A Multi-level Analysis of Student Assignment to Out-of-Field and Uncertified High School Mathematics Teachers: Implications for Educational Equity and Access

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Introduction

Out-of-field and uncertified teaching have received serious scrutiny in recent policy debates surrounding teacher quality. As schools struggle to fill vacancies left by the revolving-door nature of the teaching profession, policy makers and administrators have been forced to expand the parameters of who is qualified to teach, particularly in the hard-to-staff subjects of high-school mathematics and science. Ostensibly to address the problem of under-qualified teachers, the No Child Left Behind Act (NCLB) stipulated that schools must have a highly qualified teacher in every classroom by the end of the 2005-2006 school year. The federal mandate defines "highly qualified" as a teacher who possesses a bachelors degree in the subject taught and full teaching credentials. However, states cannot require qualified individuals to enter the teaching profession. Rather, many states have devised policies to assist potential teachers in meeting the requirements. Critics have argued that such policies address the letter, but not the spirit of certification laws. For example, to meet certification requirements many states allow teachers to pursue credentials while they teach in the classroom; other states allow prospective teachers to meet the content knowledge requirements through the passage of subject matter tests, whose rigor may be questionable. When taken together, these patchwork policies have exacerbated already wide variation in the knowledge and skills teachers actually posses.

In this paper, I examine trends in high school mathematics teacher assignment as they relate to educational equity. Specifically, I explore the association between student race, ethnicity and social class, and the likelihood of assignment to a qualified high school mathematics teacher. Numerous scholars have described aggregate relationships between school-level characteristics and teacher qualifications. Virtually all report that high-poverty, high-minority enrollment schools are more likely to provide less qualified teachers. However, research to date has not examined potential inequalities *within* schools. Using nationally representative data, this study seeks to address this important gap in the literature.

Background

Over the last two decades, American public schools have suffered serious teacher shortages. In the 1980s, reports predicted a "perfect storm": an aging teacher population heading toward retirement would meet historical increases in student enrollments. Although a teacher shortage has surfaced as predicted, its causes have been attributed to the protractedly short careers of many new teachers, rather than to a confluence of demographic trends. Indeed, an insufficient supply of early-career teachers is not the root cause of the teacher shortage. Rather, each year large numbers of teachers leave the profession permanently for reasons other than retirement (Ingersoll, 2001). This rapid turnover has been widely documented and attributed to several factors, including low status, poor working conditions and low salaries (Darling-Hammond, 2004). Furthermore, although low salaries may deter college graduates from teaching, this is especially true for graduates with backgrounds in mathematics and science who generally command greater financial rewards in the private sector. This may contribute to an exaggerated shortage in these subject areas at the high school level, where the demand for qualified teachers is particularly acute (Darling-Hammond, 2004; Bradley & Loadman, 2005).

Alternative Credentials

In an effort to rapidly address persistent teacher shortages, many states have allowed a variety of alternative certification programs to coexist with traditional teacher certification programs. Typically, these programs permit teachers to enter classrooms as full time teachers of record with few (or even no) courses in teaching, and without completing a traditional student teaching practicum. Approximately 50,000 such teachers enter America's schools each year, and most are assigned to high-poverty, low-performing schools (Darling-Hammond, 2005).

Prior to the enactment of NCLB in 2001, many states issued emergency credentials allowing teachers with neither training, nor immediate plans to attain training, to serve as full-time teachers. Although the "highly-qualified" teacher provision in NCLB disallows this practice and has reduced the number of such teachers, no state managed to meet the 2005-2006 school year deadline that a "highly-qualified" teacher be present in every core subject classroom.[1] Furthermore, although the highly qualified provision states that teachers must have full credentials, the law supports short-term alternative credentialing programs, most of which have reduced coursework requirements, and do not require student teaching. Additionally, because the law allows each state to define "highly qualified," some states, particularly those with teacher shortages, require no education course work so long as the credential process is in progress (Guha et. al., 2006).[2] These programs have gained in popularity, particularly Teach for America (TFA), which is modeled on the Peace Corps, and places high-achieving college graduates for two-year assignments in high-needs schools after a single five-week summer training course.

