STEM teacher workforce in high-need schools resilient despite shrinking supply and increasing demand

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VERSION: August 2024

Suggested citation: Hansen, Michael, Li Feng, David Kumar, and Nicolas Zerbino. (2024). STEM teacher workforce in high-need schools resilient despite shrinking supply and increasing demand. (EdWorkingPaper: 24-1024). Retrieved from Annenberg Institute at Brown University: https://doi.org/10.26300/pqd0-vh09

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July 2024

Abstract

The teacher workforce in science, technology, engineering, and math (STEM) has been a perpetual weak spot in public schools' teaching rosters. Prior reports show the pipeline of new STEM teachers into the profession is weak while demand for instruction in STEM fields continues to grow. This paper seeks to document whether and how the STEM teacher workforce in high-need settings has been impacted by these pressures. It analyzes successive waves of nationally representative teacher survey data to explore demographics and qualifications among the secondary STEM teacher workforce in high-need settings has fared over time. Results show the STEM teacher workforce in high-need schools is consistently less likely to be experienced, less likely to hold any degree in a STEM field, less likely to hold a master's degree, and less likely to be fully certified than STEM teachers in more advantaged settings. Yet, surprisingly, the observed qualifications gaps across high- versus low-need settings are either stable or slightly narrowing over time. Certain STEM fields—namely, physical sciences and computer science—rely on a less qualified workforce than those in math or biology, with low levels of teacher qualifications observed across both high- and low-need settings. Though even when considering field-specific alignment between teachers' background qualifications and their teaching assignments, the qualifications gap between high- and low-need settings has been slowly shrinking in three of four STEM fields analyzed here. In addition to high-need schools, small schools (based on enrollment size) rely more heavily on underqualified STEM teachers.

Acknowledgements: The authors thank Xiu Wu, Richard Vega, Jamie Klinenberg, and Ayanna Platt for excellent research assistance. An advisory board comprised of Michael Marder, Lisa Sporillo, Ann Cavallo, and Talia Milgrom-Elcott oversaw this project, and we thank them for their feedback and insights. This work is supported by the National Science Foundation under Grant No. 1950292, 1950284, 1950013. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Introduction

The teacher workforce in science, technology, engineering, and math (STEM) has been a perpetual weak spot in public schools' teaching rosters.[1] Prior research evidence has documented elevated levels of turnover and more difficulty staffing vacancies in STEM subjects compared to most other specializations (Dee and Goldhaber 2017). Importantly, schools vary in the level of staffing challenges they face, and those serving high-need student populations typically face the greatest difficulty in securing access to a qualified supply of STEM teachers for their students. A weak STEM teacher supply has downstream implications for industries in STEM fields, which include many of those that propel economic growth and support national security (National Academy of Sciences et al. 2010). Further, disadvantaged students' unequal access to quality STEM instruction implies historical educational and economic gaps between groups based on family backgrounds will persist and even grow over time.

Developments over the last decade suggest the STEM workforce may be growing ever more constrained. As we describe in detail below, the supply of new teachers into the workforce has been shrinking, with some of the largest recent contractions among STEM fields. Meanwhile, demand for instruction in STEM fields has been increasing over time. Prior research also shows the importance of teachers' training and background content knowledge, particularly in STEM fields, for promoting student learning. We hypothesize that the confluence of these patterns creates acute staffing pressures for the STEM teacher workforce, and schools in high-need settings are most vulnerable to feeling these pressures. Consequently, we expect that qualifications gaps for STEM teachers across settings will widen over time as schools must continually cope with a weakening supply of teachers, and instructional quality and availability would be expected to decline in these settings.

This paper explores STEM teacher workforce staffing patterns in high-need schools, comparing them against STEM teachers in low-need settings or against non-STEM teachers in similar high-need settings. We use multiple waves of the Schools and Staffing Surveys and the National Teacher and Principal Surveys, combined with supplemental data from the Common Core of Data. Descriptive analyses show how characteristics and qualifications of the STEM teacher workforce have evolved over the past three decades. The STEM teacher workforce in high-need schools is consistently less likely to be experienced,

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[1] "STEM teacher" in this report refers to all teachers in the workforce who offer instruction in an academic course in science, technology, engineering, or math. This label is not intended to imply that these teachers are specialists across multiple or all STEM fields and makes no assumptions about their approach to teaching in an integrated, interdisciplinary way.

less likely to hold an undergraduate degree in a STEM field, less likely to hold a master's degree, and less likely to be fully certified than STEM teachers in more advantaged settings. Yet, surprisingly, the observed qualifications gaps between STEM teachers in high- versus low-need settings are either stable or slightly narrowing over time despite the pressure on the STEM workforce in particular. Certain STEM fields—namely, physical sciences and computer science—rely on a less qualified workforce than those in math or life sciences, with generally low levels of teacher qualifications observed across both high- and low-need settings. Field-specific teacher qualifications gaps across settings also appear to be modestly shrinking in three of four STEM fields. These findings demonstrate a surprising resilience in the STEM teacher workforce in high-need settings, despite the pressures these schools face.

Background

Our analysis touches on three strands of prior literature: the health of the STEM teacher workforce, the role of qualifications and training in promoting student learning in STEM, and the teacher workforce in high-need settings (regardless of subject specialization). We offer background on these three separate strands in turn and then synthesize to describe this study's contribution.

An increasingly pressured STEM teacher workforce

The STEM teacher workforce appears to be especially vulnerable to staffing problems compared to other subjects. Even before the recent COVID-19 pandemic, reports warned of dwindling supplies of new certified teachers of all backgrounds coming into the profession (Garcia and Weiss 2019; Sutcher, Darling-Hammond, and Carver-Thomas 2016). The pandemic has added new stressors, elevating teacher attrition and increasing the salience of teacher vacancies nationally (Nguyen et al. 2022). Yet, reports about national teacher shortages, both before and during the pandemic, often reflect the chronic challenges of staffing math and science teachers specifically, since the teacher workforce in most other subjects (except special education) is generally reliable enough to not raise serious concern (Dee and Goldhaber 2017; Fortin and Fawcett 2022). Excessive vacancies may occur for any one of several reasons, including high turnover of existing teachers, an inadequate supply of new teachers into the profession, and increasing demand for instruction. As we describe below, the STEM teacher workforce is pressured on all three of these fronts.

First, turnover among the STEM teacher workforce is notably high. Borman and Dowling's (2008) meta-analytic review of teacher attrition and retention raises serious concerns about the health of the STEM teacher workforce specifically, finding teachers with undergraduate degrees in math and science are roughly twice as likely to leave teaching than those in other subjects. Attrition rates vary from school to school, with the highest teacher attrition rates observed among STEM teachers in disadvantaged school settings (Ingersoll and May 2012; Nguyen and Redding 2018). A likely factor behind STEM teachers' elevated turnover is that outside wage opportunities for teachers with STEM backgrounds are significantly higher than those for non-STEM teachers, on the order of 10 to 30% more at various points over teachers' careers (Hansen, Breazeale, and Blakenship 2019). Though recent analyses from two states challenge the notion of outside wages luring teachers away from the profession (Goldhaber et al. 2024; McKenzie et al. 2023), neither study examines earnings by teacher subject specialization. Conversely, a separate study by Biggs and Richwine (2021) similarly explores earnings differences among recent graduates by sector of employment and concludes that the teacher pay penalty is almost entirely due to STEM teachers' outside opportunities, not those coming from other academic backgrounds. Further, other research suggests that the earnings return to STEM majors is increasing over recent decades, in comparison to other disciplines (Noonan 2017). In summary, turnover among STEM teachers is higher than other fields, the allure of working outside of teaching is largest for STEM teachers and continues to grow, and these pressures likely reinforce existing staffing challenges for STEM teachers, particularly in high-need settings.

