underestimates, a finding that the new supply of teachers is sufficient would be strengthened, while a finding that the new supply of teachers is insufficient would be weakened.

Results

What Is the Magnitude of Demand for New Teacher Hires and the Magnitude of School Staffing Problems?

After declining through the 1970s, total elementary and secondary public and private student enrollments have increased. Data from SASS in Table 1 show that since the late 1980s, student enrollments have increased by almost one fifth (row 1). The data in Table 1 also document that there has been an aging of the teaching force. The percentage of teachers 50 years or older has greatly increased (row 3a), as has the number of teacher retirements (row 4a). Our background analyses of the SASS/TFS data indicate that the modal age of retirement for teachers is 59 and the modal age of the teaching force in 2007–2008 was 55. This suggests that the number of teachers retiring will probably continue to increase until about the 2011–2012 school year, the point at which it will probably be at an all-time high and after which the number retiring will probably begin to decline.

Given increases in both enrollments and retirements, not surprisingly, the SASS data also show that for any given year, most schools have had job openings for which teachers were recruited and interviewed, and the number of teachers hired annually has increased by almost two thirds over the past two decades (row 2). Interestingly, the size of the teaching workforce has increased at a faster rate than the student population (row 3), a point to which we will return in the next section.

In addition to this increase in teacher hiring, and importantly for our analysis, the SASS data indicate that a substantial number of school principals have reported that they have experienced difficulties finding candidates to fill their teaching job openings for the upcoming school year. Overall, the data show that for the 1999–2000 school year, 74% of all secondary schools reported that it was at least "somewhat difficult" filling one or more teaching job openings in one or more of 11 fields, and 49% indicated that it was either "very difficult" or they "could not fill" one or more openings.[2]

Moreover, as expected, the data also show large field-to-field differences in hiring difficulties (see Figure 2). For instance, in the field of English, 54% of secondary schools had job openings at the beginning of the 1999–2000

Table 1

Trends in Student Enrollments, the Teaching Force, and Teacher Flows In and Out of Schools

	School Year						
Variable	1987–1988	1990–1991	1993–1994	1999–2000	2003–2004	2007–2008	Increase 1987–1988 to 2007–2008
1. Total student enrollment (K–12)	45,220,953	44,777,577	46,592,207	50,629,075	52,375,110	53,644,872	19%
2. Total teacher hires at beginning of school year	361,649	387,807	377,135	534,861	537,001	589,786	63%
3. Total teaching force during school year	2,630,335	2,915,774	2,939,659	3,451,316	3,717,998	3,894,230	48%
a. Teachers age 50 or older	527,562	660,434	724,754	1,009,731	1,230,049	1,270,959	141%
4. Total teacher turnover after end of school year	390,731	382,879	417,588	546,247	621,427	NA	59%[a]
a. Retirees	35,179	47,178	50,242	66,788	87,271	NA	148%[a]

Note. The data in rows 2 and 4 are calculated at the level of the school. *Hires* and *turnover* refer to those newly entering or departing a particular school. Cross-school transfers within districts are counted as hires or as turnover. Within-school reassignments are not counted as either hires or turnover. NA = not available.

[a]Increase in percentage is for period from 1988–1989 to 2004–2005.

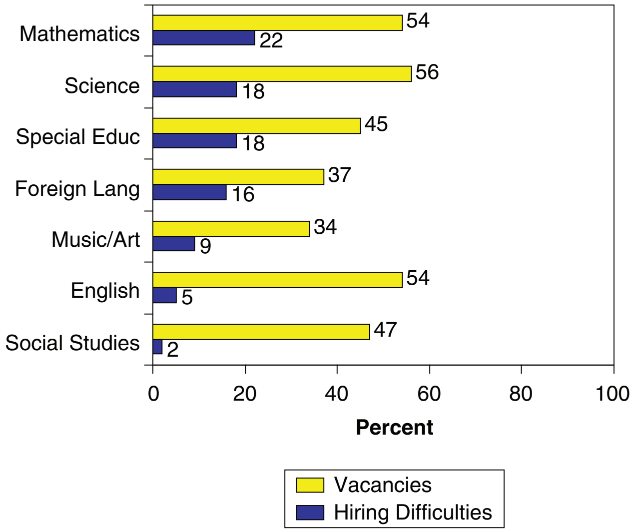

Figure 2. **Percentage of secondary schools with teaching vacancies and with serious difficulties filling those vacancies, by field (1999–2000).**

school year, but only about one tenth of these—representing 5% of all secondary schools—indicated that it was "very difficult" or they "could not fill" these openings. On the other hand, for science, 56% of secondary schools had job openings for teachers in this field, and about 35% of these indicated serious difficulties filling these openings, representing 18% of secondary schools. Of the fields represented in Figure 2, mathematics experienced among the most serious hiring and recruitment problems: 54% of secondary schools had job openings for mathematics teachers, and about 41% of these indicated serious difficulties filling these openings, representing about 22% of all secondary schools.