Teacher Quality and Educational Equity

Although teacher attrition is a major concern nationally, the problem is not evenly distributed across all schools. High-poverty schools and those that serve large numbers of students of color are disproportionately affected (Ingersoll, 1999; Darling-Hammond, 2006; Clotefelter, Ladd & Vigdor, 2005; Hanushek, Kain & Rivkin,1998). In fact, high-poverty schools experience teacher attrition rates that are 50 percent higher than low-poverty schools (Ingersoll, 2001). In

[1] Currently the federal government is working individually with states to grant waivers until 2009 to those states that have shown progress in reducing the number of unqualified teachers in their teacher corps.
[2] States must write their own definition of highly qualified which then must be subject to a federal approval process.

general, teachers who leave these schools do so either to leave the profession altogether or to move to other schools in wealthier areas with fewer minority students (Darling-Hammond, 2004). Although student characteristics *per se* do not tend to influence the migration of teachers, the higher salaries and better working conditions typically found in suburban schools often prove too great an enticement. For example, one study found that the best paid teachers in low-poverty schools earned an average of 35 percent more than the best paid teachers in high-poverty schools, taught smaller classes, and had more control and decision making power within their schools (Perie & Baker, 1997). Additionally, alternative credentialing policies and programs have produced several unintended consequences. Importantly, rather than increasing educational equity, many of the nation's neediest schools and students are frequently taught by the teachers least equipped to help them.

High teacher turnover rates disproportionately affect high poverty schools, which subsequently have the greatest hiring needs and offer disproportionate numbers of under-certified teachers. Several studies have found that schools with high proportions of poor students, students of color, and English Language Learners (ELL) also have higher numbers of alternatively certified teachers. For example, one study in North Carolina found that on average districts with high-minority enrollments employed more novice teachers than districts with lower minority enrollment (Clotfelter, et. al., 2005). The popularity of alternative certification programs have increased the number of alternatively prepared staff. For example, one study of teachers in Houston found TFA teachers disproportionately teaching low-income and African-American and Latino students (Darling-Hammond, Holtzman, Gatlin & Vasquez-Heiling, 2005). Other studies report similar results for Texas overall (Justice, Greiner & Anderson, 2003), California (Guha et. al., 2006), as well as nationally (Ingersoll, 2001).

In addition to the unequal distribution of qualified teachers between districts, as cities hire and retain more certified teachers, they are often allocated to higher-income White students within the district. Furthermore, because African-Americans are generally over-represented in lower-level and remedial mathematics classes, they are over 50-percent more likely to be assigned a novice teacher than their White counterparts (Clotfelter, et. al. 2005). The same holds for students and teachers in English classes. Overall, the practice of providing alternatively certified teachers to disadvantaged students produces some schools in which the majority of the teaching staff has little preparation or experience (Justice, et. al., 2003).

<u>Out-of-field Teaching</u>

Districts have also attempted to fill vacancies in the short term by assigning existing teachers, regardless of credential status, to teach subjects for which they have little or no content knowledge. The practice is particularly severe for hard-to-staff subject areas such as mathematics and science, although history and social studies also experience shortages. Nationally, 30 percent of secondary mathematics teachers did not major or minor in either mathematics or related fields such as engineering (Ingersoll, 1999). Furthermore, reflecting the concentration of under-certificated teachers in high-poverty schools, almost half of the mathematics teachers serving high-poverty schools are teaching out-of-field, compared to 27 percent in low-poverty schools. In science, the number of out-of-field teachers is 10 percent higher within high-poverty schools. Additionally, beginning teachers are also more likely to be assigned classes for which they have inadequate background knowledge (Ingersoll, 1999). As such, it is likely that many teachers in high-poverty schools are both poorly prepared in terms of subject matter, and are less likely to posses the pedagogical content knowledge widely accepted as the foundation for teacher success.

Teacher Qualifications and Student Achievement

A central concern of out-of-field and under-certified teaching is the potential implications for student achievement (Berry, 2004). Indeed, differences in teacher backgrounds explain significant variation in student achievement at the school level (Hanushek, et. al., 1998). Other studies that seek to identify differences in achievement between fully credentialed and under-prepared teachers have produced conflicting results. For example, multiple studies examining the relationship between assignment to a TFA teacher and student achievement have found both positive and negative effects. The Houston study mentioned above found negative effects in terms of lower gains for the students of under-prepared teachers, compared to students of teachers with standard certification (Darling-Hammond, et. al, 2005). However, another study utilizing random classroom assignment to TFA and non-TFA teachers in elementary classrooms found that students of TFA teachers performed slightly higher in mathematics and no worse in reading than students of other teachers (Glazerman, Mayer & Decker, 2006). One problem with such studies is that, by definition, under- and un-certified teachers are also novice teachers, and novice teachers of all backgrounds do not perform as well as their seasoned counterparts, particularly compared to those with five or more years of experience (Hanushek, et. al., 1998). As such, student achievement in high-poverty schools with high proportions of novice and unskilled teachers is likely to suffer on two fronts.

