Education Policy Analysis Archives

Volume 7 Number 9 March 26, 1999 ISSN 1068-2341

A peer-reviewed scholarly electronic journal
Editor: Gene V Glass, College of Education
Arizona State University

Articles appearing in **EPAA** are abstracted in the *Current Index to Journals in Education* by the ERIC Clearinghouse on Assessment and Evaluation and are permanently archived in *Resources in Education*.

High School Staff Characteristics and Mathematics Test Results

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Abstract

This study investigates the relationship between measures of mathematics teacher skill and student achievement in California high schools. Test scores are analyzed in relation to teacher experience and education and student demographics. The results are consistent with the hypotheses that there is a shortage of qualified mathematics teachers in California and that this shortage is associated with low student scores in mathematics. After controlling for poverty, teacher experience and preparation significantly predict test scores. Short-term strategies to increase the supply of qualified mathematics teachers could include staff development, and recruitment incentives. A long-term strategy addressing root causes of the shortage requires more emphasis on mathematics in high school and undergraduate programs.

Introduction

Debate on how best to teach mathematics has a long history, dating at least to Plato's Greece and the methods illustrated in the Meno. That dialogue presented mathematics instruction as an instance of a general method of teaching based on inquiry. More recent authors frame education as a system, described by indicators of instructional context, processes, and outcomes. (Levin, 1974; Murnane, 1987; Office of Educational

Research and Improvement, 1988; Shavelson, McDonnell and Oakes, 1989; and Porter, 1991) Martin (1996) describes an influential framework for the study of mathematics achievement adopted by The Third International Mathematics and Science Study (TIMSS). The TIMSS framework focused on an explanatory system with three factors: what is intended to be taught; what teachers actually do in the classroom; and what students learn.

Curriculum standards and frameworks—"what is intended to be taught"—are teaching tools that can help students to learn, depending on the skill of the teacher. Perhaps because direct measures of teaching skill are difficult to define and obtain, researchers and policymakers use teacher education and experience as plausible proxy measures. Individuals with the same amount of experience and similar teaching credentials can vary in actual skill. Even so, in an aggregate consisting of many teachers in many schools, it is not unreasonable to believe that more highly educated and experienced teachers possess greater skill. Additionally, it is likely that the presence in schools of more educated and experienced teachers is associated with better student achievement.

The departmentalized instruction found in most high schools offers an opportunity to study the linkage between teaching and learning of specific subjects, such as mathematics. Secondary school teachers typically possess single-subject credentials that require proof of specialized subject matter knowledge, and authorize teaching in specific areas. The possession of a valid credential and authorization to teach mathematics is one indicator of teacher education and experience. By contrast, at the elementary level, teachers possess multiple-subject credentials. At the elementary level there is no specific indicator of teacher skill in mathematics instruction.

Mathematics Curriculum and Achievement

Official statements of high school course requirements and curriculum standards permit an inference about the importance of high school mathematics. A national survey of states, conducted by the Council of Chief State School Officers (1998) found that 23 states require more than two credits in math, compared to 13 states in 1989. Forty-two states, including California, have mathematics content standards ready for implementation. Table 1 summarizes the minimum academic coursework expected from California students during a traditional four-year high school career. The California State University System and the University of California publish minimum subject requirements for freshman admission, including electives. Based on these recommendations, mathematics should be considered second only to English, and should occupy 20 percent or more of a student's curriculum.

Table1
California High School Core Academic Course Requirements

	High School Graduation	**California State University**	**University of California**
Mathematics	2	3	3

English	3	4	4
Science	2	1	2
History/ Social Science	3	1	2
Other/ Electives	3	6	4
Total	13	15	15

The National Assessment of Educational Progress (NAEP) (See http://nces.ed.gov/naep/.) has demonstrated influential models of standards-based assessment, and has focused attention on student achievement in mathematics by providing state-by-state summaries of student performance. The NAEP 1992 and 1996 assessments (Reese, et al., 1997) used a framework related to the National Council of Teachers of Mathematics (NCTM) "Curriculum and Evaluation Standards for School Mathematics," originally published in 1989. (See http://www.nctm.org.) These standards include five mathematics strands: number sense, properties, and operations; measurement; geometry and spatial sense; data analysis, statistics, and probability; and algebra and functions. In addition to the five strands, the NAEP assessment examined mathematical abilities (conceptual understanding, procedural knowledge, and problem solving) and mathematical power (reasoning, connections, and communication). Mathematical abilities relate to the knowledge or processes involved in successfully handling tasks. Mathematical power refers to the ability to reason, to communicate, and to make connections of concepts and skills across strands, or from mathematics to other areas. Table 2 displays percentages of students attaining mathematics achievement levels for California, the western region, and the nation. Although California's percentage is one point lower for the most advanced students in 1996, the state is ten points lower for students at or above a basic level.