In sum, over the past two decades, student enrollments and teacher retirements have increased, as have demand for and hiring of teachers. In any given year, a sizable minority of secondary schools reported hiring difficulties in mathematics or science. Our analyses of the other cycles of SASS, from the early 1990s to 2008, reveal that the 1999–2000 school year was the high point in the proportion of secondary schools that reported serious hiring difficulties in mathematics or science (see Figure 3). This makes the 1999–2000 data especially useful for testing the teacher shortage thesis. What is not clear, thus far, are the sources of, and reasons for, both the need for new teacher hires and the accompanying difficulties filling those positions, a question to which we turn in the next several sections.

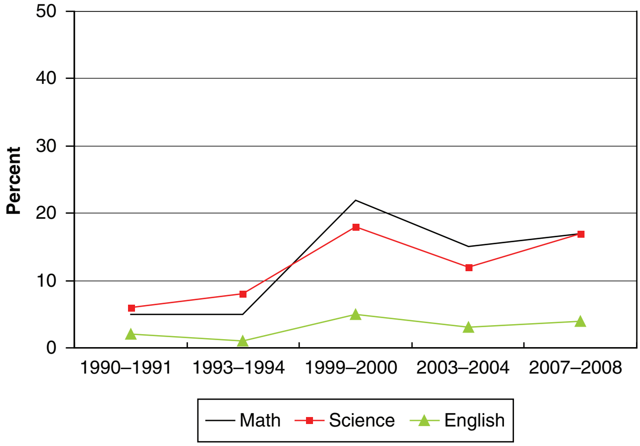

Figure 3. **Trends in percentage of secondary schools reporting serious difficulties filling teaching vacancies, by field (1990–2008).**

Is the New Supply of Teachers Sufficient?

While student enrollments, teacher retirements, and the demand for new hires have all increased and, moreover, many principals have reported hiring difficulties, what do the data indicate about whether there is a sufficient supply of teachers? Table 2 provides data from all three of our sources to address this question. It is similar to Table 1 but focuses in more detail on the school year 1999–2000, when hiring problems were at a high point, and focuses on three specific fields: mathematics, science, and English. It presents data on the flows of new hires into schools at the beginning of that school year, the size of the teaching force at midpoint in the school year, the departures of teachers from schools after the end of that school year, and the new supply of teachers produced in the pipeline by the end of that same year.

Reading down the first column, for all teachers, Table 2 indicates that there were just under 3.5 million teachers in the K–12 education system in the 1999–2000 school year (row 2). About 535,000 of these teachers entered their schools at the beginning of the school year (row 1). Of these, 302,630 of the total hires to schools were movers—that is, they moved from another school (row 1[c]). Another 232,231 were entrants from the new supply who had not taught the prior year. This latter group includes those from the pipeline of newly qualified entrants from preparation programs (row 1a[i]) and entrants from the reserve pool (rows 1b[i] and 1b[ii]).[3] By the following school year, 546,247 teachers had moved from their school jobs or left teaching (row 3). Just under half of these total departures—268,642—moved to other schools to teach (row 3a). Another 277,605 left teaching

Table 2

Teaching Hires, Turnover, and Supply, 1999–2000

Variable	All	English	Science	Math	Source
1. Total teacher hires at beginning of 1999–2000 year	534,862	50,920	35,382	29,188	SASS
a. New supply of teachers from pipeline					
(i) Newly qualified entrants: from programs, with no experience	100,377	10,827	6,831	5,230	SASS
b. New supply of teachers from reserve pool					
(i) Delayed entrants: with no teaching experience	52,103	4,847	4,339	1,649	SASS
(ii) Reentrants: with prior teaching experience	79,751	6,703	5,505	4,416	SASS
c. Movers from other schools	302,630	28,534	18,577	17,891	SASS
2. Total teaching force during 1999–2000 year	3,451,316	308,632	223,080	182,456	SASS
3. Total teacher turnover after end of 1999–2000 year	546,247	48,450	39,979	28,166	TFS
a. Migration: movers to other schools	268,642	25,003	18,352	14,416	TFS
b. Attrition: leavers from occupation (including retirees)	277,605	23,447	21,627	13,750	TFS
(i) Retirees	66,788	7,100	3,935	3,915	TFS
4. Total new supply of teachers in pipeline at end of 1999–2000 year	347,138	21,372	12,413	7,969	IPEDS/B&B
a. With education bachelor's and master's	189,554	3,313	2,390	2,173	IPEDS
b. With noneducation bachelor's and exam, certified, applied, or taught	157,584	18,059	10,023	5,796	B&B

Note. SASS = Schools and Staffing Survey; TFS = Teacher Follow-Up Survey; IPEDS = Integrated Postsecondary Educational Data System; B&B = Baccalaureate and Beyond Survey.

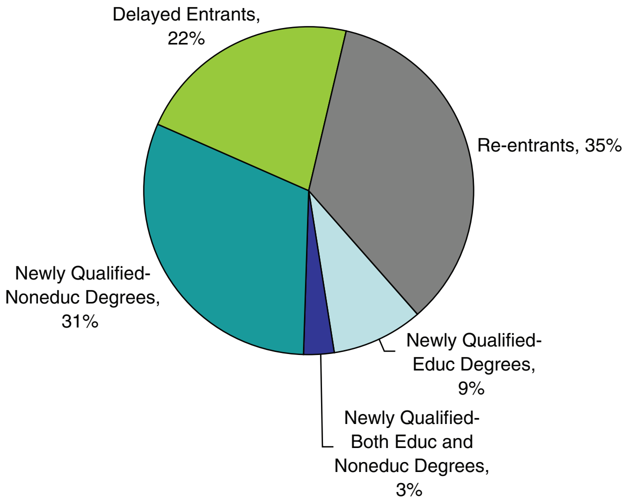

Figure 4. **Percentage of math and science teachers newly hired in the school system, by supply source (1999–2000).**

altogether (row 3b). Of the latter, 66,788 were retirees. Simultaneously, at the end of the 1999–2000 academic year, there were 189,554 new recipients of education degrees at either the undergraduate or graduate level (row 4a) and 157,584 new recipients of noneducation degrees at the undergraduate level in the pipeline (row 4b).