The Policy Result

Because policies often place unqualified teachers in high-needs classrooms, the cycle of teacher shortages in high-poverty schools is likely to continue. Not only is disillusionment with teaching more common among new teachers in urban high schools and those serving high numbers of minority students, novice teachers who feel poorly prepared express the greatest doubts about remaining in the profession (Justice, et. al, 2003). Given that these teachers are assigned classes for which they are ill-prepared, and for which they are poorly compensated, it is unsurprising that they also leave the profession as quickly as they entered (Ingersoll, 2001; Darling-Hammond, 2004). Teachers who do decide to stay in teaching become attractive candidates to wealthier districts once they earn their credential and gain a few years of experience. Furthermore, the social and professional stigma of being associated with failing schools, which most often enroll low-income students of color, heightens the pressure on experienced teachers to move to higher-achieving schools where they are more likely to receive professional recognition and rewards (Clotfelter, et. al., 2005). Finally, although some turnover is inevitable in all school settings, constant and/or high rates of teacher turnover in and of themselves serve to erode the quality and stability of the school environment, negatively impacting students performance (Ingersoll, 2001). Inevitably, such instability creates a scenario in which students are likely to have more than one under-qualified teacher, creating a cumulative experience of overall lower quality education (Loeb & Darling-Hammond, 2005). The result is that extra educational burdens are placed on students who are already socially disadvantaged, simply because they cannot abandon their schools as easily as their teachers.

Research Focus

The study described here explores the relationship between high school mathematics teacher assignments and educational equity. A central hypothesis is that when teacher assignments are made within schools, those teachers with the strongest credentials are more often assigned to higher-level mathematics classes, which require the greatest content knowledge. Conversely, teachers with weaker credentials and content skills are placed in lower-level classes. Because higher-achieving students generally take higher-level courses, these students may be more likely to experience the most qualified teachers. Furthermore, as discussed above, this causal claim leads to the hypothesis that under-credentialed and out-of-field teachers are more likely to serve minority and low-income students because they are disproportionately placed in lower-level classes. In this study, I explore whether within-school assignment to an under-qualified teacher is related to student race/ethnicity and socio-economic background. My analyses are designed to address the following research questions:

- *Research Focus 1:* How can we characterize the within-school relationship between student race/ethnicity and socio-economic background and the qualifications of their mathematics teachers?
- *Research Focus 2:* To what extent are these relationships mitigated by student achievement in mathematics? In other words, even after we account for their measured academic abilities, are traditionally disadvantaged students still more likely to experience under-qualified mathematics teachers than other students in the same school?
- *Research Focus 3:* How do school characteristics explain between-school differences in exposure to qualified teachers, above and beyond the social and academic backgrounds of the students they enroll?

Data and Methods

The data used for these analyses are taken from the Educational Longitudinal Study-10th grade class of 2002 (ELS:2002). ELS:2002 is a multi-source, multi-method dataset collected by the National Center for Education Statistics (NCES) focused on students' high school experiences beginning with the 10th grade. The ELS:2002 followed a nationally representative cohort of students from 10th grade through two years beyond secondary school as they entered the worlds of higher education and work (NCES, 2005).

ELS:2002 employed a stratified sampling design to randomly select 750 public, Catholic, and non-Catholic private high schools. Over 15,000 students were then randomly selected within those schools, and data were collected from sampled students in Spring, 2002. In addition to student surveys, the dataset includes cognitive tests in mathematics administered in the Spring of the 10th grade year. Surveys were also collected from students' parents and mathematics teachers, school principals, and school library/media center heads. For these analyses, I utilized the first wave of data.

Analytic Sample

Because my study focuses specifically on students and mathematics teachers, students who did not take the mathematics assessment were excluded from the analysis, as were students whose mathematics teachers did not complete a survey. I also eliminated students who were missing the student-level design weight. In addition, since my outcome of interest is the qualifications of public school teachers, students who attended Catholic and non-Catholic private schools were also excluded. The final sub-sample used for these analyses includes 10,086 high school sophomores nested within 518 public schools.

Measures

Outcome variable: teacher qualifications. I created a four-level categorical variable of mathematics teacher qualifications, which indicates whether teachers were teaching in-field or out-of-field, combined with whether they possessed full teacher certification. In-field teachers were defined as those with an undergraduate or graduate major or minor in mathematics. Although other fields of study (such as engineering) may provide teachers with adequate backgrounds in mathematics, the ELS:2002 survey question related to teacher background did not provide teachers an exhaustive list of subjects from which to choose. I limited the category to training in mathematics for simplicity and to eliminate arbitrary estimates of which fields other than mathematics may afford adequate mathematics content area knowledge. For the credential categories, I coded those teachers with a regular or standard certification as certified, while teachers with probationary certification, temporary or emergency certification, those enrolled in a certification program while teaching, and those who were neither certified nor enrolled in a certification program, as uncertified. The resulting four categories of the teacher qualification variable are therefore; Certified and In-field (CIF), Certified and Out-of-field (COF), Uncertified and In-field (UIF), Uncertified and Out-of-field (UOF). In my multinomial, multilevel models, certified in-field teachers are the reference category. Because of the sample size differences between the three comparison categories, the HLM reliability estimates for each category in the final model vary, with the reliability of the COF category the strongest (0.74), followed by the reliability estimate for the UIF category (0.55), and with the weakest reliability estimate found with the results for the smallest category, UOF (0.45).

