American Institutes for Research®

Prepared to Teach: Teach Preparation and Student Achievement in Eight-Grade Mathematics

Elizabeth Greenberg
David Rhodes
Xiaolan Ye
Fran Stancavage

American Educational Research Association

2004 Annual Meeting

April 12–16, San Diego, Calif.

Prepared to Teach:

Teacher Preparation and Student Achievement in Eighth-Grade Mathematics

April 2004

Elizabeth Greenberg
David Rhodes
Xiaolan Ye
Fran Stancavage

American Institutes for Research

The work on which this paper was based was performed pursuant to Cooperative Agreement Number R902F980001 of the Institute of Education Sciences, National Center for Education Statistics. It does not, however, necessarily reflect the views of that agency.

I. Introduction

The *No Child Left Behind Act* (NCLB) requires that all teachers in core academic subjects be highly qualified by the end of the 2005-2006 school year. NCLB stipulates that to be considered highly qualified, teachers must demonstrate that they have sufficient subject-matter knowledge and teaching skills to be effective teachers. Specifically, highly qualified teachers must

- have obtained full state certification as a teacher or passed the state teacher licensing examination and hold a license to teach in the state,
- have demonstrated subject matter competency in each of the academic subjects he or she teaches, and
- hold a minimum of a bachelor's degree.

Despite this emphasis on teacher qualifications in NCLB, surprisingly little research exists that links the qualifications of individual teachers to the performance level of students in their classrooms. Much of the research in the field has been conducted with state- or district-level aggregate data on teacher qualifications, rather than with data on individual students and their teachers.[1] As discussed below, there is also substantial disagreement among researchers as to which teacher qualifications make a difference in student achievement. This study uses data on individual students and their teachers from the 2000 National Assessment of Educational Progress (NAEP) eighth-grade mathematics assessment to examine the relationship between four aspects of teacher qualifications that have been identified in previous studies as potentially related to student achievement—certification, college/graduate school major and minor, highest degree, and teacher experience—and student achievement in mathematics. In addition, the study uses the background information collected with the NAEP assessment to examine whether teachers with qualifications related to student achievement are equitably distributed among students at highest risk of education failure.

[1] For example, see Darling-Hammond (2000).

II. Background: How much do we know about the qualifications of effective teachers?

NCLB focuses on three aspects of teacher qualifications: certification, subject-matter knowledge, and highest degree. While much of the literature on teacher qualifications focuses on these three areas, years of experience has also been identified as an important variable in some studies of teacher qualifications (Greenwald, Hedges, and Laine, 1996; Hawkins, Stancavage, and Dossey, 1998). In this section of the paper, we review the literature on these four areas of teacher qualifications.

Certification

The relationship between certification and teacher quality is one of the most hotly debated issues among researchers who study teacher qualifications. The discussion of teacher certification is complicated by the fact that each state has its own certification requirements. Although NCLB stresses the importance of all teachers being certified, the language in NCLB suggests that the type of certification requirements that produce effective teachers may be quite different from the type of certification requirements currently in use in most states. However, NCLB leaves direct control of teacher certification requirements to the states.

The importance of traditional teacher certification is a critical topic for education policymakers to understand, because certification is the primary gate-keeper controlling access to the teaching profession. Ballou and Podgursky (1997, 1998) have argued that current certification requirements, which generally specify that teacher candidates must complete a broad range of classes in pedagogy, may discourage talented individuals with advanced substantive knowledge in an academic field from entering the teaching profession. Their argument has drawn attention to the necessity of ensuring that any teacher certification requirements that may act as barriers to entering the teaching profession are positively related to student achievement.

In recent years, the relationship between teacher certification, as currently enforced by the states, and student achievement has been hotly debated in the pages of *Educational Evaluation and Policy Analysis.* In an article published in 2000, Goldhaber and Brewer used data from NELS:88 to investigate whether students' gains in mathematics and science performance between tenth and twelfth grades were related to whether or not the students' twelfth grade mathematics and science teachers had standard teaching certification in their state. Their model controlled for state licensing requirements, teacher undergraduate and graduate major, teacher experience, and the student's family background. After controlling for these variables, they found no difference in the achievement gain between tenth and twelfth grades among students whose teachers had standard, probationary, or emergency certification. They argue that this result should, "at the very least, cast doubt on the claims of the educational establishment that standard certification should be required of all teachers."

In a follow-up article published in the same journal in 2001, Darling-Hammond, Berry, and Thoreson disputed Goldhaber and Brewer's claim that their analysis of NELS:88 data calls into question the importance of standard teacher certification. Darling-Hammond, Berry, and

Thoreson criticized Goldhaber and Brewer for drawing such a sweeping conclusion based on a small sample size (only 24 science teachers and 34 mathematics teachers in the NELS:88 data set held temporary or emergency certification and had students who were tested in grades 10 and 12). They also pointed out that the regression coefficients for emergency and temporary certification in Goldhaber and Brewer's model were not statistically significant. Furthermore, they argued, most teachers with emergency or temporary certification have credentials from other states or are in the process of completing their coursework and testing requirements to obtain full certification, and therefore are not much different from fully certified teachers in terms of pedagogical preparation.

In a rejoinder to this critique by Darling-Hammond et al., Goldhaber and Brewer (2001) argued that the critique misrepresented their position on teacher certification and that they were in fact very careful not to draw any sweeping conclusions regarding teacher certification from their study. However, they did not dispute the claims that they based their conclusions on a small sample and on findings that were not statistically significant. They did point out that measures of statistical significance take sample size into account and that the standard errors on their regression coefficients were small, but, while that may be true, it does not directly address the criticism of Darling-Hammond et al.