Figure 4 illustrates two important points from Table 2 about these sources of newly hired math and science teachers. First, those with education degrees are not the sole or even primary source of the new supply of teachers in the pipeline. Second, the pipeline is not the sole or even main source of new teacher hires; more new hires come from the reserve pool than directly from preparation programs and higher education institutions.

How can we use the data to empirically evaluate whether the teacher supply is or is not sufficient? Our first criterion, trends in the pupil-teacher ratio, examines changes in the number of qualified and employed math and science teachers compared to changes in the number of enrolled students.

As shown in Figure 5, the total number of K-12 students increased by 19% during the past two decades. Overall, the teaching force increased at over twice the rate—by 48%—of overall student enrollments. Elsewhere, we present a closer examination of the reasons behind this relatively dramatic growth in the teaching force in the past two decades (see Ingersoll & Merrill, 2010); our focus here is on examining whether the employment of English, math, and science teachers has kept pace with student enrollment growth.

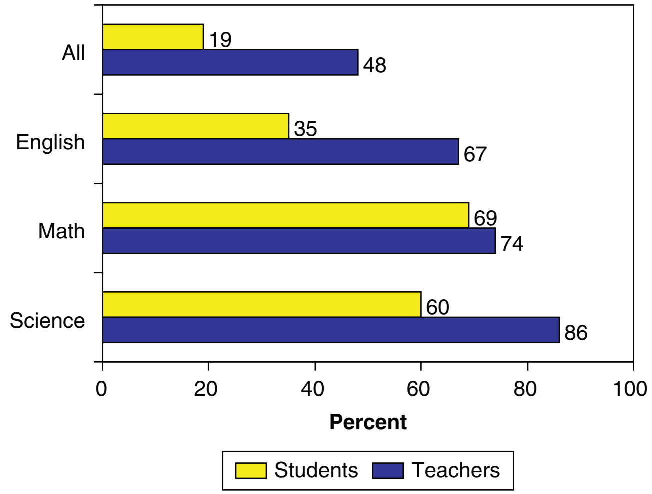

Figure 5. **Percentage increase in students and qualified employed teachers, by field, from 1987–1988 to 2007–2008.**

The SASS data show that during this same period, the average number of years of English course work required by public schools for high school graduation increased slightly, from 3.7 to 3.9 years of instruction; English course taking by students increased by 35%; and the number of qualified English teachers employed went up by 67%.[4]

The number of courses required for high school graduation has been smaller for both math and for science than for English, and also there have been proportionately fewer math or science teachers employed than English teachers (see Table 2). In 1987–1988 the ratio of math to English required courses was about .6, and the ratio of math to English teachers employed was about the same. However, during the 20-year period from 1987–88 to 2007–08, average high school graduation requirements for mathematics and science increased at a faster rate than for any other core academic field—by .7 years of instruction. The number of students enrolled in mathematics and science courses also increased—by 69% and 60%, respectively. The number of qualified mathematics and science teachers employed in schools even more dramatically increased. Math teachers rose by 74%, from about 120,000 to 208,000. Science teachers rose by 86%, from about 127,000 to 237,000. Interestingly, the data also show that the fastest rate of increase in the employment of qualified math and science teachers occurred during the 1990s, before the advent of the No Child Left Behind Act (2001). Moreover, our analyses of the IPEDS data also show that growth in the employment of math and science teachers has also outstripped growth in the production of those completing undergraduate or graduate degrees in science education, math education, math, or the sciences. We also disaggregated the science data by discipline especially to examine physics. We found that student enrollments in physics courses increased by 28% during that same period, and the number of employed teachers with degrees in physics also increased by the same amount. But as mentioned earlier, such within-science estimates must be interpreted with caution.

During this period, average class sizes at the middle and secondary level changed little, while there was a slight increase in the number of class periods teachers taught per day. Math class sizes have been just slightly less than the average for all subject-area courses at the middle and secondary levels. Science class sizes have been about average, with the exception of physics class sizes, which have been 25% smaller on average than others.

In sum, the data indicate that despite a rapid increase in math and science graduation requirements and student course taking over the past two decades, the number of qualified math and science teachers employed has more then kept pace. The numbers of math and science teachers have increased at a rate far greater than the average for all teachers. Math and science class sizes are close to the average and have changed little over the past two decades. This, of course, does not mean the math and science teacher supply is ideal—that would depend on defining desired pupil-teacher ratios and class sizes and so on. But the data do suggest that math and science teacher production and recruitment efforts have been more than successful in keeping pace.