Student-level measures. The central focus of my study is student socio-demographic background. My HLM models include student socioeconomic status (SES), a standardized composite measure of parent/guardian's occupation and education, and family income. I also included dummy variables indicating whether students are Black, Hispanic, Asian, or Other (students self-identified as either American Indian, Alaskan Native, or multiracial). Whites served as the reference category in the multivariate analyses. Historically, gender has played a role in mathematics achievement and course-taking, with high school girls under-performing in mathematics, and less likely to take, or be placed in, upper level courses. I therefore included a dummy variable for gender (1=female, 0=male).

I utilized a standardized (z-scored) measure of 10th grade mathematics achievement. The assessments, which were equated using Item Response Theory (IRT), measured simple arithmetic, operations with decimals, powers, roots and fractions, and both basic and complex multi-step word problems and advanced mathematics problems. The assessment was administered during the Spring of the 10th grade data collection year. Because pre-tests are not available in ELS:2002, I am unable to causally interpret the relationship between 10th grade teacher assignment and student performance. The direction of the relationship is unclear because the assessment was administered after students had been exposed to their 10th grade teacher for almost a full school year. For example, it is possible that higher performance was caused by assignment to qualified teachers. Conversely, prior student performance may have influenced teacher assignment in 10th grade, with higher-achieving students more often assigned to qualified teachers. However, the former relationship seems less plausible, as the influence of a single year of mathematics instruction on student performance is likely to be limited. To further account for the link between teacher assignment and students' prior ability, I include a dummy variable indicating whether students had ever been assigned to a remedial mathematics class (yes=1, no=0).

School-level measures. Because teacher shortages have been found to vary across school contexts, I included dummy variables indicating urban and rural schools locations, with suburban schools used as the un-coded reference category. In addition, because teacher shortages are also related to geographic location, my model includes census regions (South, West and Northeast, all compared to the Midwest). To adjust for the academic characteristics of schools that may influence the types of teachers they attract, I created three school-level academic variables that seek to measure academic climate. The first is a measure of whether a school serves a high proportion of English Language Learners, which I defined as schools in which 25 percent or more of 10th graders were non-English proficient (1=yes, 0=no). I also created a measure of the proportion of 10th graders in a school enrolled in a general education program (greater than 50 percent=1, 0=otherwise), or a college prep program (more than 50 percent=1, otherwise=0). My final school level variable is a school-level measure of student SES (z-scored; m=0, SD=1).

Weights

The ELS:2002 utilized a multistage stratified sampling design. To ensure adequate sample sizes, certain student sub-populations were over-sampled, including Asians, Pacific-Islanders, Alaskan Natives, and students attending Catholic and non-Catholic private schools. Therefore, the use of design weights is required to compensate for unequal selection probabilities and non-response effects. For these analyses, I utilized the student-level weight normalized to reflect the smaller sample size. As such, my results are generalizable to the entire population of public school 10th graders in the United States in the 2001-2002 school year.

Analytic Approach

My primary analyses entailed multilevel (HLM), multinomial logit models. These models examine the within- and between-school likelihood of assignment to under-qualified teachers (Raudenbush & Bryk, 2002). The Level-1 coefficients estimate the average *within-school* relationship between student background characteristics and teacher assignment while controlling for school characteristics. Reflecting my research questions, my analyses focus on the links between student race, SES, and access to qualified teachers. The Level-2 coefficients reflect the influence of school-level characteristics on teacher assignments, adjusted for the backgrounds of the students these schools enrolled. In HLM parlance, the school-level intercepts were "free", meaning that school-level variation in teacher assignment can be explored and explained as a function of school characteristics.

Results

Descriptive Results

Table 1 presents descriptive statistics, organized by teacher qualifications. For these descriptive analyses, teachers who are both certified and teaching in-field are the statistical reference category. Preliminary answers to my first research question are found here. As previous research has suggested, qualified teachers are unevenly distributed by student ethnicity. In particular, White students are considerably less likely to encounter under-qualified 10^{th} grade mathematics teachers ($p<.05$). Although White students constitute 62 percent of the weighted sample, only 46 percent of students taught by uncertified, out-of-field (UOF) teachers are White, and only 54 percent of students of certified, out-of-field (COF) teachers are White. Conversely, Hispanic students are more likely to be taught 10^{th} grade mathematics by all three categories of under-qualified teachers ($p<.05$). Fifteen percent of the weighted sample is Hispanic, yet 20 percent of the students of COF teachers are Hispanic, while 26 percent of the students of UOF teachers are Hispanic ($p<.05$). In addition, Black students and Other race/ethnicity students, are also significantly more likely to be taught mathematics by COF teachers ($p<.05$). Black students account for 14 percent of the weighted sample, but 16 percent of COF teacher's students are Black. Likewise, Other race/ethnicity students account for 5 percent of the weighted sample, but 7 percent of the students assigned to COF teachers are categorized as Other.