In her own research, Darling-Hammond (2000) matched state-level aggregate data from the National Assessment of Educational Progress (NAEP) fourth- and eighth-grade reading and mathematics assessments with state-level aggregate data on teacher qualifications (degree major, certification status), teaching assignments, and average class size derived from the School and Staffing Survey (SASS), and with information on state policies regarding teacher education and licensing collected directly from states and professional associations. She found that teacher quality characteristics, including certification status, were positively related to student achievement at the aggregate state level, even when controlling for student characteristics, per pupil spending, and other school resources.

Darling-Hammond did not explain why she chose to aggregate her data at the state level instead of matching individual students with their individual teachers in the NAEP database (NAEP collects data on the qualifications of the teachers of students in the sample). As she herself wrote, "the size of relationships found between variables measured at the state level cannot be assumed to represent the effect sizes one would find in a classroom-level analysis." This is a serious drawback of her study (and one that she implicitly acknowledged by discussing it in a section of her article labeled "Limitations"), since there is no way to isolate the effect of teacher certification on the achievement of students who are the most at risk of educational failure and the most likely to have non-certified teachers: poor students and students with low achievement in previous years.

Subject-matter knowledge

In a report published in 1996, The National Commission on Teaching and America's Future used data collected as part of the 1990-91 SASS to draw attention to the fact that 23 percent of all secondary teachers did not have even a minor in their own teaching field. They also pointed out that the percentage of out-of-field teachers was not evenly distributed across all subjects: 56 percent of high school students taking physical science and 27 percent of high school students

taking mathematics were taught by out-of-field teachers. Not surprisingly, schools with high percentages of poor students had higher percentages of out-of-field teachers than other schools, and students tracked into classes for low achievers were more likely than other students to have out-of-field teachers.

Follow-up studies have reported similar incidences of out-of-field teaching. Results from the 1999-2000 SASS showed that 21 percent of high school mathematics teachers and 65 percent of middle school mathematics teachers did not have an undergraduate or graduate major in mathematics, while 45 percent of high school physical science teachers and 86 percent of middle school physical science teachers did not have an undergraduate or graduate major in science (Seastrom et al, 2002).

The literature on out-of-field teaching generally assumes that in order to teach a subject well at an advanced level—certainly at the high school level and probably at the middle school level—a teacher must have a minimum level of subject knowledge that is the equivalent of someone who majored in the subject in college. Various empirical studies have supported this contention, although the studies differ in whether they define subject-area expertise as a college major or include a college minor in that category. In the article discussed above based upon the NELS:88 data, Goldhaber and Brewer (2000) found that twelfth grade students whose mathematics teachers have an undergraduate or graduate degree in mathematics have higher levels of mathematics achievement than comparable students whose teachers majored in another field. Wenglinsky (2000) analyzed 1996 NAEP data and found that teacher coursework in mathematics was related to student performance on the NAEP mathematics assessment.

The only real debate in the literature on out-of-field teaching is the relative importance of education in pedagogical methods versus education in a substantive area. Monk (1994) analyzed NAEP data and other data and found that while there was a positive relationship between the number of mathematics and science courses a teacher had taken and how much students of these subjects learned, the number of education courses had an even stronger positive effect on student achievement.

This result may be explained in part by a few small studies that purport to show that teachers with extensive substantive knowledge may be somewhat blinded by their own knowledge and not realize how students with little background in the subject cognitively process new concepts. Thus, teachers with extensive subject-area knowledge may require some extra instruction in pedagogical techniques in order to become fully effective teachers. For example, in a recent article in the *American Educational Research Journal*, Nathan and Pettosino (2003) report the results of a small experimental study in which preservice teachers were presented with different methods of solving an algebra problem and asked to indicate which method they thought would be easiest for students. They compared preservice teachers with a major in mathematics (or the equivalent) with preservice teachers who had a weaker mathematics background, and argued that the teachers with a weaker mathematics background actually had a better understanding of the cognitive processes beginning algebra students use to solve problems. However, the sample size for this study was very small (N=48) and their outcome variable was not student achievement, but their own understanding of how students would best learn. There are no studies based on

large samples that support the notion that extensive substantive knowledge in a field may somehow be detrimental to student achievement outcomes.

Highest Degree

NCLB specifies that all teachers must hold a minimum of a bachelor's degree. There are no studies assessing the relationship between this requirement and student achievement, because the number of teachers in the United States who do not hold a bachelor's degree is so trivially small that it would be difficult to locate a sufficient number of these individuals to support reliable statistical comparisons. Instead, studies focus on whether or not students benefit from having a teacher who has a graduate degree in addition to a bachelor's degree. Greenwald, Hedges, and Laine (1996) conducted a meta-analysis of studies that examined the relationship between school resources and student achievement. They found that there was a significant and positive relationship between teachers' education, measured as having a master's degree or not having a master's degree, and student achievement. However, Hanushek (1997) reviewed studies published through 1994 and reported that only 9 percent of the studies found a significant and positive relationship between teachers' educational level and student achievement.

Experience

NCLB does not discuss teacher experience because it is not an area that can be addressed by legislation at the state or national level: teachers must gain experience in a classroom somewhere, so a minimum level of experience cannot be specified. However, teacher experience is a topic of potential concern to policymakers, because experienced teachers often try to move to districts, schools, and classrooms with a more privileged student body and higher resources. Thus, if teacher experience is related to student achievement, and more experienced teachers are able to some extent select the schools and districts in which they teach, or even their teaching assignments within a school, poor students and students at risk of educational failure may end up being doubly disadvantaged because they are more likely to be taught by inexperienced teachers.