Our second evaluative criterion is the replacement rate, the ratio of the quantity of new qualified candidates being supplied to the quantity of those permanently leaving teaching, for instance, because of retirement. The All column in Table 2 appears to suggest that overall, there are more than enough prospective teachers produced in the pipeline to replace the loss of existing teachers through attrition. While over 347,000 new candidates were produced in the pipeline at the end of the 1999–2000 year (row 4), only about 277,000 left teaching at the end of that same year (row 3b), and of these, only about 67,000 did so because of retirement (row 3b[i]). But is there a sufficient quantity of teachers supplied each year in specific fields, such as English, mathematics, and science, to replace losses?

The English column in Table 2 shows that at the end of the 1999–2000 year, there were just over 21,000 degree holders produced in the pipeline who were eligible to teach English (row 4). This includes about 3,000 language arts education and English education majors and a much larger number of English majors (18,059) who pursued teaching. This new supply of 21,372 English teachers was 3 times the number of English teachers who retired (7,100) (row 3b[i]) but slightly less than the total number of those who left teaching at the end of that same year (23,447) (row 3b).

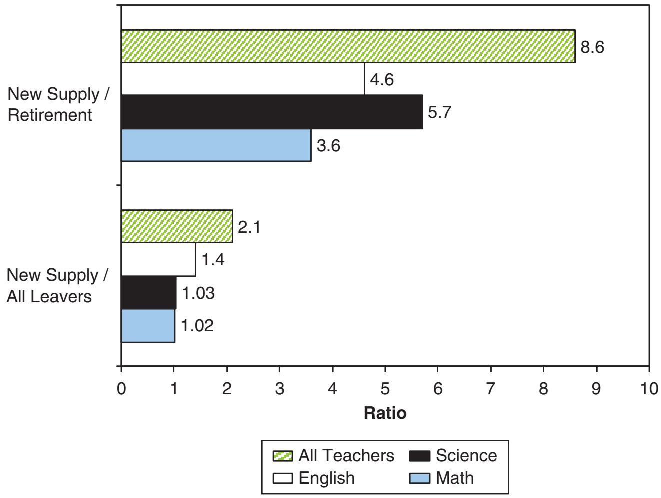

Figure 6. **Ratio of new supply of teachers to retirement and to all leavers, by field (2000).**

Table 2 shows that in contrast to English, significantly fewer potential science teachers were produced in the pipeline at the end of the 1999–2000 academic year: 12,413. This pipeline supply of new science teaching candidates was, as in the case of English, over 3 times as large as the number of science teachers who retired that same year (3,935) but was far smaller than the total number of leavers (21,627). A similar portrait holds for mathematics. The 7,969 new mathematics teachers produced by the pipeline at the end of the 1999–2000 year was about twice the number of mathematics teachers who retired (3,915) but was much smaller than the number of all mathematics teachers who left classroom teaching that year (13,750).

The above comparisons, however, leave out the other major source of new supply, the reserve pool. As mentioned, we do not know the total magnitude of the reserve pool, but as shown in rows 1b(i) and 1b(ii) in Table 2, we do know how many were actually hired from that pool for the 1999–2000 year. Derived from the table, Figure 6 presents a variant of the replacement rate that adds to the pipeline the portion of the reserve pool that ended up employed as teachers that year. Using this estimate of new supply, the figure displays the ratios of the quantity of new supply to the quantity of retirement and also the ratios of the new supply to the quantity of all those leaving teaching.

Adding this portion of the reserve pool to the pipeline shows that the overall new supply of teachers was not only more than sufficient to replace retirees but was also sufficient to replace all attrition. This, however, varies by field, and for mathematics and science, there was a very close balance.

For instance, while there were several times the number of new mathematics or science teachers for every one who retired, there was only about one math or science teacher supplied for every one math or science teacher to leave teaching.

The Figure 6 ratios for English, math, and science are not precise and must be interpreted with some caution. As we will next document, some of those in the pipeline delay their entrance into teaching and, by definition, shift from the pipeline to become part of the reserve pool. However, in Figure 6, delayed entrants are unavoidably counted twice (in both pipeline and reserve pool), hence overestimating the ratio of new supply to attrition. On the other hand, our ratios also underestimate supply to attrition, because as discussed in the Data and Methods section, our data in the numerators on the new supply of teachers do not include several supply sources, such as midcareer entrants in the pipeline and all qualified and willing candidates in the reserve pool.

We also disaggregated the science data displayed in Figure 6 by discipline. For physics, the data show that the variants of the replacement rate were 2.7 for the new supply to retirement and 1.16 for the new supply to all attrition. In other words, the data suggest that as with science as a whole, there was a sufficient supply of qualified physics teachers to replace losses. However, as mentioned earlier, limitations to our estimates of the total numbers of qualified teachers within the science disciplines could introduce error into both the numerators and denominators of our ratios.

Our third indicator assessing the sufficiency of the new supply is the employment rate, the portion of the new supply of qualified candidates in the pipeline who seek teaching jobs and enter employment as teachers. Supply-and-demand analysts often interpret significant numbers of qualified but unemployed candidates as an indicator of a labor surplus. Here we primarily analyze the employment data to discern what portion of the qualified supply is willing, or not willing, to enter the teaching occupation.