Second, the supply of STEM teacher candidates into the workforce is weak and declining. In a study examining the math and science teacher workforce over twenty years ending in 2008, Ingersoll and Perda (2010) find that schools have generally been able to maintain staffing in these subjects by relying on diversified labor sources. Specifically, they show these subjects attract a greater share of non-education majors into the profession (mostly through alternative certification programs) and attract previously trained teachers to re-enter the classroom at higher rates, compared to other subject specializations. Yet, more recent evidence shows the number of people completing a teacher license in any subject has been declining sharply since the Great Recession (Kraft and Lyon 2022). National data from Title II on teacher training programs shows the STEM teacher pipeline has been particularly impacted by these declines (Office of Postsecondary Education 2022, a40 – a41). Figure 1 visualizes these data, showing the percentage change in the number of teacher preparation program completers between the 2011-12 and 2019-20 school years (combining both traditional and alternative certification programs.[2] The number of completers in the last year of data (2019-20) is also noted, showing the

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[2] Marder (2023) presents a data visualization that uses Title II data on STEM program completers over a similar timeframe (second tab of visualization), separated by those entering through a training program based at an

relative size of each subject specialization. Virtually all fields shrank during this recent seven-year period. Notably, three of the four specializations shrinking the most were major STEM subject specializations (mathematics, biology, and chemistry). Mathematics saw the steepest national decline, where completers shrank by a third in this six-year period (dropping from 14,341 completers in 2011-12 to 9,148 in 2019-20). Earth science and physics were not as affected by these declines (earth science even posted a modest improvement), though these are smaller fields of specialization and account for just over 8% of completers in STEM subjects in 2019-20. Part of the declines observed in biology and chemistry may be explained by teacher candidates choosing to specialize in general science rather than a specific field; general science specializations saw declines of less than 10% compared to biology and chemistry (22.6% and 19.2% declines, respectively). Though many factors could be behind these declines in the number of teacher program completers, growing student debt among undergraduates is a likely one. Indeed, student loan debt has risen dramatically over recent decades and Rothstein and Rouse (2011) show a negative association between students' debt burdens and the intent to pursue often low-earning, public service occupations after graduation. Additionally, undergraduate student enrollments have begun declining over the past decade (Meyer 2023), exerting downward pressure on the number of potential candidates for the teacher pipeline.

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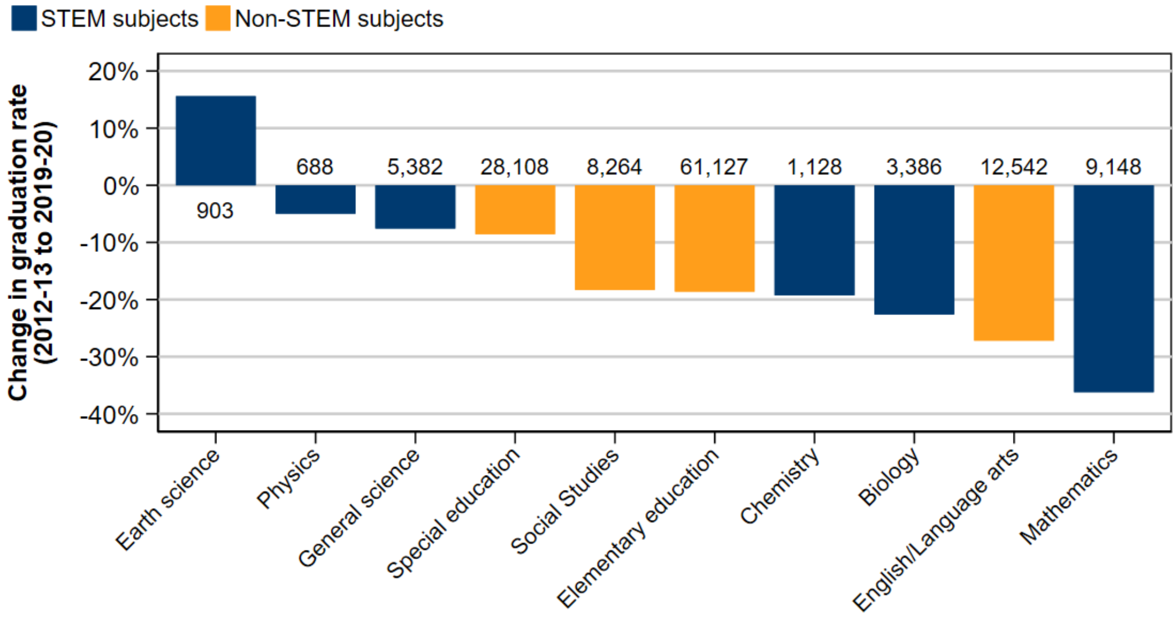
institute of higher education versus alternative certification. Non-university-based, alternative certification entrants' share increased slightly over this period, from nearly 15% in 2011-12 to 18% in 2020-21.

Figure 1


Declining completions of certified teachers in most STEM subjects

Note: Computer Science presented a strong increase but is excluded because it only had 82 completions in 2019-20.
Bar labels show number of completers of teacher preparation programs who prepared to teach in subject area in 2019-20.

Source: U.S. Department of Education Office of Postsecondary Education, Preparing and Credentialing the Nation's Teachers, July 2023.

Finally, the demand for instruction in STEM fields has only increased in recent decades. During the 1980s and 1990s, most states increased their course graduation requirements in math, science, or both subjects in response to challenges laid out in the National Commission on Excellence in Education's report, *A Nation at Risk* in 1983 (Plunk et al. 2014). STEM course taking among high school graduates increased between 1982 and 2004, with average credits per student increasing by nearly a full credit in math and more than a full credit in science over the period (Dalton et al. 2007). The focus on learning in STEM subjects continued into the No Child Left Behind era, often under the guise of promoting college and career readiness among students. For example, in California during the 2018-19 school year, two-thirds of students were enrolled in districts that required three or four years of math for high school graduation—which exceeded the state minimum of two years—with districts often referencing compliance with state college admissions standards as a motivation for the higher standards (Gao 2021). Finally, the increasing provision of computer science instruction marks another way STEM instruction is expanding. Within the last decade, 40 states have adopted policies to rapidly promote computer science education to help young people prepare for an increasingly digital job market ahead of them, including 23 states that (as of 2021) mandated computer science to be offered in all high schools (Hansen and Zerbino 2022).

Combining these three pressures, the STEM teacher workforce is under acute stress as schools are being tasked to provide more STEM instruction with the least stable segment of the public teacher workforce and increasingly fewer teacher candidates stepping in to help.

The role of teacher qualifications and content knowledge

Declines in the quantity of STEM teachers available to work also has the potential to adversely impact teacher qualifications and the quality of instruction. Indeed, a 2016 survey of school leaders in California found that hiring teacher candidates with substandard qualifications is the most reported coping strategy when faced with a shortage of applications for an open position (Podolsky and Sutcher 2016). Also, of note for our analysis, the authors found that school leaders in secondary schools (compared to elementary schools) were more likely to report facing teacher shortages, and math and science were among the top three specializations facing a shortage (special education was the most common shortage field). These results suggest that the STEM workforce in secondary schools, which is our focus, could be particularly vulnerable to declining teacher qualifications due to teacher staffing concerns.