Significant SES differences also separate students of CIF and COF teachers (ES=0.19, $p<.05$), but not students of CIF teachers and those of the remaining two categories of uncertified teachers ($p>.05$). Although the mean differences here are greater, lack of statistical significance may be related to the relatively small sample size of the last two categories of teacher qualifications. These findings also suggest that gender is related to 10^{th} grade mathematics teacher assignment. In particular, girls were slightly *less* likely to have taken mathematics with teachers who were teaching out-of-field, whether certified or not ($p<.05$). Forty-seven percent of students of COF teachers were girls, as were 43 percent of students of UOF teachers.

Further confirming existing research, Table 1 indicates that students in remedial mathematics classes are significantly more likely to take 10^{th} grade mathematics with teachers who are teaching out-of-field, regardless of certification status ($p<.05$). Specifically, 12 percent of students of COF teachers, and 14 percent of students of UOF have taken remedial mathematics, despite the fact that only 9 percent of the sample has had remedial mathematics. This finding supports my earlier hypothesis that out-of-field teachers are more likely to teach lower-performing students, possibly because the level of content is less rigorous.

Reflecting the student-level descriptive results detailed above, students in urban schools were significantly more likely to take 10^{th} grade mathematics with out-of-field teachers, certified or not, while suburban students were more often assigned to uncertified, in-field (UIF) teachers ($p<.05$). Rural schools account for 23 percent of the weighted sample, but only 14 percent of students assigned UIF teachers were located in rural schools ($p<.05$).

Qualified 10^{th} grade mathematics teachers were also unevenly distributed by geographic region. Students in high schools in the Midwest represent 25 percent of the sample, but they were less likely to experience less-qualified teachers than students in the other three geographic regions of the country. For example, just 8 percent of the students of UOF teachers go to school in the Midwest. In addition, only 21 percent of the students of COF teachers and 23 percent of the students of UIF teachers attended 10^{th} grade in the Midwest ($p<.05$). By contrast, schools in the

West account for 23 percent of the sample, but 37 percent of the students of UOF teachers were located in that region ($p<.05$). Thirty-two percent of the students who took mathematics with UIF teachers were in the West, as were 28 percent of those who experienced COF teachers. The South and the Northeast account for 35 and 17 percent of the sample respectively, but 22 and 23 percent of the students of UIF were enrolled in high schools in these regions ($p<.05$).

The distribution of teacher qualifications also varies by school social and academic composition. For example, schools with high populations of ELL students comprise just 8 percent of the sample, but 17 percent of all students of UOF teachers attended these schools ($p<.05$). In addition, 10 percent of the students of both COF and UIF teachers attended high-ELL enrollment high schools ($p<.05$). Not surprisingly, schools where more than half of all 10th graders take general education courses account for 57 percent of the sample, but more than 60 percent of the students of the three categories of under-qualified mathematics teachers attended these schools ($p<.05$). Conversely, schools in which more than half of the 10th graders are enrolled in college prep courses constitute 65 percent of the sample, but enrolled only 55 percent of the students assigned UOF teachers ($p<.05$). Lastly, on average, students of mathematics teachers who are certified but teaching out-of-field more often attend schools with lower average SES than students who have CIF teachers (ES=0.22, $p<.05$).

It is important to note that these descriptive findings reflect relationships across the full sample. This is the approach taken by previous research on the topic. However, this study focuses on differential access to qualified teachers *within* schools. This takes us to my multilevel, multinomial analysis.

Insert Table 1 About Here

Analytic Results

Within-school results. Table 2 presents the results of my multilevel, multinomial analyses. Recall that certified, in-field teachers are the comparison group. Within each teacher qualification category, Model 1 presents estimates unadjusted for students' 10th grade mathematics achievement. Model 2 then presents the adjusted coefficients. Across all three categories, Model 1 suggests significant relationships between student race/ ethnicity and socio-economic background and teacher assignment. In particular, within schools, high SES students were less likely to be exposed to under-prepared teachers. With each standard deviation increase in SES, the likelihood of having taken 10th grade mathematics with a COF teacher decreased by almost 10 percent ($p<.01$). Similarly, the likelihood of being assigned a UIF ($p<.01$) or UOF ($p<.05$) teacher decreased by approximately 15 percent for each unit increase in student SES. Note that the estimates in Model 1 are adjusted for the full compliment of school-level measures as well.