Greenwald, Hedges, and Laine (1996) found in their meta-analytical study that teaching experience had a positive and significant effect on student achievement. Hawkins, Stancavage, and Dossey (1998) found evidence that although teaching experience appears to be related to student achievement, the relationship may not be linear; students whose teachers had fewer than 5 years of experience had lower levels of mathematics achievement as measured by the NAEP mathematics assessment, but there were no differences in mathematics achievement among students whose teachers had more than 5 years of experience. Other researchers have disagreed with these findings. Hanushek (1997) wrote that 71 percent of the studies he reviewed did not find any results to support a relationship between teaching experience and student achievement.

III. Data

We used data from the National Assessment of Educational Progress (NAEP) Grade 8 Mathematics assessment conducted during the spring of 2000 to examine the relationship between the teacher qualifications discussed above and student achievement among students enrolled in public schools. The NAEP mathematics assessment provides a comprehensive view of what America's students know and can do in mathematics. The NAEP mathematics assessment framework was developed by the National Assessment Governing Board (NAGB) through a consensus process that included input from a wide range of educators, curriculum specialists, researchers, mathematicians, and policymakers. In addition to testing students, NAEP asks all students, teachers, and school administrators that are part of the NAEP sample to complete background questionnaires. We relied on NAEP background data for measures of teacher qualifications, student background, and school characteristics.

The data available from the NAEP assessment are cross-sectional. That is, they reflect a single point in time and there is no measure of the students' achievement in prior years that can serve as a baseline to measure the "value added" by the eighth-grade teacher. However, slightly over half of eighth-grade students were tracked into mathematics classes that their teachers described as high, medium, or low ability (the remainder were in mixed-ability classes). For those students who were in classes grouped by ability level, we included the level of the class in our multivariate analyses as a proxy for achievement in prior years. It is an imprecise proxy: schools are inconsistent in the ways they define high-, medium-, and low-ability classes. However, if we assume that schools are reasonably internally consistent in how they define the ability levels of mathematics classes, the fact that the data set includes students in a range of classes in the schools that do ability grouping may somewhat compensate for the differences in how these levels are defined across schools.[2] Given the imprecision of this measure of prior achievement—and the fact that it is not available for almost half of the sample—the reader is advised to exercise caution in inferring any causality in the relationships between teacher qualifications and student achievement highlighted in this paper.

The analyses in this report were limited to public school students because one of the central measures of teacher qualification examined in the report, being certified by the state, may not be relevant to teachers in private schools. Furthermore, NCLB and the education policy debate concerning teacher qualifications focus on the public sector.

We focused on four specific teacher qualifications: teacher certification, academic major or minor, highest postsecondary degree, and years of teaching experience. We defined them as follows:

Certification

Teachers were categorized as certified if they reported having one or more of the following in their main assignment field in the state in which they teach: an advanced professional certificate,

[2] Because of a change in the way NAEP matches teachers to students, data on the ability level of students mathematics classes is not available for any NAEP administrations after 2000. Therefore, we have not been able to repeat the analyses in this paper using more recent NAEP data.

a regular or standard state certificate (standard certificate offered in the state), or a probationary state certificate (the initial certificate issued after satisfying all requirements except completion of a probationary period). All other teachers were categorized as not certified. Teachers with a probationary state certification were categorized as certified because they met all the requirements for certification except the teaching experience requirement.[3] Teachers who had emergency, temporary, or provisional certification were categorized as not certified because they did not meet the regular standards for certification in their state.[4]

Academic major or minor

Mathematics teachers were categorized as having a major or minor in their teaching field if they reported having an undergraduate or graduate major or minor in mathematics or mathematics education. Mathematics teachers were categorized as having a major or minor in education outside of their teaching field if they had a major or minor in education, but not in mathematics or mathematics education.

Highest degree

Teachers were categorized according to whether or not they had a master's degree or higher, regardless of the field in which the degree was earned. Virtually all teachers have at least a bachelor's degree, so in effect this classification divided teachers into two groups: those with a bachelor's degree and those with higher degrees.

Teaching experience

Teachers were categorized according to whether or not they had more than five years of teaching experience. Teachers were also categorized according to whether or not they had five or more years of experience in teaching mathematics.

[3] A preliminary analysis of the data showed that the achievement levels of students whose teachers had probationary certification did not differ from those of students whose teachers had full certification.

[4] The NAEP teacher survey grouped these three categories—emergency, temporary, and provisional certification—into one question. Among students whose teacher we categorized as not being certified, 87 percent had a teacher with emergency, temporary, or provisional certification. The number of other "non-certified" teachers in the NAEP sample using our definition was not large enough to support statistically reliable estimates.

IV. Methodology

We performed difference-of-means tests and assessed the coefficients in multivariate models to determine whether or not any differences in academic achievement observed in the sample data were statistically significant. We also assessed differences in the tendency of different types of students to have an eighth-grade math teacher with various qualifications.