Declines in teacher qualifications could negatively impact student learning. The role of teacher qualifications and content knowledge among teachers in promoting student learning has been a frequent, if sometimes contentious, point of investigation in the literature for decades. A 2003 review of this literature (Wayne and Youngs 2003) concludes that several preservice teacher qualifications, including teachers' standardized test scores (particularly on verbal tests) and undergraduate college selectivity are positively associated with gains in student achievement. More recent studies have also shown that scores on assessments specific to the teaching occupation, including those for licensure and National Board Certification, are also modestly associated with student learning gains (Goldhaber 2007; Goldhaber and Anthony 2007; Goldhaber, Cowan, and Theobald 2017). Similarly, entry into teaching through a traditional teacher training program and standard license is often (though not always) associated with slightly higher student learning outcomes (Kane, Rockoff, and Staiger 2008). Despite these modest positive associations between teacher qualifications and student outcomes, much of the more recent literature on teacher quality emphasizes the importance of unobserved teacher effectiveness measured through value-added models, which is far more influential in predicting future gains in student learning and is only weakly associated with these observable qualifications (e.g., Aaronson et al. 2007; Goldhaber and Hansen 2013)

Yet, one thread of this literature on teacher characteristics highlights the importance of content knowledge pertinent to the field that teachers teach, and these findings are particularly relevant for our inquiry on the qualifications of the STEM teacher workforce. For example, Wayne and Youngs's (2003) review found teachers' graduate degrees and certification status also matter, though only when aligned with the teacher's subject specialization; this relationship was most clear in the case of math, and less clear in science and other subjects. Dee and Cohodes (2006) come to a similar conclusion about the importance of math teachers' training and certification aligned with their classroom instruction (this relationship was also significant for social studies teachers in their analysis). Also, Clotfelter, Ladd, and Vigdor (2010) argue that when considering the collective role of various teacher qualifications in high school students' learning, credentials explained at least 20% of the variation in overall teacher effectiveness, with large roles for subject alignment in graduate training and licensure, especially among math and science teachers. Finally, a pair of studies from Lee and Mamerow (2019) and Lee and Lee (2020) emphasize the importance of STEM teachers' cumulative training and content mastery in promoting student outcomes. Lee and Lee (2020) finds students who are exposed to math or science teachers with higher cumulative years of experience in their subject matter (based on their own credentialing and educational attainment) were positively and significantly associated with their students' higher educational degree attainment. Lee and Mamerow (2019) considers cumulative experience, though aggregating across all teachers to whom students are exposed, and find similar associations with student learning; they also demonstrated students in high-need schools were much less likely to be exposed to STEM teachers with high cumulative qualifications.

The alignment between teachers' formal training and the subject(s) they teach captured significant policy attention during the late 1990s. The elevated incidence of out-of-field teachers, particularly in disadvantaged settings and among teachers in STEM subjects (Ingersoll 1998), was part of the motivation in establishing high-quality teacher mandates (described further below) as part of the No Child Left Behind Act (NCLB) (Ingersoll 2003). Out-of-field teaching is especially prominent in science fields and is both associated with lower-quality instruction for students and inhibits teachers' ability to develop professionally (Nixon, Luft, and Ross 2017). This issue has received little policy attention since NCLB's enactment in early 2002, as much of the focus on teachers has shifted towards measures of teacher quality rather than qualifications. The literature discussed in this section, however, points to the alignment between teachers’ background credentialing and their classroom assignments as important, if incomplete, proxies for instructional quality. The evidence shows this alignment is especially pertinent among STEM teachers.

Staffing weaknesses among all teachers in high-need school settings

Finally, ample research evidence shows schools in high-need settings have difficulties maintaining their teacher workforces, regardless of the subject specialization area. Teachers in high-need schools report, on average, lower levels of administrative support, poorer school climate measures, and more challenging working conditions than those in more affluent settings, which are typically drivers of the elevated turnover that is endemic (Simon and Johnson 2013). Consequently, high-need schools have been found to often rely on a revolving door of less-qualified teachers who have less prior teaching experience, fewer graduate degrees, and lower levels of licensure, among other qualifications (e.g., Feng 2009; Hanushek et al. 2004). Beyond differences in qualifications, recent research also shows that teachers in high-need schools are, on average, less effective than those in more affluent contexts (Isenberg et al. 2013; Sass et al. 2012; Xu, Ozek, and Hansen 2015). Weaker STEM instruction in high-need settings implies that schools would serve to reinforce social inequalities in the long term, as weaker instruction and fewer opportunities for exposure to rigorous content is expected to limit access to the most lucrative majors in college and occupational opportunities (e.g., Thompson, 2021).

Inadequate teacher compensation is frequently identified as an issue in high-need settings, both as a likely cause of elevated turnover and an effect of relying on an inexperienced workforce. With the widespread use of single salary schedules across districts, aggregate spending on teacher salaries is typically lower in high-need schools, reflecting the lower experience and credential levels of the teachers (Knight 2019; Hall and Ushomirsky 2010). Some locales have experimented with bonuses or other incentives for teachers in high-need settings and generally find they do attract more effective teachers and reduce turnover (e.g., Glazerman et al. 2013). Yet, the incentive values estimated to sustain turnover levels comparable to more affluent schools are large and are often seen as cost prohibitive; for example, Clotfelter et al. (2008) estimate bonuses of more than 20% would be required to close turnover gaps across settings. Also, teachers (and unions representing them) generally oppose efforts to differentiate compensation for teaching in difficult-to-staff schools as differentiation is seen as antithetical to collegiality (Goldhaber et al. 2011; Liang et al. 2015). Recent analyses of school spending allocations and staffing patterns in high-need schools suggest low average teacher salary spending is often, though not always, accompanied by additional instructional spending in these schools, contributing to higher staffing levels for either teachers or instructional support personnel (Hansen and Zerbino, 2022; Knight 2019). In other words, school districts implicitly compensate students in high-need school settings with a "higher quantity [of teachers] when local schools provide lower levels of quality [teachers]" (Hansen and Zerbino, 2022).

Historically, persistent socioeconomic and race-based gaps in student access to qualified teachers were important motivations for the adoption of teacher qualifications standards in NCLB. NCLB contained both guidelines for states to create definitions for highly qualified teachers and mandates to ensure that 100% of teachers providing instruction met those standards. As with other parts of NCLB that created aspirational goals for all schools, the teacher qualifications provisions were criticized over time as being vague and too easily gamed by states, where earning a "highly qualified" designation says little about teachers' actual quality (Walsh 2004). A 2007 interim report by the US Department of Education on implementation of teacher qualifications provisions from NCLB found high variability in states' requirements for being a highly qualified teacher and that 60 and 65% of districts reported difficulty in attracting highly qualified teacher candidates for math and science, respectively (U.S. Department of Education 2007). More recent federal initiatives, including teacher evaluation during the Race to the Top era and Educator Equity plans in 2014-15, have attempted to equalize student access to effective teachers; though these efforts faded in importance once the Every Student Succeeds Act was enacted in late 2015, replacing NCLB. According to the National Council on Teacher Quality's 2021 report on teacher preparation policies (Putman and Walsh 2021), the majority of states now require secondary teachers to take subject-specific assessments in order to be licensed to teach those courses, though the authors note that many states have deficiencies for teachers of multiple content areas, particularly in science. Worryingly, they report that 10 states do not require any content tests at all for teaching in high school grades. Thus, even as NCLB's effects on educator qualifications and equity were more modest than the law prescribed, it has nonetheless been an important policy tool that has focused states' and districts' attention on workforce quality and qualifications.

Staffing challenges for STEM teachers in high-need settings

Our review of the evidence shows both the STEM teacher workforce and teachers in schools serving high shares of socioeconomically disadvantaged students are weak and at risk for ongoing staffing challenges, with declining teacher qualifications and instructional quality as likely consequences. The joint intersection of these issues—the qualifications of the STEM teacher workforce in high-need settings—may be particularly at risk and is not well understood. The few studies that focus on STEM teachers across various school settings have presented evidence of an unequal distribution of teacher qualifications across students and modestly higher attrition rates in disadvantaged settings (Ingersoll and Perda 2010; Nguyen and Redding 2018). Our analysis below is similar to both of these prior studies, which also used successive waves of national teacher survey data to describe how the STEM teacher workforce is changing over time. However, our analysis here differs in a few key ways. First, we update the data with two additional waves of teacher survey responses beyond the most recent analysis, from Nguyen and Redding (2018), including one wave collected in 2020-21 during the COVID-19 pandemic recovery. Second, we focus squarely on the strength of the STEM teacher workforce in high-need settings, specifically drawing comparisons against non-STEM teachers in high-need settings and STEM teachers in low-need settings. And third, we evaluate the alignment of subject-specific credentials and teachers' assignments by different STEM fields; the last analysis that does this among STEM teachers nationally is Ingersoll (2003).