Student race/ethnicity was also a significant factor in within-school teacher assignment. Specifically, Black students were 40 percent more likely to have been taught by a COF teacher ($p<.01$), and more than 60 percent more likely to have taken mathematics with a UOF teacher ($p<.05$) than with a certified, in-field teacher. Similarly, Hispanic students were also almost 40 percent more likely to have taken mathematics with COF teachers, and almost twice as likely to have experienced UOF teachers ($p<.01$). Additionally, Other race/ethnicity students were also more likely to have taken 10th grade mathematics with out-of-field teachers, regardless of certification. Specifically, these students were more than 40 percent more likely to have been exposed to a COF teachers ($p<.01$), and almost 75 percent more likely to have been assigned a UOF teacher ($p<.05$). These results are interesting in that they provide preliminary evidence that minority students, and students of lesser means, were assigned under-qualified teachers, even within the same schools as their White, and comparatively better off classmates.

The other within-school results indicate disparities in teacher assignment by gender and academic track. Surprisingly, girls were 15 percent less likely to have taken mathematics with COF teachers ($p<.01$), and almost 30 percent less likely to have experienced a UOF teacher ($p<.05$). In addition, students who had taken remedial mathematics were more than 50 percent more likely to have had a COF teacher ($p<.01$), and almost 70 percent more likely to have been assigned a UOF teacher. The finding regarding gender affects on teacher assignment suggests that girls may be taking more upper-level mathematics classes, while the remedial mathematics finding confirms that teachers with weaker content background are more likely to teach students in lower academic tracks.

Although the results of Model 1 indicate race and socio-economic inequities in the assignment of under-qualified teachers, in order to fully examine the within-school likelihood of exposure to under-qualified teachers, Model 2 controls for student achievement in mathematics. With this model, I find that all socio-economic and race/ethnicity estimates are rendered non-significant; those racial and socio-economic relationships were spurious, reflecting instead the well-established associations between students' social and academic backgrounds. As student achievement increases, the likelihood of being assigned a COF or UIF teacher declines significantly ($p<.001$). Specifically, a one standard deviation increase in student mathematics achievement is associated with a 32 percent decrease in the likelihood of assignment to a COF teacher, and a 30 percent decrease in the likelihood of assignment to a UIF teacher, compared to a highly-qualified teacher ($p<.001$). Similarly, for each standard deviation increase in mathematics achievement, the likelihood of exposure to a UOF teacher decreases by 55 percent ($p<.001$). Interestingly, even with the addition of the achievement variable, remedial math students are still 33 percent, rather than 53 percent, more likely to be assigned a COF teacher. Finally, the addition of achievement only slightly changed the results for girls, decreasing the likelihood of being taught by COF and UOF teachers by four and six percent respectively ($p<.01$).

Between-school results. Level-2 results for Model 1 indicate that the greatest contributing factor to between-school disparities in teacher assignment is census region. Note that the odds ratios for Northeast, South, and West, which are compared to Midwest, are all above one. This suggests that students who attended schools in the Midwest were less likely to experience under-qualified teachers. This is unsurprising given that the Midwest has experienced considerable population declines, which mitigate the need for flexible teacher staffing policies. Other regions, however, particularly the West, have experienced population increases that have created pressing demand for teachers. In particular, students who attended schools located in the West were more than twice as likely to have taken mathematics with COF teachers, compared to students in the Midwest ($p<.001$). Students who attended schools in the West were also more than two and a half times as likely to have taken mathematics with UIF teachers ($p<.01$). Students who attended high schools in the Northeast were almost 50 percent more likely to have taken mathematics with COF teachers ($p<.05$). Finally, students in the Northeast, South, and West were all significantly more likely to have experienced UOF teachers. Students in the Northeast were four times as likely to have been assigned one of these teachers ($p<.01$), while students in the South were three and half times as likely, and students in the West were more than six times as likely ($p<.001$). The only other school-level characteristic that was related to teacher assignment was high-ELL student enrollment. Students in high-ELL enrollment schools were 40 percent more likely to have taken mathematics with COF teachers ($p<.001$), even after adjusting for their student and school attributes. Students in these schools were also roughly two and a third times more likely to have experienced UOF teachers ($p<.05$).

At the school level, the addition of the mathematics achievement measure in Model 2 did not change the likelihood of being assigned and under-qualified teacher in either the South or the West. However, for students who attended schools in the Northeast, the likelihood of being assigned a COF teacher becomes non-significant ($p>.05$). Simultaneously, students who attended schools in the Northeast were almost twice as likely to have taken math with a UIF teacher ($p<.05$). Finally, the inclusion of the achievement measure also altered the results for schools with high-ELL enrollment. The likelihood of students enrolled in these schools to experience a COF teacher became non-significant, but the likelihood of these students to have taken 10th grade math with a UOF teacher increased slightly, to just under two and half times as likely ($p<.05$).