Table 2
NAEP Grade 8 Percentages of Students at Achievement Levels

	At or Above Advanced	At or Above Proficient	At or Above Basic	Below Basic
1996				
Nation	4	23	61	39
Western Region	3	22	59	41
California	3	17	51	49

1992				
Nation	3	20	56	44
Western Region	3	21	58	42
California	2	16	50	50

Teacher characteristics may explain some of the variation in NAEP scores. Hawkins (1998) used eighth grade data from the 1996 assessment to show that students taught by teachers with an undergraduate or graduate major in mathematics scored higher than students taught by teachers with majors in education or some other field. Moreover, students taught by teachers with certificates in mathematics outperformed students taught by teachers with certificates in other areas. Finally, students of teachers who rated themselves as knowledgeable or very knowledgeable about the NCTM curriculum and evaluation standards scored higher than students whose teachers reported little or no knowledge of the standards.

Achievement of College Entrants

The California Postsecondary Education Commission (1998) estimates that thirty percent of public high school graduates are eligible for freshman admission at the California State University (CSU). Admission requirements in mathematics include three years of college preparatory coursework, normally Algebra I, Algebra II, and Geometry. CSU requires all entering freshmen to demonstrate proficiency in mathematics, either by taking the Entry Level Mathematics (ELM) examination or by presenting proof of adequate performance on an appropriate Advanced Placement, SAT, or ACT mathematics test. Those who cannot demonstrate proficiency must take remedial courses. California public high schools produced 269,071 graduates in 1997 and California State University enrolled 26,781 of them in fall 1998, for a college going rate of ten percent. Fifty-five percent of these first time freshmen required remedial mathematics instruction. (See http://www.co.calstate.edu/asd/index.html.)

Supply and Preparation of Teachers

Supply and demand for mathematics faculty is one part of a larger system that prepares and employs teachers. Growing student enrollment is driving the demand for qualified teachers. The National Center for Educational Statistics (NCES, 1996) estimates that total K-12 enrollment will grow about 10 percent from 49.8 million in 1994 to 54.6 million by 2006. California public school enrollment will rise over 11 percent from 5.6 million students in 1997 to 6.2 million ten years later. (California Department of Finance, 1998) California public schools employed 270,000 teachers in 1997. (California Department of Education, 1998). Other factors remaining equal, the enrollment growth should create about 30,000 new teaching positions over the next decade. This growth, combined with turnover related to retirement and attrition, and with efforts reduce class size, have resulted in estimates of a need to hire more than 300,000 teachers in California over the next ten years.

Given that teaching skill is associated with student achievement, school districts and policymakers are interested in how teachers are prepared. (Darling-Hammond and Hudson, 1990; National Commission on Teaching and America's Future, 1996; Ashton, 1996; Education Week, 1997) While teaching skill is a goal of preparation, usually a credential only requires an academic degree and coursework. Virtually all public school teachers in the United States have at least a bachelor's degree, and a majority possess an advanced degree. (NCES 1995a) The trend is toward higher levels of education. In 1971, 28 percent of public school teachers possessed a master's, specialist, or doctoral degree. Twenty years later 53 percent of teachers had an advanced degree.

Although high demand for teachers is prompting reforms, California's degree and coursework requirements tend to resemble those of many other states. (National Association of State Directors of Teacher Education and Certification, 1998). Historically, a California preliminary credential required a Bachelor's degree in a subject other than professional education, and a one-year preparation program with training in educational principles and teaching strategies. Those seeking a clear credential fulfill additional course requirements and a year of educationally related study. Career changers with at least a Bachelor's degree and competence in their subject of instruction may work as paid teaching interns while they receive support and training in pedagogy from school districts or universities.

Nationally, schools are filling an increasing proportion of vacancies with inexperienced applicants. (NCES 1995a) From 1988 to 1991 public schools hired more first-time teachers and fewer reentrants or transfers. Teachers who transfer from other schools or return to a school have more experience, but receive higher salaries than first-time teachers. First-time teachers earn less, but are more likely to leave the profession. Teacher retirement and migration into other occupations influence turnover in schools. (NCES 1995b) Nationwide, between 1990-91 and 1991- 92 about 5 percent of teachers left teaching, including retirees. Teachers with less full-time teaching experience were more likely to leave. Smaller schools experience higher teacher attrition. Lower salaries and benefits may be a factor in this relationship. Small schools offer teachers less compensation than larger schools. School with more student poverty have higher turnover than other schools.