Research Questions

Our investigation fills several existing gaps in the literature on the STEM teacher workforce by exploring the following research questions:

1. What are the demographic characteristics and qualifications of STEM teachers in high-need school settings? How have these dimensions changed over time, in comparison to non-STEM teachers in the same settings or STEM teachers in low-need schools?
2. How do STEM teachers' qualifications align with their assignments, and do they differ across STEM fields? Has this alignment shifted over time?
3. Beyond being a high-need school, what other school- or district-level factors predict a greater reliance on weakly qualified STEM teachers?

Based on the background literature and the workforce trends described in the section above, we are concerned about the STEM teacher workforce in high-need settings, especially as it has faced more acute staffing pressures in recent years. We hypothesize that these pressures will be associated with widening gaps in qualifications between high- and low-need settings over time, leaving students in high-need settings vulnerable to lower quality instruction.

Data and Methods

This analysis uses multiple waves of nationally representative survey data from the Schools and Staffing Surveys (SASS) and National Teacher and Principal Surveys (NTPS) to examine workforce characteristics and school practices. The U.S. Department of Education's National Center for Education Statistics (NCES) has regularly administered surveys to districts, schools, teachers, and principals since the 1987-88 school year. Teacher survey responses provide information about teachers' demographics and background, as well as information about their teaching assignment, which provide the necessary information to estimate workforce characteristics in various settings. For this analysis, we use the 1993-94, 1999-2000, 2003-04, 2007-08, and 2011-12 waves of the SASS due to the restricted availability of free or reduced-price lunch eligibility measures (FRPL, the most common proxy for poverty in schools) in the earliest waves.

Starting in the 2015-16 school year, NCES replaced the SASS with the NTPS. The teacher-level data captured in the NTPS is largely analogous to that captured under the SASS's teacher questionnaire, though the sampling methods and collection instruments have been updated. Thus, most of the analyses will use both the SASS and any available NTPS responses that are consistent over both surveys. Yet, because the question format for some key variables significantly changed during the panel of survey collections (e.g., teacher certification in a specific subject between 1999-2000 and 2003-04) consistent values for some items are not included in all survey waves. This study uses data from the 2015-16, 2017-18, and 2020-21 waves of NTPS, which are the most recent available for research use as of this writing.

Other supplemental data are drawn from the Common Core of Data (CCD). The CCD data are primarily used to complement school poverty measures, described in the Appendix. We also use the CCD to incorporate some district-level characteristics, such as per-student expenditures and district-level enrollment.

Sample definition

We focus on the characteristics and health of the STEM teacher workforce in public secondary schools across the US. Though some elementary schools employ subject specialists to teach STEM classes, relatively few elementary school teachers (14.5% of teachers in grades 6 and below based on combined survey responses) are in departmentalized instruction models where teachers usually cover just one or two academic subjects. We focus on secondary schools to simplify comparisons between various teacher groups (i.e., those specializing in STEM subjects vs. not) and to avoid the possibility of differential sample selection of elementary schools choosing to departmentalize instruction from confounding our comparisons. Our analysis sample is comprised of all secondary teachers in grades 7 to 12 using waves of the SASS and NTPS data from 1993 to 2020. The sample contains most of the important teacher characteristic and assignment measures that will be critical to the analysis, and observations where the survey respondent fails to provide all the information are dropped from the sample (see Appendix for further details). Because the school poverty context is an important dimension of the analysis, observations in which the FRPL share is missing from both SASS/NTPS and CCD sources are dropped from the sample. We rely on CCD FRPL information first, when possible, and complement missing values with FRPL measures from SASS/NTPS.

Table 1 presents select basic statistics for our sample by each successive wave of the SASS and NTPS data. STEM teachers (defined below) make up about a third of all teachers in each survey wave. Note that the sample average of FRPL-eligible students increases over the time span of the data; this increase has been noted and discussed in other studies about using FRPL-eligibility shares as a measure of student poverty (e.g., Bass 2009). Consequently, in our analyses we use relative school FRPL-eligibility comparisons by year (i.e., comparing the top 25% vs. bottom 25% of schools based) to categorize school contexts based on relative student need. This allows the FRPL value for category boundaries to shift slightly each year in our analysis, though it maintains a constant focus on the most high-need schools over time instead of diluting the comparison pool through expansion to an increasingly wider set of schools over time. See further information on FRPL measures and categorizing high-need schools in the Appendix.

Table 1. Observation and descriptors of teacher sample

	1993 SASS	1999 SASS	2003 SASS	2007 SASS	2011 SASS	2015 NTPS	2017 NTPS	2020 NTPS	Total
STEM teachers	32.21	32.36	32.82	32.71	33.07	31.65	33.07	33.63	32.72
Share of FRPL	29.32	29.57	34.89	37.07	43.15	48.24	46.96	48.28	40.89
Observations	21,230	21,070	23,690	21,550	22,170	14,110	19,680	17,730	161,230

Note: Nationally representative weights are employed. Sample consists of teacher teaching grade 7 and above. STEM teachers are defined as those teaching at least one STEM class. See Appendix for details.
Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

Methods

We use descriptive methods to compare the characteristics of STEM teachers in high-need settings and against other groups (i.e., non-STEM teachers in high-need settings, STEM teachers in low-need settings). We compare how various attributes of teachers and their assignments change over the nearly three decades spanned by the survey responses. Individual teacher survey weights are used to produce national estimates. Teacher weights are adjusted for survey nonresponse and, within a year, sum to the population surveyed. Because of this, all our estimates are either year specific or use year fixed effects to account for different sample sizes across the years (the descriptive statistics in Table 2 excepted). Also, a regression analysis presented in Research Question 3 explores whether district or school-level covariates are factors in explaining the prevalence of various STEM staffing strategies and STEM teacher workforce outcomes. For this section, we use a simple linear regression model where staffing strategies and outcomes are the dependent variables and the school-level and district-level factors are independent variables. Further details are presented below as we come to that point.

Defining STEM teachers

We define STEM teachers as those who report teaching a STEM subject in at least one class period in a departmentalized model of instruction. Specifically, they teach at least one academically oriented course in mathematics (such as basic math, algebra, calculus, geometry, probability, or statistics), natural or physical sciences (such as chemistry, physics, geology, or biology), computer science, or engineering.[3] Vocational courses that overlap with STEM disciplines (e.g., health sciences) are excluded. We also follow this method to categorize STEM-specific teacher certification. We use a similar approach to categorize STEM degree holders: those who hold a bachelor's (either major or minor specialty) or master's degree in any of these fields are considered STEM degree holders. Teachers with an education degree specializing in a STEM field (e.g., math or science education) are also included in STEM degree holders. We exclude degrees in vocational or career training and business or economics-related majors (e.g., accounting) from our definition of STEM degrees.

To examine differences across specific STEM fields in sections of our analysis, we also categorize teachers into four specific STEM fields: mathematics, physical science, biology, and computer science drawing from Ingersoll (2003). Some STEM areas, such as general science, are excluded from these within-STEM categorizations. Details about this categorization and alignment between teaching fields, degree fields, and certification fields can be found in the appendix.

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[3] For the 2020-21 NTPS data, courses are categorized based on the Subject Matter Code from Table 1 (p. 9 of the NTPS Teacher Questionnaire). STEM classes are those listed under the "Mathematics and Computer Science" and "Natural Sciences" subheadings. Social sciences and Career and Technical Education classes are not considered STEM classes, even if the course title deals with STEM-related content. Other survey waves have analogous categorizations in their teacher questionnaires, which we likewise employ for categorizing STEM courses from the course list. See Appendix Table 1 for further details.

Results

Research Question 1: What are the demographic characteristics and qualifications of STEM teachers in high-need school settings? How have these dimensions changed over time, in comparison to non-STEM teachers in the same settings or STEM teachers in low-need schools?