Insert Table 2 About Here

Conclusion

Previous research on the topic of equity and teacher quality has found between-school associations between student socio-demographic characteristics and the qualifications of their teachers. Overall, findings have suggested that low-income and minority students are more often taught by under-qualified teachers than are their White counterparts. The study presented here expanded these findings to explain within-school disparities in teacher assignment. My results indicate that minority and lower-SES students are less likely to experience qualified mathematics teachers, even compared to non-minority and high-SES students in the same school. However, these *within-school* race and social class differences in the likelihood assignment to an under-qualified high school mathematics teacher can be explained by the generally lower levels of student achievement among traditionally disadvantaged students. Within schools, inequality of student exposure to under-qualified teachers is entirely predicated on student achievement in mathematics. I find that higher-achieving students have more access to the most qualified teachers.

In addition, previous research indicates that higher-achieving students also take more difficult courses. Therefore, my findings suggest that higher-achieving students have greater access to more qualified teachers because those teachers are more likely to teach the courses those students take. Furthermore, remedial mathematics students are more likely to have out-of-field teachers, but are no more or less likely to be taught by in-field teachers, even those who are uncertified. This finding further supports my hypothesis that teachers with less content knowledge are more likely to teach remedial, and possibly other lower-achieving students, because the level of content covered in these classes is less advanced. However, although my results indicate that teacher assignment is a function of student achievement, rather than students' socio-demographic characteristics, it does not address the well-documented achievement gap, or the over-representation of disadvantaged and minority students in remedial and lower-level high school mathematics courses.

Furthermore, although these analyses suggest strong links between student achievement in mathematics and access to qualified teachers, it is thus far unclear whether students who are low achieving are assigned teachers who are less than optimally qualified, or if these students are performing lower because of the teachers they have been assigned. Because the mathematics assessment was given at the end of the 10th grade year, the direction of the relationship is unknown, and a causal inference cannot be made. That said, the fact that there is also strong evidence that students who have been assigned to remedial mathematics at least once in their academic careers more often experience under-qualified teachers, indicates that student performance was linked to teacher assignment prior to the beginning of the 10^{th} grade year.

The findings on gender are particularly interesting because, although there is literature to suggest that boys are more frequently assigned to remedial mathematics classes, they have also been found to be more likely to take higher-level classes. In my final model, I have controlled for both mathematics achievement and remedial mathematics assignment, and yet the gender effects remain significant. Although it is unclear from these results why girls are more likely to take mathematics with in-field teachers, it provides a basis for possible future research.

The findings related to geographic region are also less than surprising, given that the Midwest has seen population declines, while the coastal regions, particularly the West, have experienced population growth, which has created especially severe teacher shortages. States and districts have been forced to expand the teaching force in order to staff classrooms. In particular, California, which likely constitutes the largest portion of Western schools in the ELS:2002 sample, has faced a combination of population growth and a class size reduction policy that caused a crisis in teacher staffing in the state in the late 1990s and early 2000s. The year before these data were collected, almost 14 percent of the state's teaching staff lacked a full credential (Guha et. al, 2006). Given the demands of NCLB, and changes in state teacher credentialing policy, which have brought changes to the teaching profession as a whole, it is unlikely that the findings on census region would be the same, were the ELS:2002 data collected today. That said, thus far, state teacher staffing policy corrections have largely been directed at improving teacher credentialing ratios, and have not addressed the more difficult problem of out-of-field teaching. Although states may be able to funnel existing teachers into alternative and short-term credentialing programs, the challenges of attracting teachers with rigorous content backgrounds in mathematics to high school teaching remains a difficulty that states and districts have yet to solve.

The research presented here indicates that within-school disparities in teacher quality are tied to student achievement in mathematics. This finding, however, raises further research questions. The first being whether there is a causal relationship between the assignment of under-qualified teachers and students achievement in mathematics. If so, does consecutive year assignment to such teachers either compound or even create lower achievement? These are questions potentially to be addressed by my future research.