Credential requirements restrict access to the teaching profession. One way to meet increased demand is to relax the requirements, reducing the time and cost to become a teacher. For example, when there are too few fully qualified applicants, California school districts use emergency permits to hire individuals who lack some requirements for a credential, usually proof of competence in their subject(s) of instruction or pedagogy. (Hart and Burr, 1996) In recent years emergency permits have become more popular. A risk of this increased popularity is that less well prepared teachers may be less effective in their jobs or more prone to attrition.

States have sought to increase the supply of teachers by setting up alternatives to traditional training programs. Zumwalt (1996) describes alternative certification as easing entry requirements, minimizing preparation needed prior to paid teaching, and emphasizing on-the-job training. Proponents portray these programs as attracting higher-ability, more diverse, experienced people with subject matter majors. (Ashton, 1991; Dill, 1996; Feistritzer, 1994; Haberman, 1992) Zumwalt cautions that it is difficult to generalize about the success of alternative programs. Alternative approaches assume that school staffs have the resources to support unprepared novice teachers. The success of alternative approaches may actually depend on the extent to which novice teachers actually receive needed support and obtain classroom assignments appropriate to their abilities.

Mathematics Teachers

Nationwide, 90 percent of teachers in grades 9 through 12 for whom mathematics is their main assignment report having a major or minor in that subject. (NCES; 1998, 1999) Students at public secondary schools with a higher poverty level or with a higher percentage minority enrollment were more likely to be taught any of the core subjects, including mathematics, by a teacher who had not majored in that subject.

Brunsman (1997) describes California's requirements for a single-subject credential in mathematics and the number of qualified mathematics teachers. In addition to the requirements that apply to all credentials, high school mathematics teachers must demonstrate their competence in the subject either by completing a subject matter program, or they can demonstrate their competence through an examination.

Approved subject matter programs include a core with at least 30 semester units of mathematics coursework that is related to subjects that are commonly taught in departmentalized mathematics classes. This core includes courses in first and second year algebra, geometry, first and second year calculus, number theory, mathematics systems, statistics and probability, discrete mathematics, and the history of mathematics. Programs also include a minimum of 15 semester units of supplemental coursework to provide breadth.

Optionally, a credential candidate can demonstrate subject matter competence in mathematics through examination. California has adopted a standardized subject matter test in mathematics that includes two hours of multiple-choice questions and a two-hour performance assessment. Historically, less than half of the examinees pass the examination.

School districts can assign less than fully qualified teachers to mathematics classes by several methods. An emergency permit requires a Bachelor's degree, passing a basic skills test, and completing a minimum of 18 semester hours or 9 upper division/graduate semester units of course work in mathematics. In order to renew the permit, the teacher must complete six semester units toward earning a credential in mathematics. A limited-assignment emergency permit requires that the teacher have a valid teaching credential in another subject. A waiver requires only that the teacher pass or not ever have taken the mathematics portion of a basic skills test.

Table 3 shows the numbers of single subject credentials, emergency permits, and waivers issued 1993-94 to 1996-97 in mathematics. The number of emergency/waiver teachers in mathematics far outpaces the number of fully qualified new teachers. Over the four year period California granted credentials to 2,689 fully qualified new mathematics teachers, and granted other permits or assignments to 6,339 less well-qualified teachers. Unfortunately, it is not known how many fully qualified teachers actually applied for and accepted jobs in public schools. Virtually every waiver and emergency permit represents an employed teacher. These figures suggest that the supply of fully qualified teachers does not meet current demand. There is a downward trend in the number of fully qualified teachers prepared and possibly hired, and an upward trend in the number of less than fully qualified people actually hired on waivers or permits.

Table 3
First Time or New Type Single Subject Credentials,
Emergency Permits, and Waivers in Mathematics

Credentials	**1993-4**	**1994-5**	**1995-6**	**1996-7**
Credentials Via Completed Program	470	475	431	449
Credentials Via Passed Examination	278	218	242	126
Total Credentials	**748**	**693**	**673**	**575**
Total Emergency Permits and Waivers	**1,480**	**1,380**	**1,465**	**1,617**

Student Performance

Some research suggests that teacher skills and ability influence student achievement. Greenwald, Hedges and Lane (1996) reviewed a number of studies of the relationship between school inputs and student outcomes. Some school resources, i.e., teacher ability, teacher education, and teacher experience were strongly related to student achievement. On the other hand, Hanushek's (1996) synthesis of research studies found mixed support for a relationship between school resources and achievement. Although Hanushek did not detect a clear pattern, measures of teacher experience were more consistently related to achievement than measures of teacher education. Ashton (1996) notes that teachers with regular state certification receive higher supervisor ratings and student achievement than teachers who do not meet standards. Teachers without preparation have trouble anticipating and overcoming barriers to student learning, and are likely to hold low expectations for low-income children. Ashton suggests that reducing certification requirements and hiring of teachers who do not meet certification standards, worsens the quality of education of low income children.