We begin by exploring overall characteristics of the data sample. Table 2 pools all survey waves of the teacher sample and presents the data separately by specialty field (Non-STEM vs. STEM teachers in columns 1 and 2, respectively) and then by high-need context (bottom-quartile of school FRPL by year vs. top-quartile in columns 3 and 4, respectively). The final column presents descriptive statistics for those who sit at the intersection of both STEM teachers and working in high-need settings.

Table 2. Descriptive statistics of STEM vs non-STEM teachers in high and low need settings.

	(1) STEM	(2) Non-STEM	(3) FRPL Q1	(4) FRPL Q4	(5) STEM FRPL Q4
Subject assignment:					
STEM Teacher	1.00	0.00	0.33	0.33	1.00
Teaches math	0.59	0.00	0.19	0.20	0.60
Teaches biology	0.19	0.00	0.06	0.06	0.18
Teaches physical sciences	0.24	0.00	0.08	0.07	0.21
Teaches computer science	0.05	0.00	0.02	0.01	0.04
Demographics:					
Age	42.15	42.87	42.66	42.57	41.88
Female	0.59	0.61	0.60	0.61	0.61
Asian, Am. Ind., two races	0.05	0.03	0.03	0.05	0.07
Black	0.07	0.06	0.02	0.16	0.16
Latino	0.06	0.07	0.04	0.13	0.12
White	0.83	0.83	0.91	0.67	0.66
Other teacher characteristics:					
Total experience	13.82	14.47	14.82	13.30	12.70
Union member	0.74	0.73	0.80	0.70	0.70
MA degree	0.55	0.53	0.62	0.48	0.50
Fully licensed	0.91	0.93	0.94	0.89	0.88
Part time	0.02	0.03	0.04	0.02	0.01
Substitute	0.01	0.02	0.02	0.02	0.01
Base salary (2020 dollars)	61,472.96	61,168.26	67,767.70	59,296.81	59,313.37
School and district characteristics:					
District per-pupil spending (2020 dollars)	12,576.02	12,493.90	13,620.35	12,265.39	12,352.32
Large district (> 25,000 students)	0.27	0.27	0.21	0.41	0.41
School enrollment	1,113.67	1,122.63	1,292.04	978.91	965.06
Urban	0.26	0.26	0.15	0.44	0.43
Suburban/Town	0.38	0.38	0.58	0.25	0.25
Rural	0.37	0.36	0.27	0.32	0.32
Observations	53,560	107,660	37,720	37,620	12,910

Note: Nationally-representative weights are employed.
Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

STEM teachers in our sample (column 1) show few notable differences in demographics and qualifications from non-STEM teachers (column 2). Though many of these sample mean differences are statistically significant based on t-tests, there are few binary variables that differ by more than 2 percentage points. The most notable differences between STEM and non-STEM teachers are observed in gender (STEM teachers are less likely to be female), teaching experience (STEM teachers have 0.65 fewer years of teaching experience, on average) and holding a MA degree or higher (STEM teachers have higher educational attainment). STEM teachers also report a base salary that is $300 higher than non-STEM teachers. Among STEM teachers, most (59%) teach at least one math course, and only 5% teach computer science (by definition, non-STEM teachers do not teach courses in any of these fields). Note that STEM teachers can teach in multiple STEM fields; hence, the field percentages do not sum to 1, and there are some STEM courses that are not categorized in any of the fields shown, such as general science.

Conversely, when exploring differences among all teachers (both STEM and non-STEM) based on the school context, teachers in low-need schools (column 3) show a starkly different set of characteristics and qualifications in comparison to those in high-need settings (column 4). Teachers in high-need settings are much more racially/ethnically diverse, have less teaching experience, are less likely to be a union member, and are less credentialed (based on holding an MA degree or being fully certified). High-need school teachers also report earning nearly $8,500 less than those in low-need settings. As discussed above, lower salary spending is common in high-need settings (e.g., Hansen and Zerbino 2022). The share of individuals teaching a course in a STEM field differ by only one percentage point across high- and low-need settings—showing that the mix of STEM teachers being employed (as a share of all teaching staff) are very similar across contexts.

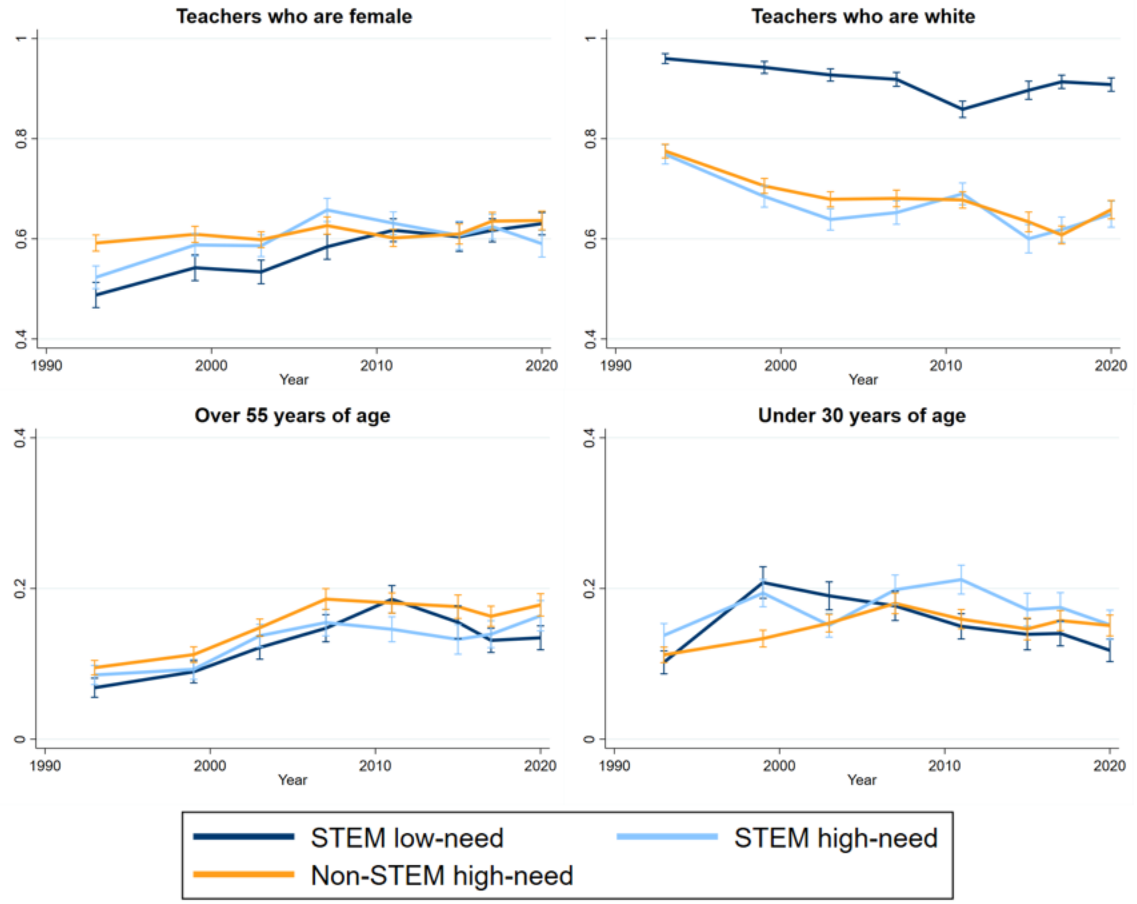
Finally, the attributes of STEM teachers in high-need schools (column 5) are most similar to those of all teachers in high-need schools (column 4), though are slightly more likely to be male and having slightly higher educational attainment, as is the case with other STEM teachers generally (compare column 1). STEM teachers in high-need settings are also the youngest and show the lowest levels of prior teaching experience and licensure among all teacher subgroups considered in Table 1. Thus, STEM teachers in high-need schools are unique among other secondary teachers, though many of their unique attributes are most closely mirrored with colleagues in high-need settings, less so with STEM teachers in low-need settings.