To accurately examine the actual employment rates of those in the pipeline, we analyzed the 2000–2001 B&B data on the teaching employment status 1 year after graduation for all of those who completed a bachelors degree at the end of the 1999–2000 year and who entered the pipeline. We focused on a key group and major component of the pipeline: those with noneducation degrees in math, English, or any one of the science disciplines in the teaching pipeline (Table 2, row 4b).

As shown in Figure 7, the data indicate that large proportions of those in the teaching pipeline who completed degrees in math, science, or English had taught within only 1 year of their graduation (the left portion of the bars). Another significant portion of those with such degrees had applied for teaching jobs but had not taught within a year (the middle portion of the bars). A far smaller portion of those with such degrees had neither applied for a teaching job nor taught within 1 year (the right portion of

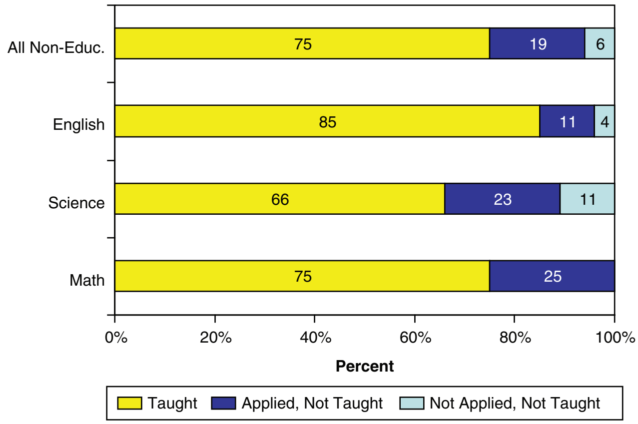

Figure 7. **Of total new supply of teachers in pipeline with a noneducation bachelor's degree, percentage who taught or applied within 1 year after graduation, by field (2000–2001).**

the bars). Notably, none in the sample of those in the pipeline with math degrees had neither taught nor applied, but it must be cautioned that the math pipeline sample was small ($n = 58$).

Of those in the middle portion of the bars (who had applied for teaching jobs but had not taught within a year), 42% had received an offer for a teaching position. Of these, about half accepted their offers but had not yet begun their teaching job as of the month of the survey (July). Of those who did not accept offers, about half indicated that this was because of dissatisfaction with salary, safety, or location of the school (representing about one tenth of the middle portion of the bar).

Of those in the right portion of the bars (who had neither applied for a teaching job nor taught), less than 1% indicated that a "lack of interest in teaching" was the reason that they had not applied to teach during their 1st year out of college. In contrast, a far larger number indicated that their reason for not teaching was that they had not passed required tests or obtained proper certification. These breakdowns were generally similar for each of the separate fields, but small sample sizes (<30) suggest caution for disaggregating the data within portions of the bars for each field.

Comparable data on the employment rates of those who completed education degrees in math education, English education, and science education (Table 2, row 4a) are not available, but the 2000–2001 B&B data do show similar patterns for those with secondary-level subject area education degrees as a whole. Furthermore, our analyses of the earlier 1993 B&B survey data also show that of those in the pipeline who did not teach immediately after finishing their degree, within a decade, almost all had sought teaching jobs at one point or another and over 90% had been employed as teachers.[5]

In sum, the data show that there is a sufficient number of new math and science teachers supplied to keep pace with enrollment and retirement increases. Moreover, the data indicate that of the new supply of teachers in the pipeline, the majority entered teaching right after finishing college, and another portion were delayed entrants who spent a period of time in the reserve pool. Of those few qualified candidates who never taught, some may have been willing to teach but were never hired, and only a very few indicated they were not interested in ever teaching.

Do School Staffing Problems Vary by Location?

Of course, a sufficient or insufficient national supply does not necessarily mean there is a sufficient or insufficient local supply. Indeed, educational analysts have long held that elementary and secondary teaching has a highly localized labor market in contrast to, for instance, the national labor market for professors in higher education. In turn, a widely believed variant of the teacher shortage thesis holds that teacher shortages are not national but vary by location and are geographically based. From this view, shortages are a result of an uneven production of new teachers across states and locales (e.g., Murphy et al., 2004; National Commission on Teaching and America's Future, 1997). Moreover, in this view, barriers to cross-state and cross-district movement, such as a lack of pension portability, nontransferability of certification across states, and little coverage of moving expenses, exacerbate these geographically based shortages (e.g., Curran et al., 2001; State Higher Education Executive Officers Association, 2004). In addition to these structural barriers, a number of studies have shown that those entering teaching tend to prefer to teach in schools like those they themselves attended and, hence, seek teaching jobs close to home (e.g., Boyd, Lankford, Loeb, & Wyckoff, 2005; Loeb & Reininger, 2004). The result of all these factors, analysts argue, is that the teacher supply is unevenly distributed, and the supply available for one district or state is not necessarily available for others.

However, data from various sources raise several questions for this geographically based teacher shortage thesis. First, the IPEDS data do show that the production of new teachers varies across state and region. But it should be recognized that this is not due to a lack of teacher-training programs. The United States is unusual because of its large numbers of accessible, nonselective, low-cost, widely dispersed teacher preparation programs—an average of 25 per state (Lortie, 1975). China, with about 4 times the number of students as the United States, has less than half the number of teacher-training programs (Ingersoll, 2007).