In making statistical inferences from the NAEP sample data to the U.S. eighth-grade public school population, we needed to account for two distinct sources of variability. The first is the familiar sampling variability, present any time researchers wish make inferences based on sample data. Because of the complex sampling procedures used in collecting NAEP data, conventional formulas for sampling variability, which assume simple random samples, underestimate the variance attributable to sampling. To account for this, NAEP assigns each student a series of replicate weights that take into account variability based on sampling procedures and weight the sample so that it is representative of the eighth-grade school population.[5]

The second source of variability arises from the design of the NAEP mathematics assessment—specifically, the fact that individual students complete only a subset of the assessment questions. This introduces a second type of uncertainty into our population estimates of student achievement. To address this issue, NAEP assigns each student participating in the assessment five plausible values. These values represent five separate estimates of the NAEP score the student would have obtained if he or she had completed the entire assessment. All results reported here are based on the average of the five plausible values. By incorporating the variation we observed between the five plausible value estimates into our standard error estimation, we were able to account for the variability introduced by individual students only completing a subset of assessment questions.

Therefore, when making comparative statements about subgroups of students or schools and about the percentage of students or schools possessing certain characteristics, we used statistical procedures that take into account *only* the degree of uncertainty associated with the sampling, or sampling variability. When making comparative statements about student achievement, we took into account *both* sampling variability and variability based on the fact that each student answered only a subset of the mathematics questions.

We used a jackknife replication procedure, which utilizes the plausible values and replicate weights associated with each student, to calculate the standard errors associated with subgroup mathematics achievement estimates.[6] To account for the complex sample design, we used a Taylor Series linearization procedure to adjust the standard errors for all other population estimates and for the coefficients in regression models.

In the regression model we accounted for the estimation of NAEP scores by estimating five separate regression models predicting each of the five plausible values. The results reported

[5] For information on how replicate weights are calculated, see NAEP 2000 *Technical Report*.
[6] For further details, see Johnson and Rust (1992).

reflect the average coefficient across the five models, and the standard error estimates reflect the variance observed between the five coefficient estimates as well as the average of the standard errors across the five models. All statistical estimation was carried out using STATA® statistical software package.

We used a multiple regression model to estimate the relationship between our measures of teacher qualifications and mathematics achievement, controlling for other factors. The model assumes that mathematics achievement can be modeled as a linear function of teacher (T) as well as student and school (S) characteristics, with a normally distributed random error term (ε):

$$Y = \beta T + \gamma S + \varepsilon .$$

In this model, β estimates the influence of teacher quality measures and γ indicates the contribution of individual school and student background factors on achievement. Specifically, we controlled for differences in the following school factors: number of students, urbanicity, and the ability level of the class (mixed, high, medium, or low ability). We controlled for student gender, race/ethnicity, eligibility for the federal free and reduced price lunch program, number of reading materials in the student's home, and parental education. This type of model allowed us to statistically estimate the independent effect of each teacher attribute on mathematics achievement, net of other factors included in the model.

V. Results

We used the 2000 NAEP eighth-grade mathematics assessment data to address two sets of questions about the relationship between teacher qualifications and mathematics achievement. First, we identified which teaching credentials were associated with higher NAEP mathematics scores. Second, we addressed issues of equity in student access to teachers with the qualifications shown in the first part of our analysis to be associated with higher mathematics scores. We organized our analyses of NAEP data to answer the following research questions:

Questions about the relationship between teacher qualifications and student achievement in mathematics

1. Which teacher qualifications are related to student achievement in mathematics?
2. Do the relationships observed between teacher qualifications and mathematics achievement remain when we control for other factors?

Questions of equity

1. Are teachers with qualifications related to student achievement in mathematics equitably distributed among eighth-grade public school students?
2. Among students at risk of educational failure, are differences in access to qualified teachers related to differences in mathematics achievement?

Which Teacher Qualifications Are Related to Student Achievement in Mathematics?

In order to begin to identify which attributes of teachers were related to the level of eighth-grade student achievement in mathematics, we compared the mean mathematics scores of students whose teachers differed in our qualification measures. Table 1 presents average NAEP mathematics scores for eighth-grade public school students of teachers with specific qualifications.

Table 1: Average NAEP Mathematics for Public School Students by Teacher Qualifications

	Mean Score (standard error)
Total	274 (0.8)
Certification	
Certified	277 (1.0)*
Not certified	264 (2.9)
Academic major or minor	
In mathematics	279 (1.0)*
In education (outside of mathematics)	261 (2.3)
Highest degree	
Master's degree or higher	276 (1.5)
Less than a master's degree	275 (1.3)
Total teaching experience	
More than 5 years	277 (1.0)
5 years or less	273 (1.9)
Experience teaching mathematics	
More than 5 years	278 (1.0)*
5 years or less	272 (1.8)

* Significantly different at $p < 0.05$ from students with teachers without the specified qualification

Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

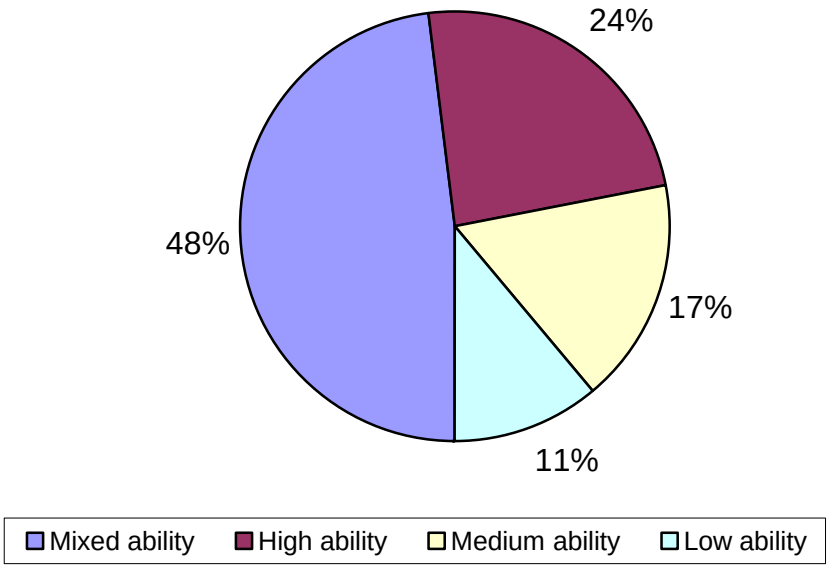
As shown in Table 1, eighth-grade students whose teachers were certified had higher average scores on the mathematics assessment than eighth-grade students whose teachers were not certified. Students whose teachers had a major or minor in their teaching field also had higher mathematics scores than students whose teachers had a major or minor in education outside of their teaching field. Having a teacher with a master's degree or with overall teaching experience were not significantly related to students' mathematics scores. However, students whose teachers had more than five years of experience teaching math scored significantly higher on the NAEP mathematics assessment than those students whose teachers had less experience teaching mathematics.

So far we have looked at the relationship between teacher qualifications and eighth-grade student achievement, without accounting for the effects of other factors that might have been related to student achievement. Other analyses of NAEP data have shown that student achievement is related to a variety of student characteristics, including gender, race/ethnicity, and parents' socioeconomic status (Braswell et al 2001). To assess the relationship between teacher

qualifications and student achievement net of other factors, we estimated a multiple regression model, controlling for school size, student eligibility for free and reduced-price lunch program, school urbanicity, student gender, student race/ethnicity, number of reading materials in the student's home, parental education, and the ability level of the student's mathematics class (mixed, high, medium, or low ability).

The ability level of the class provides a proxy measure for a student's prior (before eighth grade) mathematics achievement. Schools often group eighth-grade students into classes on the basis of ability level, as measured by students' past performance on tests, students' performance in previous classes in the same subject, and teachers' assessments of students' ability. As indicated in Figure 1, slightly more than half of eighth-grade public students in 2000 were being taught mathematics in a classroom grouped by ability level. Nearly one-fourth of eighth-grade students were receiving instruction in classes serving high-ability students, while only eleven percent of students were in low-ability classrooms. We do not have a proxy for prior achievement for the 48 percent of eighth-grade students who were in mixed-ability classrooms.

Figure 1: Percentage of Students Receiving Mathematics Instruction in Ability and Non-Ability Grouped Classrooms, Grade 8



Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

Table 1 looked at the relationship between each teacher qualification in isolation and student achievement. Most teachers possess more than one of the qualifications we are interested in. By including measures for all teacher qualification areas of interest in the same multiple regression model we were able to estimate the independent relationship of each to student achievement.

Being able to examine the impact of multiple teaching credentials simultaneously allowed us to expand beyond the single distinction made in Table 1 between teachers who had majored or minored in mathematics (or mathematics education) and teachers who had an education degree outside of mathematics. This specification failed to distinguish teachers who have degrees in both education and mathematics from teachers who only majored (or minored) in mathematics. In the multiple regression analysis, we were able to include separate measures for both mathematics and education degrees (double coding teachers who had both), thereby allowing us to estimate the independent influence of each on students' mathematics achievement score.

As presented in Table 2, the multiple regression analysis found that, net of other factors and other teaching credentials, certification and having a degree in mathematics were the teacher qualifications associated with higher mathematics achievement among eighth-grade public school students. The estimated difference in NAEP mathematics scores, as measured by the unstandardized regression coefficient, between students having a certified versus a non-certified teacher was roughly equivalent to the estimated difference between students who were and were not eligible for the free and reduced-price lunch program. The estimated size of the independent relationship for having a teacher with at least a minor in mathematics was roughly half of the estimated difference between students who had a parent with some college versus students whose parents left school after graduating high school. Because the analysis included a control for the ability level of a student's mathematics class, the findings for certification and having a degree in mathematics are not just a result of any tendency of students in high-ability mathematics classes to be more likely to have a teacher with these credentials than students in low-ability mathematics classes.

None of the other teacher qualifications examined in this report, including having a major or minor in education, had a statistically significant relationship to student achievement in mathematics.

Table 2: Regression Analysis, Dependent Variable = NAEP Mathematics Score, R2=.40, Grade 8[7]

Independent variables	Unstandardized Coefficient	Standard Error	T-Value
More than 5 years of experience teaching mathematics	0.39	1.53	0.26
Master's degree or higher	-0.39	1.55	-0.25
Certification	8.02*	3.47	2.31
Major or minor in mathematics or mathematics education	4.91*	1.72	2.85
Major or minor in education or mathematics education	-5.30	3.10	-1.71
Large school	0.20	2.16	0.09
Small school	1.94	3.93	0.49
Eligible free/reduced-price lunch	-8.52*	1.06	-8.02
No information free/reduced-price lunch	-5.21*	2.53	-2.06
Urban	-1.81	2.11	-0.86
Rural	-2.00	2.49	-0.80
Female	-2.28*	0.81	-2.81
Black	-28.08*	1.64	-17.08
Hispanic	-17.31*	2.15	-8.06
Three types of reading materials in the home	3.47*	1.34	2.58
Four types of reading materials in the home	8.15*	1.45	5.63
Parent education, <H.S.	-3.06	1.93	-1.58
Parent education, HS+, not BA	9.21*	1.66	5.55
Parent education, BA or more	10.65*	1.34	7.92
High-ability math class	24.93*	1.99	12.54
Medium-ability math class	0.71	2.00	0.36
Low-ability math class	-14.91*	3.32	-4.49
Intercept	266.00*	4.09	65.04

* Statistically significant at $p < 0.05$

Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

Questions of Equity

The analysis in the previous section identified teacher certification and subject-area expertise as being the two teacher credentials most associated with higher NAEP mathematics scores. Next we ask whether or not different types of eighth-grade students were equally likely to have teachers with these and other qualifications.