Next, we explore how demographics among the STEM teacher workforce are shifting against our comparison subgroups (non-STEM teachers in high-need settings, and STEM teachers in low-need settings). Figure 2 documents the sample average over each survey wave of female, white, young (under

30 years old), and older (over 55 years old) teachers among the different teacher subgroups. Several trends are evident from Figure 2. First, STEM teachers in high-need settings—and the other comparison subgroups—are all increasingly growing more female, less white, and older over time. Similar trends have been previously documented across the national teacher workforce overall; indeed, growing more female, more racially and ethnically diverse, and growing older in age are three trends (of seven total) that Richard Ingersoll and co-authors (2021) identified as important shifts in the teacher workforce over recent decades. Conversely, the share of relatively young teachers (less than 30 years old) differs somewhat from that found in Ingersoll et al. (2021); where they find a steady decline in the share of junior teachers, we find that the share of young teachers peaked in the mid- to late-2000s and has been declining to similar levels compared to the beginning of the series (see bottom right figure).

On closer inspection of figure 2, some notable patterns specific to STEM teachers in high-need settings arise (light blue). For example, STEM teachers in high-need settings were historically more female than those in low-need schools, but they have converged in recent years, and, in the most recent survey wave, those historical positions have reversed. Also, teachers in high-need settings (both STEM and non-STEM teachers) have been growing more racially/ethnically diverse at a faster rate compared to STEM teachers in low-need settings. This is also consistent with broader workforce trends, which show much of the growing teacher diversity in the workforce is concentrated in schools serving high shares of students of color, which tend to be socioeconomically disadvantaged (Gershenson, Hansen, and Lindsay 2021).

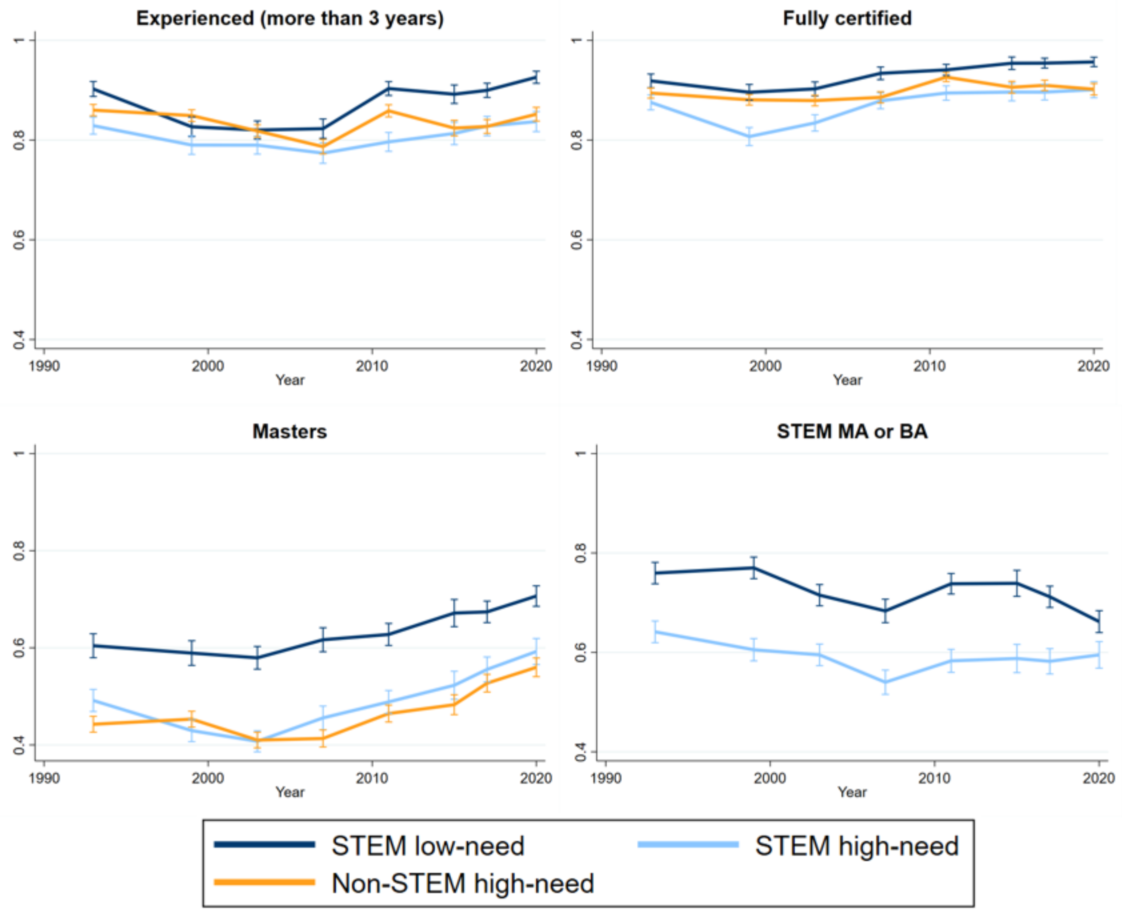
Figure 2. Teacher demographic characteristics by STEM teaching status and school level of need



Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

We now turn our focus specifically to teacher qualifications that are commonly taken as proxies for teacher workforce quality: teaching experience (coded as 1 if a teacher has more than three years of prior teaching experience), holding a master's degree (or higher), being fully certified (i.e., not holding an emergency, temporary, or provisional license), and having a bachelor's or master's degree in a STEM field. Figure 3 shows how the workforce has shifted on these domains over time.

Figure 3. Teacher qualifications by STEM teaching status and school level of need



Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

We highlight three patterns evident in Figure 3. Focusing first on STEM teachers in high-need settings (light blue), their overall level of qualifications appears to be remarkably stable across survey waves; for three of four qualifications measures, the confidence intervals of the earliest and most recent waves overlap, even as they bounce around slightly in the years between. The share of teachers with a master's degree even shows significant improvement during this period, with steady upward progress observed over the last 15 years of data collection.

Second, echoing the patterns shown in Table 2 above, the characteristics of STEM teachers in high-need settings are generally most similar to non-STEM teachers in the same settings—the light blue and goldenrod lines frequently have overlapping confidence intervals across these measures. (Note that we do not include a line for non-STEM teachers' holdings of STEM BA or MA degrees, as we do not expect non-STEM teachers to seek such a qualification.)

Third, a notable qualification gap exists between STEM teachers in high-need settings and those in low-need settings. Across all four of these characteristics, those in high-need settings are less qualified, as similarly documented in prior literature. We also observe a rough consistency over time on the magnitude of these gaps, though the most notable changes appear to be a slight *narrowing* in the share of teachers holding a master's degree and those holding a degree with a STEM specialization in the last available survey year. The slight narrowing, when evident, is due more to changing qualifications among STEM teachers in low-need settings vis-à-vis those in high-need settings.

Research Question 2: How do STEM teachers' qualifications align with their assignments, and do they differ across STEM fields? Has this alignment shifted over time?

The analyses in Figure 3 above offer some encouraging results for high-need settings, though may still mask underlying inequalities in two ways. First, it is possible that those who are unqualified on one dimension (for example, on holding a STEM degree) may be more likely to be unqualified on other dimensions (e.g., being fully certified). If we considered teacher qualifications as bundled characteristics, which is how they occur in individuals, then it's plausible that the STEM teacher workforce in high-need settings is more disadvantaged than any single binary measure could convey (this follows a similar logic developed in Clotfelter, Ladd, and Vigdor 2010). Second, following the disparate teacher training completion rates presented in Figure 1, it's also plausible that teacher qualifications in one or more STEM fields may be more vulnerable to staffing pressures across school settings than others. If we analyze differences in qualifications by STEM field, we may see greater differences across settings that are glossed over when combining all fields under the STEM umbrella as is presented in Figure 3 above.