Method

The 795 regular California high schools in this study typically serve 1.3 million students per year. About 93 percent of regular high schools offer instruction in grades 9 through 12, although various other grade configurations are represented, most commonly 10-12, or 7-12. These schools reported employing 56,571 full-time equivalent (FTE) teachers in fall 1998, with 14.1 percent of the FTE dedicated to mathematics instruction.

Approximately 600 non-traditional high schools serving about 100,000 students per year were excluded from the study. Generally, non-traditional schools have small enrollments and do not offer the academic curriculum needed to attend California's public universities. Reasons for referral to a non-traditional school could include an unstable home environment, emotional difficulties, pregnancy, etc. Non-traditional schools diverge from regular schools in serving a population of students with different needs and providing different kinds of services.

The web site for California's Standardized Testing and Reporting (STAR) program (http://star.cde.ca.gov/) provided school average mathematics achievement test scores. The Stanford Achievement Test Series, Ninth Edition, (Stanford 9), was administered to all students in grades 2 through 11 between March 15, 1998 and May 25, 1998. Obtaining direct measures of mathematics skill is probably no easier than obtaining direct measures of teaching skill. Multiple-choice test scores are commonly used as expedient indicators of student skill. The Stanford 9 high school mathematics tests require 45 minutes of examination time and include 48 questions. The content of the tests is oriented towards basic skills and is based on the NCTM framework. Scaled scores were derived using Item Response Theory Rasch model techniques. (Harcourt Brace, 1997). Results for schools testing fewer than 10 students were not available.

Overall, 2.5 percent of students were legally exempted either by parent request or by means of an Individual Education Plan or Section 504 Plan for students with disabilities. Possible effects of selective testing were examined with the help of an estimate of student participation in the assessment. Grade level participation rates were estimated using fall 1998 grade enrollment as the denominator and the number tested as the numerator. Given California's increasing enrollment, this statistic slightly underestimates actual participation statewide.

Teachers with instructional assignments in mathematics were identified from the results of the 1998 Professional Assignment Information Form (PAIF), an annual survey conducted as a part of California Basic Educational Data System (CBEDS). The information requested on the PAIF is required of each certificated staff person, and includes demographics, assignments, and position/credentials. The educational level of teachers with instructional assignments in mathematics was coded as: (1) Doctorate; (2) Master's degree plus 30 or more semester hours; (3) Master's degree; (4) Bachelor's degree plus 30 or more semester hours; (5) Bachelor's degree; and (6) Less than Bachelor's degree. Very few teachers possess less than a Bachelor's degree, so these individuals were aggregated with those who did possess the degree. Years of educational service included service in the current district, other states, and countries, but did not include substitute teaching. School summary statistics for staff with mathematics assignments included the numbers with emergency permits, teaching credentials, and mathematics authorizations. The percent of emergency permits was computed using the headcount of staff with one or more mathematics assignments as denominator and the number of staff with emergency permits as numerator.

AFDC is the percentage of students in the school's attendance area who are enrolled in either public or private schools and who are from families receiving aid. As an indicator of poverty AFDC often correlates with student achievement (White, 1982), and functions in this study as a control variable.

The descriptive and correlational statistics used in this study permit informed speculation about relationships among the phenomena measured by the study variables. Of course, these techniques by themselves do not justify conclusions regarding cause and effect.

Results

Table 4 displays the percent of teachers with one or more mathematics assignments by educational level and possession of an emergency permit. There is a discrepancy between the number of teachers with emergency permits reported by districts on the fall CBEDS census for regular high schools, and a larger number of permits actually issued by the California Commission on Teacher Credentialing (CTC). The CTC number reflects a year- cumulative total for all schools. Differences in the scope and method of data collection likely account for much of the discrepancy.

Table 4

Educational Level and Emergency Permits of Mathematics Teachers

Degree	Emergency Permit	
	Yes	**No**
Ph.D.	1.3%	1.4%
MA+	5.2%	23.3%
MA	7.7%	16.6%
BA+	26.3%	46.7%
BA or Less	59.6%	12.0%
Total Percent	100.0%	100.0%
Total Head Count	1,009	8,516

The results indicate that 10.5 percent of mathematics teachers in regular high schools have emergency permits. Although some emergency permit teachers have advanced degrees, a majority possessed only a baccalaureate degree. By contrast, the majority of mathematics teachers with credentials completed post baccalaureate work, and about one-fourth of them completed work beyond the masters degree.