Second, the data show that there are, in fact, large cross-state flows of teachers, and the degree to which the teacher labor market is local, regional, or national varies. Federal data collected under the federal Higher Education Act's Title II (1998 Amendments to the Higher Education Act) indicate that in 2003–2004, over a quarter of applicants for teaching jobs across the nation were from out-of-state candidates. In almost one third of the states, more than one third of the teaching job applications were from candidates certified in other states (Barnes, 2006).

Third, requirements impacting cross-state mobility are not unique to teaching, and the degree to which they are deemed overly burdensome barriers is relative. For example, bar exams in the law profession are partly state based and attorneys moving out of state usually are required to pass an exam in the new state before being allowed to practice. It is unclear to what extent these requirements decrease cross-state mobility of attorneys. However, the law profession in general does not suffer from labor supply shortages; indeed, it is often referred to as a surplus field. At issue is the ratio between requirement and rewards, between costs and benefits, in a given occupation. Even time-consuming and financially costly requirements for cross-state occupational mobility could be deemed acceptable by candidates if the job and occupation are sufficiently attractive. The data suggest that this ratio varies in the teaching occupation. The above Title II data indicate that some schools and school districts in some states clearly have been successful in attracting candidates from a regional or national labor market; others, less so.

Fourth, the largest variations in hiring difficulties and in staffing problems by location are those between different schools, even within the same district. As shown in Figures 2 and 3, only a minority of schools have serious math and science hiring difficulties in any given year. Our analysis of variance of these data found that variation in reported school hiring difficulties is far greater within, than between, states, and moreover, such variation is far greater between schools than between districts.[6] In other words, within the same state and locale, the same teacher labor market, and the same licensure and pension system, the extent of staffing problems varies greatly among different types of schools. In the same metropolitan area in the same year, some schools could have extensive waiting lists of qualified candidates for their teaching job openings while other nearby schools may have great difficulty filling their teaching job openings with qualified candidates (see, e.g., Liu et al., 2008; National Commission on Teaching and America's Future, 1997).

In sum, discussion of shortages and staffing problems at a national level masks an important part of the diagnosis, which is revealed by disaggregation. The data show that both the production of new teachers through teacher preparation programs and hiring problems are not evenly distributed across different locations. But the largest source of difference in hiring problems is not between regions or states but between schools, even within the same district.

Moreover, that some locations have staffing problems does not necessarily mean they suffer from shortages in the sense that too few new teachers are produced in their particular pipeline. Rather, the data suggest that staffing problems are due to the relative ability, or inability, of particular schools, even within the same district, to ensure that their classrooms are all staffed with qualified teachers drawn from the available supply, whether from the pipeline, the reserve pool, or in state or out of state. All of this suggests that school staffing problems, and apparent imbalances between supply and demand, must be examined from a school- and organizational-level perspective to be fully understood. The next section turns to an examination of an alternative source of these school staffing problems.

What Is the Role of Teacher Turnover in School Staffing Problems?

In addition to the level and adequacy of the new supply of teachers, the data in Table 2 illuminate several other important points. Because teaching is one of the largest occupations (U.S. Bureau of the Census, 2008), the flows of teachers in and out of schools are numerically large. As shown in Table 2, over 64,000 qualified math and science teachers newly entered schools at the beginning of the 1999–2000 school year; by the following year, a larger number—about 68,000 math and science teachers—moved from or left their schools. In other words, during that period, there were over 100,000 job transitions by mathematics and science teachers, representing almost one third of the mathematics and science teaching force. Large outflows, in particular, of teachers likely incur a variety of different costs and benefits and advantages and disadvantages (for a detailed discussion, see Ingersoll & Perda, 2010). Here we focus on one consequence: their connection to math and science staffing problems.

The data in Table 2 suggest that the attrition of math and science teachers is linked to the increasing need for new hires and accompanying staffing problems. For instance, at the beginning of the 1999–2000 year, about 16,675 science teachers entered, or reentered, teaching (rows 1a[i], 1b[i], and 1b[ii]), but by the following school year, about 21,627 (row 3b)—equivalent to 130% of those just hired—left teaching altogether. For mathematics, at the beginning of the 1999–2000 year, about 11,300 new mathematics teachers entered teaching, but by the following school year, 13,750—equivalent to about 120% of those just hired—left teaching.

Moreover, although teacher retirements have increased in recent years, as shown in both Tables 1 and 2, they account for only a portion of attrition. For example, at the end of the 1999–2000 year, there were about 7,850 math and science retirees, accounting for only 22% of all those math and science teachers leaving teaching and 12% of the total math and science teacher turnover during that period. This has been fairly consistent across the five cycles of SASS/TFS from 1988 to 2004 (see Table 1, row 4a).

In addition, the data suggest that math and science teacher migration is also linked to staffing problems. Teacher migration between schools, of course, does not decrease the overall net supply of teachers, as does attrition due to retirement and career changes. Hence from a systemwide level of analysis, migration does not contribute to overall shortages. However, from an organizational level of analysis, teacher migration and attrition have the same effect: Both result in a decrease in staff in that particular organization that usually must be replaced, at times with difficulty.