Finally, this research also raises a question that may best be addressed by policy and theoretical experts in the fields of mathematics curriculum and instruction. Namely, we should question the common assumption that teaching lower-level mathematics content requires minimal knowledge of that content. It seems possible that students who under-perform in mathematics do so because they have struggled to understand content that has been presented to them through traditional teaching methodologies. However, teachers who have either rote or minimal understanding themselves may not be the best equipped to address student misconceptions in mathematics. In fact, deep content knowledge may be required in order to best help students find multiple entry points into content topics they do not understand. Although shortages of teachers with high-level mathematics content knowledge likely necessitate the assignment of high-level mathematics courses, such as calculus, to those teachers with the backgrounds to teach it, the wisdom of providing teachers who are less prepared in content to students who struggle the most needs to be addressed through further research, as well as adjustments in mathematics teacher training, and policy. Otherwise, we run the risk of possibly further exacerbating student failure in mathematics.

Table 1: Descriptive Statistics for Students and Schools, by 10th Grade Mathematics Teacher Qualifications

	Overall Mean	Certified, In-field[a] (n=6516)	Certified, Out-of-field (n=2505)	Uncertified, In-field (n=645)	Uncertified, Out-of-field (n=395)
Students (n=10086)					
Student SES	0.00	0.02	**-0.16***	-0.17	-0.19
Race					
% White	0.62	0.67	**0.54***	**0.58***	**0.46***
% Black	0.14	0.13	**0.16***	0.14	0.18
% Hispanic	0.15	0.12	**0.20***	**0.18***	**0.26***
% Asian	0.04	0.04	0.03	0.05	0.02
% Other	0.05	0.05	**0.07***	0.05	0.07
% Female	0.50	0.51	**0.47***	0.51	**0.43***
% Remedial Mathematics	0.09	0.08	**0.12***	0.08	**0.14***
10th Grade Mathematics Achievement	0.00	0.14	-0.04	0.04	-0.04
Schools (N=518)					
Urbanicity					
% Urban	0.25	0.24	**0.27***	0.27	**0.36***
% Suburban	0.52	0.52	0.51	**0.59***	0.46
% Rural	0.23	0.24	0.22	**0.14***	0.18
Geographic Region					
% Northeast	0.17	0.17	0.17	**0.23***	0.16
% Midwest	0.25	0.28	**0.21***	**0.23***	**0.08***
% South	0.35	0.36	0.34	**0.22***	0.39
% West	0.23	0.19	**0.28***	**0.32***	**0.37***
School Academics					
% High ELL	0.08	0.07	**0.10***	**0.10***	**0.17***
% High College Prep	0.65	0.66	0.64	0.65	**0.55***
% High General Ed	0.57	0.55	**0.60***	**0.62***	**0.66***
Average School SES	0.00	0.01	**-0.21***	-0.12	-0.16

**p<.05*

a- Certified, Infield is the reference category.

Table 2: Multi-level, Multinomial Model of 10th Grade Mathematics Teacher Qualifications (results reported as Odds Ratios)

	Certified, Out-of-field[a] *(n=2491)*		Uncertified, In-field *(n=643)*		Uncertified, Out-of-field *(n=393)*	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Students (n=10043)						
Student SES	**0.91****	0.99	**0.83****	0.91	**0.85***	1.02
Black [b]	**1.40****	1.10	0.95	0.77	**1.62***	1.05
Hispanic	**1.38****	1.19	1.02	0.88	**1.97****	1.46
Asian	0.80	0.85	0.99	1.03	0.57	0.60
Other	**1.41****	1.27	1.07	0.97	**1.73***	1.47
Female	**0.85****	**0.81****	0.96	0.92	**0.69***	**0.63****
Remedial Mathematics	**1.53*****	**1.33****	1.04	0.91	**1.70****	1.23
10th Grade Mathematics Achievement		**0.68*****		**0.70*****		**0.45*****
Schools (n=518)						
Urban[c]	1.16	1.14	1.16	1.14	1.42	1.40
Rural	0.93	0.94	0.57	0.58	1.00	1.02
Northeast[d]	**1.47***	1.52	1.89	**1.95***	**4.09****	**4.32****
South	1.26	1.29	0.80	0.82	**3.50*****	**3.62*****
West	**2.01*****	**2.06*****	**2.46****	**2.52****	**6.25*****	**6.47*****
School Academics						
High ELL[e]	**1.40*****	1.43	1.64	1.68	**2.27***	**2.39***
High General Ed[f]	1.17	1.14	1.38	1.35	1.18	1.12
High College Prep[g]	1.12	1.14	1.13	1.14	0.74	0.76
School SES mean	0.91	0.96	1.02	1.06	1.02	1.14
Intercept	**0.19*****	**0.20*****	**0.04*****	**0.04*****	**0.01*****	**0.01*****

p<.05;p<.01;***p<.001*

a-Certified, Infield is the reference category; b-White is the reference category; c-Suburban is reference category; d-Midwest is reference category; e-High ELL defined as more than 25% of 10th graders; f-High General Ed defined as more than 50% of 10th graders enrolled in general education courses; g-High College Prep defined as more than 50% of 10th graders enrolled in college prep courses

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