Table 5 displays the percent of teachers with one or more mathematics assignments by number of years of service and authorization to teach mathematics. The distributions are bimodal with relatively higher percentages of mathematics teachers with five or less years of experience, consistent with the hypothesis that mathematics teachers tend leave the education profession after several years. At the same time, more than half of all mathematics teachers report ten or more years of teaching experience. Results indicate that one-fourth of those who teach mathematics lack authorization. Although the data do not track teaching assignments over time, about 60 percent of those lacking authorization have ten or more years of experience.

Table 5
Years of Service and Authorization of Mathematics Teachers

Years of Service	Mathematics Authorization	
	Yes	**No**
0	0.7%	2.3%

1	7.6%	9.8%
2	5.9%	6.6%
3	5.2%	4.5%
4	5.1%	3.4%
5	5.0%	4.0%
6	4.2%	2.9%
7	3.5%	2.5%
8	3.9%	2.5%
9	3.9%	2.1%
10+	55.3%	59.5%
Total Percent	100.0%	100.0%
Total Head Count	7,228	2,383

Table 6 displays mean test scores, proportion of students participating in the assessment, AFDC, years of experience of mathematics teachers, and education level of mathematics teachers. Grade-level mean test scores and participation rates were weighted by the number of students tested. AFDC and the teacher statistics reflect the entire school and were weighted by total school enrollment. An increasing trend in test scores may indicate improvement in achievement from grade 9 to 11. However, the declining number of students enrolled in higher grades is consistent with student attrition from dropping out. Moreover, the decreasing trend in student participation is consistent with more selective testing in grade 11. Higher scores could be accounted for either by attrition or selective testing.

Table 6
Means of Selected Variables

	School	Grade 9	Grade 10	Grade 11
Test Score	n/a	690	697	703
Participation	n/a	.86	.85	.81
AFDC	15.7%	N/a	n/a	n/a

Years Teaching	14.4	N/a	n/a	n/a
Education Level	3.6	N/a	n/a	n/a
Number Tested	n/a	347,201	313,303	260,933
Number Enrolled	n/a	405,516	370,080	321,896
Number of Schools	n/a	785	794	789

Table 7 displays selected correlations of school mean scaled scores and other variables, weighted by the appropriate grade enrollment. The results appear to be consistent across grades. All correlations are statistically significant, ($p < .001$). Appendix A includes all pairwise correlations of study variables. The empirical correlations probably underestimate the relationships between the study variables for several reasons. The measures of mathematics teacher characteristics are based on a relatively small proportion of all teachers at a school. The student outcome measure, a narrowly defined indicator of mathematics achievement, focuses on one of many areas of study expected of students. More broadly defined measures could produce stronger correlations. Differences in the level of aggregation could also limit the correlations. AFDC and the teacher characteristics are school-wide measures. Test scores and student participation are grade specific. Greater consistency in aggregation, not possible with the available data, could also produce stronger correlations.

The strong relationship often found between poverty and achievement is replicated in this study. AFDC correlates more strongly with test scores than do the other study variables. Correlations with AFDC are largest for ninth grade test scores and smallest for eleventh grade. An investigation of this trend is beyond the scope of this study. However, it is possible that lower achieving students are less likely to be tested in higher grades, possibly the result of attrition or selective testing. If true, the absence of lower achieving students may have resulted in a restriction of range of the variables and lower correlations.

The positive relationship between student participation and test scores is counter-intuitive and seems inconsistent with the hypothesis that lower participation rates are associated with widespread exclusion of lower achieving students. However, school participation rates are negatively related to poverty. Schools with more poverty tend to have lower participation rates and lower test scores. Schools with less poverty tend to have higher participation rates and higher scores. Of course, school characteristics other than poverty could be related to student participation. For example, participation rates might reflect administrative competence. Students at better run schools might have better opportunities to learn and might be more likely to take and do well on tests.

Teaching experience, measured by the average number of years in service, is positively related to test results. Schools with well-prepared teachers tend to have higher mathematics scores, whether preparation is measured as percent of mathematics teachers with emergency permits or as an education level index. To some extent, the effect of teaching experience is mediated by poverty. That is, schools with more poverty tend to have both less well- prepared teachers and lower test scores. One way to assess the influence variables independently is to include all of them in a multiple regression analysis.