To address our second set of research questions, we compared the qualifications of teachers across student sub-populations defined by participation in the free and reduced-price lunch program and the ability level of a student's mathematics class. These two measures allowed us to identify two student populations potentially at risk of educational failure: economically

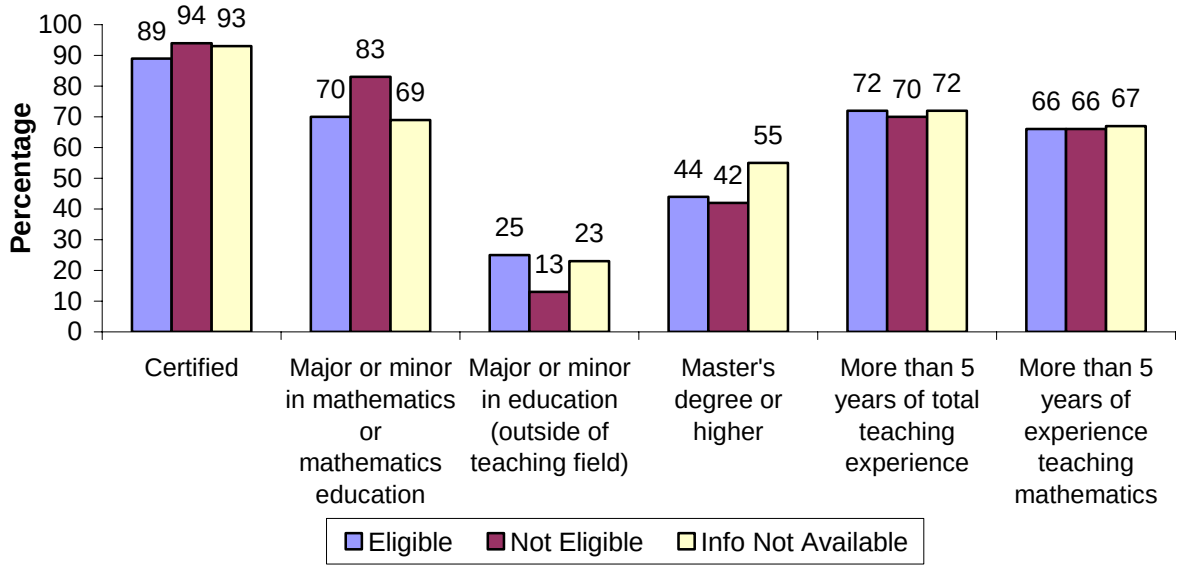
[7] We tested our model with several interaction terms, but none of them improved the fit of the model. Therefore, we have not included any interaction terms in this presentation.

disadvantaged students and students who did poorly in previous mathematics classes and therefore were assigned to a class for low-ability students.

Data on eligibility for the free and reduced-price lunch program were missing for 16 percent of eighth-grade mathematics students participating in the NAEP 2000 assessment. Therefore, information about teacher qualifications is reported separately for this group of students. The students whose schools reported they were eligible or not eligible for the free and reduced-price lunch program made up 28 percent and 55 percent, respectively, of the eighth-grade public school student population.

Were economically disadvantaged students less likely to be taught by qualified teachers? Figure 2 displays the relationship between free and reduced-price lunch program participation and teacher qualifications. Economically disadvantaged eighth-grade public schools students were less likely to have a mathematics teacher with a degree in mathematics than wealthier eighth-grade public school students. Only 70 percent of economically disadvantaged eighth-grade students had teachers with a major or minor in mathematics, compared to 83 percent of eighth-grade students not eligible for the free and reduced-price lunch program. Conversely, economically disadvantaged eighth-grade students were more likely to have teachers with a degree in education outside of their teaching field than eighth-grade public school students who were not eligible for the free and reduced-price lunch program. Students eligible for the free and reduced-price lunch program were also less likely to have a certified mathematics teacher (89 percent) than eighth-grade public school students who were not eligible (94 percent).