A similar impact holds for temporary attrition—those who leave teaching for a year or more and then return. The latter, of course, do not represent a permanent loss of human capital from the teacher supply; as shown in Table 2, the reentrance of former math and science teachers is a major source of new supply. However, from an organizational perspective, temporary attrition, like migration, also results in a decrease in staff that usually must be replaced.

We further empirically tested our alternative hypothesis of a link between math and science teacher turnover and school staffing problems (Figure 1) using a school-level of measure of turnover (obtained from principals in the 1990–1991 SASS). Turnover, of course, is one factor leading to job openings and hiring. And in any given year, as shown earlier in Figure 2, the majority of secondary schools have job openings in math and science, but only a minority of these reported experiencing serious difficulties filling their openings. The latter schools were almost twice as likely, and at a statistically significant level, to have had above-average turnover rates the prior year as those schools reporting no difficulties. This held true for both teachers leaving and teachers moving.

In sum, the data show that the majority of the hiring of new mathematics and science teachers is simply to fill spots vacated by other math and science teachers who departed their schools at the end of the prior school year. And the majority of these departures are not a result of a "graying workforce." Rather, math and science migration and preretirement turnover are primary factors behind the need for new hires and the accompanying difficulties some schools have adequately staffing math and science classrooms with qualified teachers. In other words, our alternative organizational perspective reveals that one negative consequence of math and science teacher turnover is its connection to the larger math and science staffing problems that exist in a significant minority of the school population.

In a companion study, we followed up by more closely focusing on the rates, destinations, variations, and determinants of mathematics and science teacher turnover in public schools (see Ingersoll & May, 2010). Here we briefly summarize our main findings. Average annual total turnover rates for math and science teachers increased slightly since the early 1990s to 2005, but notably, mathematics and science teachers have not had, on average, significantly higher rates of turnover than other teachers. The data also show that there are large differences in rates of math and science turnover between different schools, even within the same district. The data showed that the bottom quartile of schools had an average annual turnover rate of 8% in 2004–2005. In contrast, the top 25% of public schools had an average annual turnover rate of 32% and accounted for 45% of all turnover. High-poverty, high-minority, urban and rural public schools have among the highest rates of both attrition and migration of math and science teachers. Moreover, in the case of those moving between schools, there is a large annual asymmetric reshuffling of a significant portion of the math science teaching force, with a net loss on the part of poor, minority rural and urban schools and a net gain to nonpoor, nonminority suburban schools. Over half of math and science teachers who departed reported that the reason was primarily to pursue another or better job or because of dissatisfaction with some aspect of the teaching job—many times the number of teachers who departed because of retirement. In detailed multivariate, multilevel analyses, we found that among the strongest school predictors of mathematics and science teacher turnover in public schools were the degree of student discipline problems in schools, the degree of individual classroom autonomy held by teachers, the provision of useful content-focused professional development, and professional development concerning student discipline and classroom management; for science teachers, an additional predictor was salary levels.

Conclusions and Implications

Contemporary educational thought holds that one of the pivotal causes of inadequate student performance is the inability of schools to staff classrooms with adequately qualified teachers, especially in mathematics and science. One of the most prominent explanations holds that the root of these staffing problems are shortages primarily resulting from an insufficient supply of math and science teachers in the face of increasing student enrollments and increasing teacher retirements (e.g., Liu et al., 2008; U.S. Department of Education, 2002). What do the data in our analysis indicate?

The data show that in any given year, a significant number of schools experience difficulties filling their classrooms with qualified candidates; that there are large school-to-school variations in the extent of these hiring difficulties, even within the same school district; and that math and science are the most severely effected fields. In 1999–2000, when hiring difficulties were at a 20-year high point, about 7,200, or 31%, of secondary schools reported that they had serious difficulty finding qualified teachers to fill either their mathematics or science teaching openings. The data also show that the reasons for these math and science school staffing problems are more complex and varied than simply an insufficient production of new teachers.

There are multiple sources of the new supply of math and science teachers. A relatively minor source was the pipeline of the newly qualified with education degrees. Far larger sources were those in the pipeline with non-education degrees in math and science, and the reserve pool.

The data show that the math and science teacher supply, from all of the above sources combined, has been more than sufficient to cover both student enrollment and teacher retirement increases. Despite an increase over the past two decades in graduation requirements for math and science, and a subsequent dramatic rise in math and science course taking by students, the data show that the employment of qualified math and science teachers has more than kept pace, while class sizes have remained stable. Moreover, the number of newly qualified mathematics and science teachers produced in the pipeline has been more than sufficient to cover increases in mathematics and science teacher retirements. These findings are further reinforced because our data sources are downward biased and provide underestimates of the new supply of math and science teachers.

Nevertheless, a significant number of schools each year report serious problems filling their math and science teaching openings. An important source of these problems is preretirement losses of teachers—a figure that is many times larger than losses due to retirement— and a primary factor behind the need for new hires. Mathematics and science teachers have had about the same annual rates of attrition as other teachers. But unlike, for instance, the case of English teachers, the educational system does not enjoy a surplus of new mathematics and science teachers relative to losses. For mathematics and science, there was a much tighter balance between the new supply and total attrition. Moreover, an annual migration of math and science teachers from some schools to others also contributes to the difficulties the former schools face in ensuring that their mathematics and science classrooms are staffed.