Table 7
Correlations for Selected Variables

Variable	9th Grade Test Score	10th Grade Test Score	11th Grade Test Score
Percent AFDC	-0.64	-0.61	-0.59
Percent Participation	0.45	0.48	0.35
Years Teaching	0.24	0.26	0.27
Education Level	-0.24	-0.23	-0.22
Percent Emergencies	-0.39	-0.36	-0.36

Table 8 displays the results of three multiple regression analysis for grades 9, 10, and 11. Achievement test scores were the dependent variables and the analyses were weighted by the number of students tested. The raw weights reflect the variables as originally measured. The beta weights reflect the predictors after scaling to standard deviation units and aid comparisons of the importance of predictors within and across grades.

Table 8
Multiple Regression Analyses by Grade Level

	Grade 9 Weights		Grade 10 Weights		Grade 11 Weights	
	Raw	Beta	Raw	Beta	Raw	Beta
Intercept	671.1	0	667.5	0	686.3	0
AFDC	-0.6	-10.7	-0.5	-9.3	-0.6	-9.0
Participation	30.7	3.7	39.4	4.5	24.6	2.9
Years Teaching	0.3	1.7	0.4	2.1	0.5	2.4
Percent Emergencies	-27.8	-4.1	-19.8	-3.1	-24.4	-3.2

R-Square	0.50	0.47	0.44

The three multiple regressions yield similar patterns of results. Student poverty, measured by AFDC, demonstrates the strongest relationship with test scores. Student participation, following the pattern of related simple correlations, is positive related to test scores, even taking poverty into account. The percent of mathematics teachers on emergency permits predicted test scores about as well as student participation. Higher percents of emergencies were associated with lower scores. Finally, the average number of years of teaching experience was positively related to scores. Schools with more experienced mathematics teachers tend to have higher mathematics achievement.

The values of R-square, a measure of how well a combination of the independent variables predicts test scores, appear to trend down as the grade levels increase. This downward trend parallels a similar downward trend in the importance of AFDC as a predictor. One explanation for the trend could be increasing homogeneity of students at higher grade levels. As more disadvantaged students either drop out or find placement in alternative schools, those remaining in regular high schools become more similar socially and demographically. If this hypothesis is true, it could account for some of the increase in test scores in higher grades.

Discussion

The results of this study are consistent with the hypothesis that there is a shortage of qualified mathematics teachers and that this shortage is associated with weak student achievement in mathematics. Student poverty strongly predicts mathematics achievement in this study, as in many others. After factoring out the effects of poverty, teacher experience and preparation are significantly related to achievement.

Several California state policies communicate the importance of learning mathematics. Long standing high school graduation course requirements oblige students to commit a significant amount of time to mathematics instruction. Similar course requirements for college entrance reinforce the message. A state curriculum framework for mathematics appeared in 1985, and the state colleges and universities published a statement of desired competencies in 1982. More recently, the State Board has adopted mathematics curriculum standards for what students are expected to know and be able to do at each grade level. Finally, the current and past statewide assessment programs include mathematics tests. Historically, California policymakers and educators have consistently proclaimed the importance of teaching and learning mathematics. To what extent has the setting of priorities and goals resulted in desired student outcomes?

There are several indications that high school student performance in mathematics does not rise to expectations, for those who are college bound or for others. The 1992 and 1996 NAEP mathematics results are troubling for several reasons. In general, relatively large percentages of students exhibit "below basic" skill levels. Compared to the nation, California has lower percentages of students that are "at or above basic." The NAEP results are consistent the 1998 findings from the STAR assessment program that suggest lagging performance of California high school students on the basis of national norms. Additionally, the California NAEP results do not follow improvements nationwide from 1992 to 1996. Another negative indicator is the finding that over half of 1998 first time freshman at California State University required remedial classes in mathematics.

One explanation for the lower than desired results in mathematics relates to student demographics. Traditionally, student poverty correlates with low achievement. Possibly, disadvantaged students enjoy less support for academic pursuits from their families and peers, and are more focused on meeting needs related to safety and survival. California has a growing number of students whose primary language is not English. These students do not have the same degree of access to the curriculum or assessment as native English speakers. On the other hand, many believe that teaching and learning mathematics depends less on mastery of English than other subjects. Although language skills are important for assessments of writing or reading comprehension, they probably play a lesser role in understanding mathematical notation, solving equations, etc.

Of course, public schools do not control the demographics of their students. Except for those students exhibiting serious disciplinary problems, a public school must serve all who live in its attendance area. There is little that schools can do to change the social and economic circumstances of students. However, the lack of power to alter demographics does not justify complacency towards the education of disadvantaged students. Leverage to improve student outcomes exists at other points in the educational system. Ideally, schools will provide a safe and positive learning environment along with programs and resources to compensate for particular disadvantages. Beyond such compensatory programs, outcomes for disadvantaged students likely depend on sound curriculum standards and quality teaching.