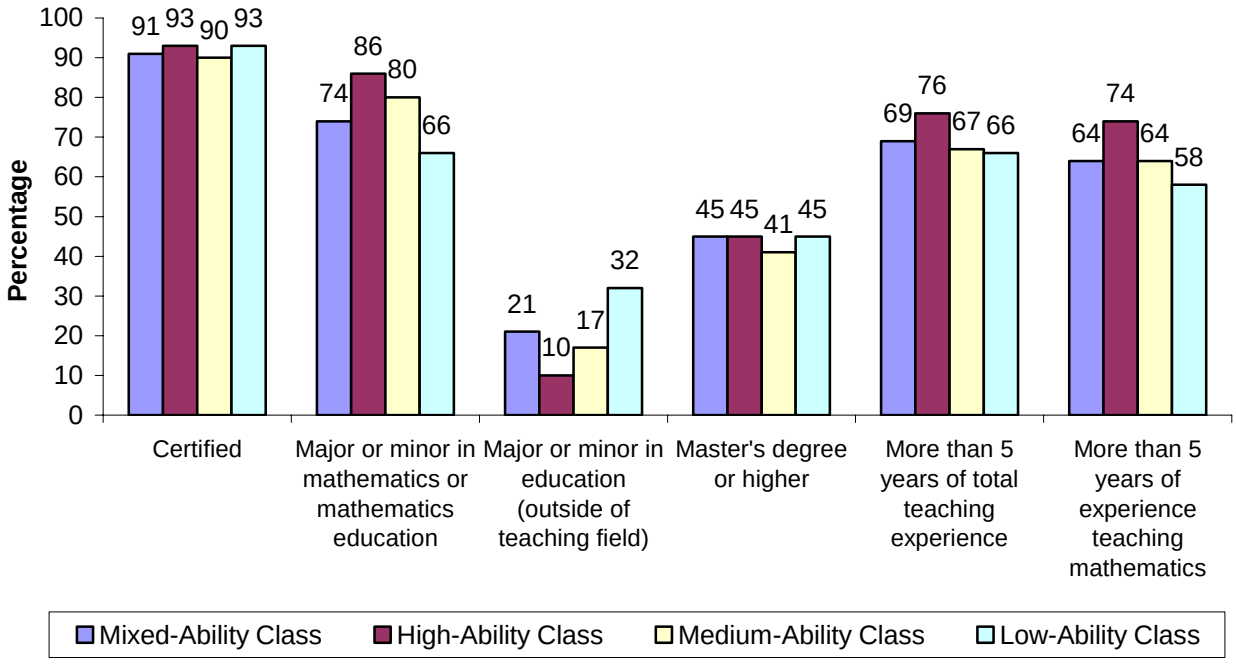
Figure 2: Percentage of Public School Students With Teachers With Specified Qualifications by Eligibility for the Free and Reduced-Price Lunch Program, Grade 8



Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

Were mathematics classes targeting low-ability students less likely to be staffed with qualified teachers? Figure 3 presents the relationship between class ability level and teacher qualifications. Students in high-ability mathematics classes were more likely to have teachers with a major or minor in mathematics or mathematics education than students in mixed- or low-ability mathematics classes. Eighty-six percent of students in high-ability mathematics classes had a teacher with a major or minor in mathematics or mathematics education, compared with 66 percent of students in low-ability mathematics classes. Conversely, students in low-ability mathematics classes were more than three times as likely to have teachers with a major or minor in education outside of their teaching field (32 percent) than students in high-ability mathematics classes (10 percent). Students in low-ability classes were also less likely to have a teacher with more than five years of experience in mathematics instruction (58 percent) than students in high-ability classes (74 percent).

Figure 3: Percentage of Public School Students With Mathematics Teachers With Specified Qualifications, Grade 8



Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

Figures 2 and 3 indicated that economically disadvantaged students and students who entered eighth grade academically behind their classmates were both less likely to be taught mathematics by a teacher with a major or minor in mathematics. Economically disadvantaged students were also less likely to have a certified teacher. Students in low-ability courses were less likely to have a teacher with more than five years of experience teaching mathematics.

We also examined the distribution of teachers with qualifications related to educational achievement by student race/ethnicity. Although our analyses showed that black and Hispanic students are less likely than white students to have a certified teacher or a teacher with a major or minor mathematics, we think that this difference is primarily due to the fact that black and Hispanic students are more likely than white students to be economically disadvantaged. As shown in Table 3, black students represent only 14 percent of the total population of public school eighth-grade students, but 28 percent of the population of public school eighth-grade students who are eligible for the free and reduced-price lunch program. Similarly, 15 percent of the eighth-grade public school population is Hispanic, but 28 percent of eighth-grade students who participate in the free and reduced-price lunch program are Hispanic. When we looked separately at black and Hispanic students who were not eligible for the free and reduced-price lunch program, there were no differences between these students and white students in the qualifications of their teachers.

Table 3: Percentage of Total Public School Students and Public School Students Eligible for the Free and Reduced-Price Lunch Program by Race/Ethnicity, Grade 8

	Total Students	Eligible for Free/ Reduced Price Lunch
White	66	37
Black	14	28
Hispanic	15	28
Asian/Pacific Islander	4	4
American Indian	1	2

Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

Did these disparities in the distribution of teachers with qualifications related to student achievement have consequences for the eighth-grade achievement scores of students eligible for the free and reduced-price lunch program and for students assigned to low-ability classrooms? The regression analysis presented in Table 2 suggests that the differences in the percentages of students who had teachers with a major or minor in mathematics and differences in the percentages of students who had certified teachers are the differences to be most concerned about. These were the teacher qualifications that had an independent effect on math achievement, net of other factors included in the model.

One way to address this question is to look at differences in NAEP mathematics scores within a disadvantaged student population by differences in teacher qualifications. Table 4 presents average NAEP math scores for eighth-grade public school students by eligibility for the free and reduced-price lunch program and their teachers' academic major or minor. Within all eligibility categories, including economically disadvantaged students, students who had teachers with an academic background in mathematics scored higher, on average, on the NAEP mathematics assessment than students in the same free and reduced-price lunch program whose teachers had a major or minor in education outside of mathematics. We were unable to do a similar comparison for students with and without certified teachers (the other teacher factor that our analysis showed

was related to student achievement), because the small sample size in some of the cells would have produced unreliable results.