Our strategy to examine differences in qualification alignment combines both subject-specific degrees and subject-specific certifications and maps them onto the specific STEM fields in which a teacher offers instruction. Figure 4 below shows the degree of qualification alignment among teachers in high- and low-need settings for physical sciences, math, computer science, and biology.[4] These fields were

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[4] For these field-specific analyses, teachers with a BA in science education or holding a certificate in general science only are not considered aligned with any specific field. A parallel figure for science teachers in general (i.e., not differentiating between physical versus life sciences in the fields) can be found in the appendix.

selected to represent content variety among the largest STEM specializations that are commonly offered in high schools. For each field, we categorized teachers as having both subject-specific qualifications (degree and certification aligning with the course content they teach), one of these qualifications (we consider only holding a degree in the field as a more significant endorsement and order it next, followed by holding certification in field only), or none of them. For example, if an Algebra 1 teacher is certified to teach to math and holds a BA degree in business management, we categorize them as having only certification in subject, but not an aligned academic degree when examining math teachers. If this same teacher also teaches a section of computer science, they would be categorized as having no subject-specific qualification among computer science teachers. Note that because all teachers in a field will fall into one of these mutually exclusive qualification categories, the data is presented as stacked bars that sum to 100 percent, and the same teacher can appear in multiple fields depending on the courses they teach.[5]

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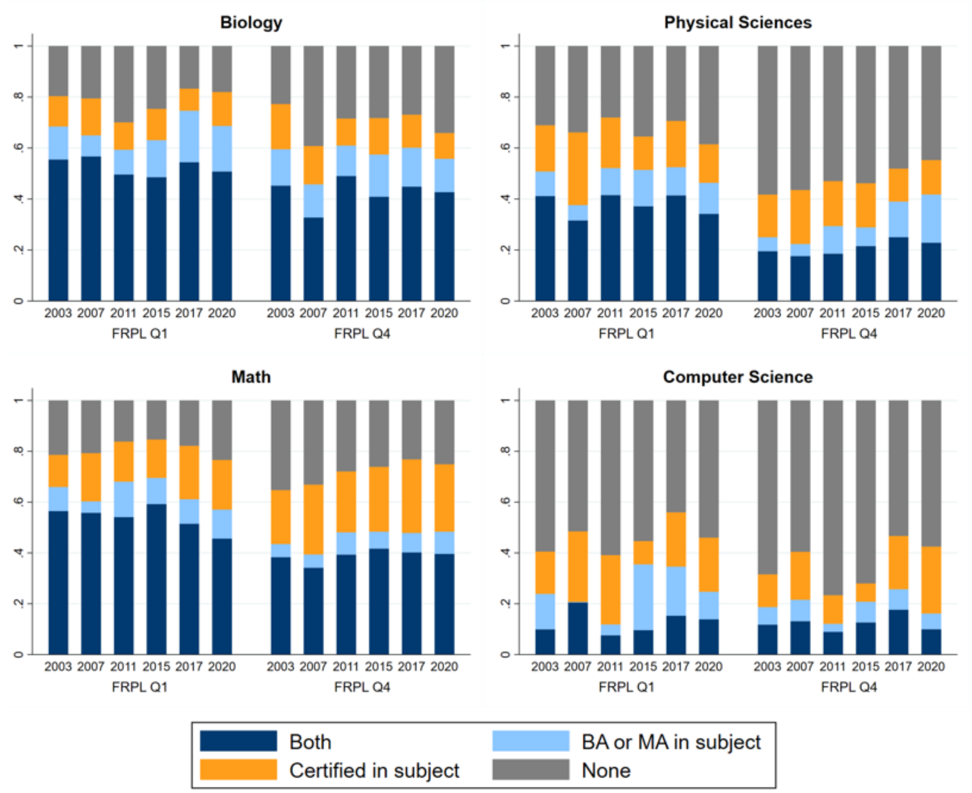
[5] Teachers teaching only one section of a STEM course could be more likely to have no qualifications aligned with the subject than teachers who have a heavier course load in the subject. Because of this, the approach in Figure 4 reporting the share of individual STEM teachers with qualifications could underestimate the overall level of qualifications when considering the proportion of course sections that have a qualified teacher. We found qualitatively similar results when considering the proportion of course sections with a qualified teacher rather than the proportion of qualified teachers. For reasons of consistency and readability, we chose to present the results here using individual teachers as the unit of analysis.

Figure 4. Share of teachers with field-specific qualifications by school FRPL quartile



Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

Figure 4 reveals several important trends that were not apparent in Figure 3. First, the share of teachers with aligned subject-specific qualifications varies significantly across fields. More than two-thirds of math (75%) and biology (66%) teachers in high-need settings hold at least one in-field qualification in 2020. Contrast this against physical sciences and, especially, computer science teachers in high-need settings, where 45% and 57% of teachers had no subject-specific credential in 2020. Looking over time and across settings, computer science is clearly the weakest field in terms of teacher qualifications, then (in order of increasing shares of qualified teachers) followed next by physical sciences, biology, and math.

Second, fields also differ in their reliance on teachers with a degree in the field (combining the dark and light blue stacked bars) versus those only holding a certification (goldenrod bars). In computer science, roughly half of teachers in high-need and less than half in low-need settings, have any qualification and half of those (or more, in high-need settings in the most recent year) are teachers only certified in the field and presumably have relatively little academic training. Even among math teachers, the most taught subject, more than a quarter of all teachers in high-need settings hold a certificate as their only qualification in the field; this is on top of the quarter that hold no aligned qualification at all.

Finally, similar to the encouraging trends presented in Figure 3, a gap in the share of unqualified teachers across school settings is also apparent in these graphs, though appears to be shrinking over time in most fields. In physical sciences, computer science, and math, the differences in the share of unqualified teachers across settings is smaller in 2020 than it was in 2003. Further, the narrowing gap was due more to increasing qualifications among teachers in high-need settings, rather than qualification declines in low-need settings. The gains in qualifications in high-need settings among math and computer science teachers were primarily fueled by increasing shares of certification-only teachers (the weakest subject-matter qualification category, in our view), though the workforce in low-need settings also showed modest increases in the share of certification-only teachers during this period, particularly in math. The trends in biology differ: here, the qualification gap across school settings grew over this period and the widening gap is mostly due to declines in qualifications among teachers in high-need settings.

Summing up, teaching qualifications among the STEM teacher workforce in high-need schools continues to show encouraging signs, with slight improvements over time in qualifications for teachers of physical sciences, math, and computer science. Ironically, the one STEM field where we see an evident decline in teachers' qualifications in high-need settings is in biology, which is the one STEM field where Marder (2021) estimates there is a small surplus in the teacher supply among high school grades. It is unclear why biology teachers' qualifications are declining while those in other STEM fields improve. Even more, it is unclear why teacher qualification levels have improved in most STEM fields in high-need settings, even amidst the declines in teacher supply and increasing demand for instruction. Part of this strength is apparently due to a growing reliance on field-certification only, not those with significant academic training in the subject; though even the ranks of those with in-field degrees has been surprisingly resilient over time.

Research Question 3: Beyond being a high-need school, what other school- or district-level factors predict a greater reliance on weakly qualified STEM teachers?

Our final analysis considers what types of schools are more likely to rely on less-qualified teachers to lead STEM instruction. This paper has primarily used high-poverty schools as the lens for examining differences in STEM teacher qualifications, though we suspect other factors could similarly influence a school's willingness to hire teachers with inadequate qualifications. For example, rural schools have been shown to have systematically lower access to teacher training programs and labor markets, making teacher supply challenges especially acute (Goldhaber et al. 2021). Additionally, charter schools in many states have greater flexibility on teacher qualifications compared to traditional public schools, which may enable them to hire teachers less qualified in STEM subjects (Education Commission of the States 2020). Prior research has found charter schools generally rely on less experienced, more alternatively certified teacher workforces, which contribute to higher levels of teacher turnover (Carruthers 2012; Bruhn et al. 2022). Other factors, including higher per-student spending or larger schools may be able to use economic factors to their advantage to attract a more qualified workforce aligning with their needs.