Despite the powerful effect of poverty, the experience and education of mathematics teachers predicts student achievement. Schools with more experienced and more highly educated mathematics teachers tended to have higher achieving students. Schools with higher percentages of teachers on emergency permits tended to have lower achieving students.

Unfortunately, teacher credential information indicates a declining trend in the number of newly-prepared, fully- qualified, high school mathematics teachers, and increases in the number of those who are teaching out of their area or on emergency permits. One reason advanced for these trends is that college students with an interest in mathematics avoid teaching in favor of more lucrative career pathways found in science or engineering. There appears to be a shortage of mathematically able students to meet the overall demand in teaching and other professions. Given growing K-12 enrollments, a strong policy commitment to learning mathematics, and likely growth in technical professions that compete with education, this shortage is likely to persist and grow more severe.

One way to mitigate the effects of this shortage would be to provide training in mathematics to teachers who lack subject matter preparation. One difficulty with such staff development is that the amount of training needed to develop the necessary skills is likely to be great, and that limited staff time and resources will result in long, sustained periods of training. The challenge, in some cases, will be to provide the equivalent of an undergraduate minor spanning multiple courses over a period of years, to a teacher who is already employed full-time. Some under-prepared teachers may not have taken the necessary courses in college because they lacked prerequisite skills from high school. This in-service challenge will be difficult to reconcile with the limited time and resources usually provided for staff development. Given the difficulties, it would be prudent to evaluate the effectiveness of such in-service programs, and to consider other ways of easing the shortage.

Financial incentives might induce more people to take up teaching mathematics. There is abundant anecdotal evidence that higher starting salaries in other fields have drawn people with technical skills away from teaching. One drawback of financial incentives is the potential for inequality and divisiveness that it might create in the teaching profession. An additional issue is whether policy makers could make available sufficient additional funds for an incentive program effective enough to meet the needs of schools.

An alternative long-term strategy to address a shortage would be to require higher levels of mathematical skills of all undergraduate students, possibly by increasing the rigor and number of required lower division mathematics courses, and by requiring more upper division mathematics courses. The general education breadth requirement at the California State University only calls for "a minimum of twelve semester units or eighteen quarter units into the physical universe and its life forms, with some immediate participation in laboratory activity, and into mathematical concepts and quantitative reasoning and their applications." (California State University, 1993) This policy often translates into a requirement for one mathematics course at specific state universities. The general education requirement for students who transfer from a community college only calls for three semester units in "mathematical concepts and quantitative reasoning." Considering the weight given to mathematics in the CSU entrance requirements, the general education mathematics requirement appears inconsequential. Although little has been published on general education requirements, CSU's policies probably resemble those of many other colleges and universities. Strengthening the mathematics requirements could increase the numbers of students who major or minor in the subject, and could help to meet the growing demand for such expertise in teaching and technical professions.

A change in course requirements will face a number of challenges. Some believe that there has been a trend over the last several decades to weaken undergraduate mathematics requirements. One reason sometimes advanced for this trend is that many entering freshmen are not prepared to handle college mathematics. Increasing the rigor and number of required mathematics courses might adversely impact student retention and degree attainment. There may also be difficulty in providing sufficient faculty and resources to support additional requirements in mathematics.

High school student ability in mathematics should be seen as one outcome of a larger system that includes both K-12 schools and higher education. It would be unfortunate if weakened undergraduate requirements are related to poor high school preparation. This pattern could be a symptom of a downward spiral in mathematics literacy in the population. As collegiate requirements are weakened, resources for undergraduate mathematics programs lessen, the mathematics skills of teachers decrease, and the students of these teachers are less well prepared. Expectations of faculty and administrators in high school and college could drift lower, making it more difficult to provide the resources and leadership needed to create and implement high standards. In the short run a pattern of low expectations and low performance is the path of least resistance. Rigorous mathematics courses are not popular with students and are unrewarding for faculty. Easing the requirements provides short term relief. In the long run the path of least resistance results in lowered student ability and decreased capacity to make improvements. Public discontent with school performance will grow unless teaching and learning improve.

Schools and teacher preparation programs need to coordinate their programs more closely in preparing, recruiting, and hiring teachers. One basis for cooperation would be to set policy goals at both the state and local levels to eliminate the use of less than fully qualified teachers within a given time frame, for example, within five years. At the state level it would be useful to reduce the options for hiring less than fully qualified teachers and simplify the procedures for obtaining an authorization to teach mathematics. Subject matter preparation programs are approved partly on the basis of course titles and descriptions. Unfortunately, titles and descriptions permit considerable latitude in the rigor of such programs and there is little assurance as to the skills that prospective teachers actually develop. Given the apparent shortage of mathematically inclined undergraduates there may be an incentive to lessen the rigor of preparation programs in order to keep the "pipeline" full and meet school district demands. One way to cope with variation in rigor is to establish a uniform assessment of subject matter knowledge needed to teach high school mathematics.