The data also show that there are large differences in rates of math and science turnover between different schools, even within the same district. There are many factors behind these school differences in teacher turnover. A major set of factors involves the attractiveness of the teaching job and teachers' dissatisfaction with aspects of their schools.

It is useful to reiterate some limitations to our study, introduced earlier in the Data and Methods section. While the data indicate that there is sufficient new supply of qualified math and science teachers to cover increases in student enrollments and increases in teacher retirements, our study does not address the question of whether the supply of math and science teachers is ideal or optimal—that would depend on defining desired pupil-teacher ratios, class sizes, and graduation requirements. Moreover, our study focuses on qualified teachers; we do not address the issue of the quality, character, fit, performance, or effectiveness of such teachers. In addition, our data may not accurately indicate whether there is sufficient new supply for each of the separate disciplines with the larger field of science. Finally, our study indicates that teacher turnover contributes to staffing problems. Our study does not suggest that all teacher turnover is negative or that 100% retention could, or should be, a goal of schools.

From the framework of supply-and-demand theory, any imbalance between labor demand and supply can technically be referred to as a shortage, in the sense that there is an inadequate quantity of individuals able and willing to offer their services under given wages and conditions.

From this framework, the situation we find—math and science staffing problems in a significant portion of schools significantly driven by migration and preretirement attrition—can technically be referred to as a shortage. However, in the context of teachers and schools, the term *shortage* is typically given a narrower connotation: an insufficient production of new teachers in the face of increasing student enrollments and increasing teacher retirements. These terminological and diagnostic differences have crucial implications for prescription and policy.

Where the quantity of teachers demanded is greater than the quantity of teachers supplied given the prevailing wages and conditions, there are numerous possible policy responses. Recruiting new qualified mathematics and science candidates has long been a dominant strategy, and nothing in this study suggests that this is not worthwhile. Indeed, our data appear to show that this approach has yielded results; in the past two decades, there has been a disproportionately large increase in the employment of qualified mathematics and science teachers. Of the many examples of recruitment approaches, one strategy that has been less emphasized—yet is suggested by our data analysis—is to further tap into the large reserve pool of former teachers.

But the data indicate that teacher production and recruitment strategies alone do not directly address a major root source of mathematics and science teacher staffing problems—turnover. This analysis suggests that recruiting more teachers, while an important first step, will not fully solve school staffing inadequacies if large numbers of such teachers then depart in a few years (see, e.g., Fowler, 2008; Liu, Johnson, & Peske, 2004). Again, the turnover of mathematics and science teachers is especially important to address because these fields do not have the same large "cushion" of new supply enjoyed by fields such as English. To illustrate, President Bush pledged in his 2006 State of the Union speech to recruit 30,000 new mathematics and science teachers across the nation. However, the data indicate that over 35,000 mathematics and science public and private school teachers left teaching just after the 1999–2000 school year alone. Only about 8,000 of these left because of retirement. Over twice as many indicated that job dissatisfaction was a major factor in their decision to leave. Decreasing the attrition of those recruited by such initiatives could lessen losses of the investment and also lessen the ongoing need for creating new recruitment initiatives. Moreover, production and recruitment strategies alone do not address the role of school-to-school teacher migration in mathematics and science staffing problems.

What alternative policy prescriptions are suggested by this analysis? From the organizational perspective of this analysis, schools are not simply victims of external demographic trends, and there is a significant role for the management of particular schools in both the genesis of and solution to school staffing problems. This analysis suggests the efficacy of improving teacher recruitment and teacher retention simultaneously by improving the attractiveness of the teaching job in those settings that suffer from staffing problems.

Notes

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[1]In a related study, we closely examine data and research on teacher turnover compared to employee turnover in other occupations and the benefits and costs of teacher turnover. See Ingersoll and Perda (2010).

[2]The Schools and Staffing Survey (SASS) school questionnaires asked school administrators, "Were there teaching vacancies in this school for this school year, that is—teaching positions for which teachers were recruited and interviewed?" and "How difficult or easy it was to fill the vacancies for this school year?" in each field. Answers were on a 4-point scale: *easy*, *somewhat difficult*, *very difficult*, and *could not fill*. In Figures 2 and 3, we counted as having "serious" difficulty those schools reporting either *very difficult* or *could not fill*.

[3]In Table 2, because of limitations in the SASS teacher questionnaire, many of those enrolled in alternative certification programs during their 1st year of teaching are unavoidably classified as delayed entrants (row 1b[i]) rather than newly qualified entrants from the pipeline (row 1a[i]). Hence, Table 2 underestimates the number of those hired from the pipeline.

[4]The data in Figure 5 for math, science, and English represent students enrolled in and teachers instructing departmentalized subject area courses, predominant at the middle and secondary school levels.

[5]Note that our findings in Figure 7 showing that most qualified candidates end up teaching at some point appear to contradict the findings of other analyses (e.g., Henke, Chen, & Geis, 2000). Once disaggregated, we found large differences across fields in employment rates.

[6]Using a one-way random effects ANOVA model, the data show that the variance component within states is 44 times the size of the variance component between states, and between schools, it is 84 times that between districts.

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