Table 4: Average NAEP Mathematics Scores for Public School Students by Eligibility for Free and Reduced-Price Lunch Program and Teacher Academic Major/Minor, Grade 8

	Eligible (s.e.)	Not Eligible (s.e.)	Info Not Available (s.e.)
Academic major or minor			
In mathematics	260 (1.2)*	288 (1.3)*	279 (2.0)*
In education (outside of mathematics)	247 (3.2)	272 (2.8)	265 (5.9)

* Statistically significantly different at $p < 0.05$ from students with teachers without the specified qualification

Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

Table 5 looks at the relationship between a student's teacher's academic background and mathematics achievement, holding the ability level of the class constant. Students in low-ability mathematics classes who had teachers with a major or minor in mathematics scored higher, on average, on the NAEP mathematics assessment than students in low-ability mathematics classes whose teachers had a major or minor in education outside of their teaching field. Students in high- and medium-ability mathematics classes whose teachers had a degree in mathematics or mathematics education also had higher average scores on the NAEP mathematics assessment than students in high- and medium-ability mathematics classes whose teachers had a degree in education outside of their teaching field.

Table 5: Average NAEP Mathematics Scores for Public School Students by Ability Level of Class and Teacher Academic Major/Minor, Grade 8

	Mixed-Ability Class (s.e.)	High-Ability Class (s.e.)	Medium-Ability Class (s.e.)	Low- Ability Class (s.e.)
Academic major or minor				
In mathematics	270 (1.7)	305 (1.7)*	277 (2.2)*	258 (4.3)*
In education (outside of mathematics)	262 (3.6)	289 (4.3)	260 (3.1)	236 (5.1)

* Statistically significantly different at $p < 0.05$ from students with teachers without the specified qualification

Source: National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2000 Mathematics Assessment

VI. Conclusion

NCLB requires that all teachers in core academic subjects (including mathematics) be highly qualified by the end of the 2005-2006 school year (six years after the data on which this report is based were collected). The findings in this report support the importance of certification and subject matter competency as key components of teacher quality. However, the findings also show that at the time the data presented here were collected, teachers with qualifications associated with higher mathematics achievement (certification and a major or minor in mathematics or mathematics education) were not equitably distributed among all students, and that students at the greatest risk of educational failure—poor students and students tracked into low-ability classes—were less likely to have teachers with these qualifications. However, when these students at-risk of educational failure had teachers with postsecondary degrees that indicated they had subject matter competency (a major or minor in mathematics or mathematics education), they scored significantly higher on the NAEP mathematics assessment than their peers whose teachers did not major in mathematics or mathematics education.

Black and Hispanic students are disproportionately represented among poor students eligible for the free and reduced-price lunch program, making these findings particularly troubling during this 50th anniversary year of Brown vs. Board of Education. Although schools are no longer formally segregated, highly qualified teachers are not yet equitably distributed among all students and schools. Poor students tend to be concentrated in specific schools, but the tracking of students into low-ability classes is a phenomenon that occurs within schools that group students by ability level. The fact that both these groups of students were less likely to be assigned mathematics teachers with qualifications associated with higher mathematics achievement is particularly troubling, because it indicates that there are issues in the equitable assignment of teachers both across schools and within schools.

References

Ballou, D., and Podgursky, M. (1997). Reforming teacher training and recruitment. *Government Union Review,* 17(4), 1-47.

Ballou, D., and Podgursky, M. (1998). The case against teacher certification. *Public Interest,* 132, 17-29.

Braswell, J.S., Lutkus, A.D., Grigg, W.S., Santapau, S.L., Tay-Lim, B., & Johnson, M. (2001). *The nation's report card: Mathematics 2000.* Washington, DC: National Center for Education Statistics.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Educational Policy Analysis Archives,* 8(1), 1-50.

Darling-Hammond, L., Berry, B., & Thoreson, A. (2001). Does teacher certification matter? Evaluating the evidence. *Educational Evaluation and Policy Analysis*, 23(1), 57-77.

Goldhaber, D.B., & Brewer, D.J. (2000). Does teacher certification matter? High school teacher certification and student achievement. *Educational Evaluation and Policy Analysis,* 22(2), 129-145.

Goldhaber, D.B. & Brewer, D.J. (2001). Evaluating the evidence on teacher certification: A rejoinder. *Educational Evaluation and Policy Analysis,* 23(1), 79-86.

Greenwald, R., Hedges, L.V., & Laine, R.D. (1996). The effect of school resources on student achievement. *Review of Educational Research,* 66(3), 361-396.

Hanushek, E.A. (1997). Assessing the effects of school resources on student performance: An update. *Educational Evaluation and Policy Analysis,* 19(2), 141-164.

Hawkins, E.F., Stancavage, F.B., & Dossey, J.A. (1998). *School policies and practices affecting instruction in mathematics.* (NCES 98495). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Johnson, E. G. and Rust, K.F. "Population Inferences and Variance for NAEP Data," *Journal of Educational Statistics* 17 (2) (1992): 175–190.

Monk, D.H. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review,* 13(2), 125-145.

Nathan, J. & Petrosino, A. (2003). Expert blind spot among preservice teachers. *American Educational Research Journal,* 40(4), 905-928.

Seastrom, M.M., Gruber, K.J., Henke, R., McGrath, D., & Cohen, B.A. (2002). *Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987-88 and 1999-*

2000. (NCES 2002-603). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

The National Commission on Teaching & America's Future (1996). *What Matter's Most: Teaching for America's Future.* New York, NY: The National Commission on Teaching & America's Future.

Wenglinsky, H. (2000). *How teaching matters: Bringing the classroom back into discussions of teacher quality.* Princeton, NJ: Educational Testing Service.