The effectiveness of setting goals is reduced and the implementation of well-designed programs is undermined without timely and accurate data that describe how faithfully the programs are implemented and the extent to which outcomes are attained. In particular, monitoring of the supply and demand of teachers is severely hampered when information about credentials, teaching assignments, and employment is scattered across separate agencies or administrative units and is not easily linked. Although one state agency tracks credentials, it does not know how many credential holders are employed in public schools, or elsewhere. Another state agency conducts an annual staff census of teaching assignments, but lacks detailed information about credential status and does not track employment of individuals across time or schools. The agency responsible for teacher retirement maintains some employment history information, but does not follow credentials or assignments. Finally, student outcome data is not readily associated with information about teachers. Employment history, credentials, assignment information and student outcomes should be combined to provide more useful information for policy makers and program administrators.

The possibility of a unified data system in order to guide and evaluate education programs raises legitimate concerns about confidentiality and conditions of employment. Reasonable protection for the rights of individual teachers should be built into any such system. Balancing these concerns for privacy is the need to design, implement, and evaluate high quality programs that work for students. Beyond a responsibility to spend public money wisely there is a moral obligation to prepare students well for success in work and higher education. The use of timely and relevant information is one way to improve the odds for success.

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Note

A significant portion of the research reported here was completed while the author was a staff member of the Califonria Commission on Teacher Credentialing.

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Appendix A
Pairwise Correlations

Pairwise Correlations

Variable	by Variable	Correlation	Count	Signif Prob
Scaled Score - 10	Scaled Score - 9	0.9487	773	0
Scaled Score - 11	Scaled Score - 9	0.9381	770	0
Scaled Score - 11	Scaled Score - 10	0.9629	778	0

Participation - 9	Scaled Score - 9	0.3873	776	0
Participation - 9	Scaled Score - 10	0.3733	774	0
Participation - 9	Scaled Score - 11	0.3695	770	0
Participation - 10	Scaled Score - 9	0.3883	775	0
Participation - 10	Scaled Score - 10	0.3916	782	0
Participation - 10	Scaled Score - 11	0.3897	778	0
Participation - 10	Participation - 9	0.5876	782	0
Participation - 11	Scaled Score - 9	0.2882	773	0
Participation - 11	Scaled Score - 10	0.2942	780	0
Participation - 11	Scaled Score - 11	0.2913	778	0
Participation - 11	Participation - 9	0.5214	779	0
Participation - 11	Participation - 10	0.7383	787	0
AFDC	Scaled Score - 9	-0.6182	771	0
AFDC	Scaled Score - 10	-0.5863	777	0
AFDC	Scaled Score - 11	-0.5837	775	0
AFDC	Participation - 9	-0.3947	777	0
AFDC	Participation - 10	-0.3145	787	0
AFDC	Participation - 11	-0.2791	784	0
Years Teaching	Scaled Score - 9	0.1711	774	0
Years Teaching	Scaled Score - 10	0.2045	780	0
Years Teaching	Scaled Score - 11	0.2204	776	0
Years Teaching	Participation - 9	0.0588	780	0.1009
Years Teaching	Participation - 10	0.0817	790	0.0216
Years Teaching	Participation - 11	0.077	785	0.031
Years Teaching	AFDC	-0.0843	787	0.018
Education Level	Scaled Score - 9	-0.1852	774	0
Education Level	Scaled Score - 10	-0.1901	780	0

Education Level	Scaled Score - 11	-0.2016	776	0
Education Level	Participation - 9	-0.0663	780	0.0642
Education Level	Participation - 10	-0.1225	790	0.0006
Education Level	Participation - 11	-0.1004	785	0.0049
Education Level	AFDC	0.121	787	0.0007
Education Level	Years Teaching	-0.2919	792	0
Percent Emergencies	Scaled Score - 9	-0.3058	774	0
Percent Emergencies	Scaled Score - 10	-0.285	780	0
Percent Emergencies	Scaled Score - 11	-0.3017	776	0
Percent Emergencies	Participation - 9	-0.0953	780	0.0077
Percent Emergencies	Participation - 10	-0.1145	790	0.0013
Percent Emergencies	Participation - 11	-0.0969	785	0.0066
Percent Emergencies	AFDC	0.1945	787	0
Percent Emergencies	Years Teaching	-0.4056	792	0
Percent Emergencies	Education Level	0.2071	792	0

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