To conduct this analysis, we estimate the following linear regression model:

$$q_{isdt} = \beta_0 + X_{dt}\beta_1 + X_{st}\beta_2 + \gamma_t + \gamma_{STATE} + \varepsilon_{isdt}$$

Here, the estimated dependent variable are the qualifications observed for teacher *i* in school *s* located in district *d* at time *t* *(*q_{isdt}*).* Explanatory variables are district- and school-level factors (X_{dt}, X_{st}) that we suspect may be associated with differing availability of labor in the area. Year and state fixed effects (γ_t, γ_{STATE}) are included to account for systematic differences in qualifications at these higher levels. We iteratively estimate this model for different teacher qualifications, to explore whether qualifications have differing associations with these factors. This series of regressions is run on a subsample of our survey respondents, which limits the main analysis sample in two key ways. First, we focus on STEM teachers only. And second, we keep observations from 2003-04 and beyond; this keeps the analytical sample consistent across all qualification types we consider (recall subject-specific certification items in the teacher questionnaires are consistently in the same format only from 2003-04 onwards).

Table 3 presents the results of this series of regression models. The qualifications presented in columns 1 through 4 are binary measures of the teacher characteristic described in the column heading. The last two columns combine qualifications, looking at those who have either a STEM degree or STEM certification (column 5) versus those who hold both (column 6). The intuition here is that column 5 represents a lower standard to be considered qualified, and column 6 represents a higher standard. Note that STEM degree and certification in this table refer to any STEM field, regardless of which courses the teacher leads (a parallel table looking at field-specific alignment is presented in Table 4 below).

Table 3. School contexts associated with lower STEM teacher workforce qualifications

	(1) Experienced (>3 years)	(2) Masters	(3) Fully licensed	(4) STEM degree	(5) STEM degree or certification	(6) STEM degree and certification
Large district	-0.00771	0.00751	-0.0106	0.00593	0.00426	0.00884
	(0.00757)	(0.0133)	(0.00743)	(0.0145)	(0.0111)	(0.0166)
High-spending district	-0.00486	0.0331***	-0.0201**	0.0230*	-0.00409	0.0246**
	(0.00766)	(0.00878)	(0.00576)	(0.00898)	(0.00928)	(0.00817)
Urban	0.00205	0.00562	-0.0138	0.0344***	0.0116	0.0344***
	(0.00765)	(0.00863)	(0.00833)	(0.00905)	(0.00724)	(0.00964)
Rural	0.00546	-0.0503***	-0.00136	0.0196**	0.00641	0.0314***
	(0.00481)	(0.00828)	(0.00479)	(0.00610)	(0.00747)	(0.00628)
Charter	-0.121***	-0.0814***	-0.123***	0.0280	-0.000646	-0.0265
	(0.0130)	(0.0221)	(0.0224)	(0.0147)	(0.0131)	(0.0207)
School enrollment (log)	0.00565	0.0291***	0.00719**	0.0737***	0.0543***	0.0847***
	(0.00307)	(0.00731)	(0.00265)	(0.00678)	(0.00380)	(0.00961)
FRPL Q2	-0.000240	-0.0453***	0.00568	-0.0132	-0.00760	-0.00576
	(0.00465)	(0.0127)	(0.00517)	(0.0107)	(0.00816)	(0.00974)
FRPL Q3	-0.0257***	-0.0675***	-0.0194**	-0.0518***	-0.0356**	-0.0445***
	(0.00681)	(0.00831)	(0.00599)	(0.0106)	(0.0118)	(0.0108)
FRPL Q4	-0.0567***	-0.0762***	-0.0384***	-0.0766***	-0.0501***	-0.0773***
	(0.00819)	(0.0130)	(0.00855)	(0.0124)	(0.00715)	(0.0125)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	39,710	39,710	39,710	39,710	39,710	39,710
r2	0.0214	0.116	0.0399	0.0420	0.0312	0.0447

Note: Large districts are those with enrollment over 25,000. High spending districts have per-pupil annual spending over $12,000 using 2020 dollars. Urban and rural settings have suburban as base category. Teachers in sample are those who teach at least one STEM subject in grades 7 and above. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

We highlight several patterns surfacing in Table 3. First, for all of these qualifications, school poverty (as measured through the different quartiles of FRPL eligibility, abbreviated FRPL Q2 – Q4; the lowest need schools are the omitted category) is statistically significant in the expected direction, where higher poverty is associated with lower qualifications among the teacher workforce. Second, school enrollment emerges here as an important factor predicting STEM teachers' qualifications (with the exception of experienced teachers). This relationship makes intuitive sense: larger schools have more students to serve, which should enable schools to hire more specialized teachers (i.e., small schools may find it easier to assign an out-of-field teacher to cover a section or two of a given class).[6] Third, charter schools do hire teachers that are significantly less likely to be experienced, hold a MA degree or higher, and be fully licensed. Interestingly, this negative charter school association does not extend to STEM-specific qualifications in columns 4 through 6. Fourth, district spending levels and school locale do show some associations with qualifications, though these relationships are not consistent across qualification types. And finally, we find it instructive to compare the lower STEM standards in column 5 against the higher standards in column 6; most point estimates increase in magnitude (in both positive and negative directions), making some of these statistically significant in column 6. This suggests that weakly qualified teachers are more likely to be concentrated in high-poverty schools or those with lower enrollments, attenuating the point estimates for these variables when weak qualifications count in column 5.

Table 4 runs a similar series of regressions, though focusing instead on the subject-specific alignment of qualifications and teachers' course assignments. Results corresponding to the four different STEM fields are presented in pairs (math in columns 1-2, biology in columns 3-4, etc.). Following Table 3 above, the first column for each subject pair represents teacher qualifications based on the lower STEM standard where either a STEM degree or a field certification counts for being qualified, and the second column represents the higher standard where teachers hold both the degree and in-field certification. Note that the sample size shifts for each subject analysis, as the samples are limited to those teachers offering instruction in that field only.

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[6] Note that urban and rural schools have smaller enrollments than those in suburban settings. Consequently, the inclusion of the log of school enrollment removes the statistical significance of both of these variables compared to a model that omits school enrollment size (see Appendix Table A2). The results shown in Tables 3 and 4 here show that urban and rural settings do not have a consistent association with the various teacher qualifications independent of school enrollment size.

Table 4. Characteristics of districts and schools associated with teachers having no subject specific credentials for subjects they teach.

	(1) Math degree or certification	(2) Math degree and certification	(3) Biology degree or certification	(4) Biology degree and certification	(5) Physical sciences degree or certification	(6) Physical sciences degree and certification	(7) Computer Science degree or certification	(8) Computer Science degree and certification
Large district	-0.00449	0.00130	0.00423	0.000194	-0.00831	-0.00372	0.0728	-0.0137
	(0.0173)	(0.0216)	(0.0213)	(0.0270)	(0.0389)	(0.0285)	(0.0512)	(0.0269)
High-spending district	0.00139	0.0221**	0.00581	0.0229	0.0163	0.0207	-0.0330	0.00552
	(0.00984)	(0.00822)	(0.0156)	(0.0177)	(0.0248)	(0.0139)	(0.0453)	(0.0202)
Urban	0.0145	0.0335*	0.0217	0.0110	-0.00847	-0.0238	-0.0435	0.0273
	(0.00837)	(0.0125)	(0.0206)	(0.0192)	(0.0245)	(0.0166)	(0.0524)	(0.0278)
Rural	-0.0117	0.0236*	0.0280	0.0328	0.00339	0.00926	-0.0535*	-0.0150
	(0.0107)	(0.00993)	(0.0158)	(0.0178)	(0.0213)	(0.0246)	(0.0262)	(0.0241)
Charter	-0.0431*	-0.0571**	-0.0237	-0.00350	0.0251	0.0319	0.00489	-0.0309
	(0.0195)	(0.0209)	(0.0387)	(0.0331)	(0.0287)	(0.0398)	(0.0521)	(0.0377)
School enrollment (log)	0.0566***	0.0681***	0.0958***	0.0950***	0.107***	0.0974***	0.0434*	0.0163
	(0.00565)	(0.00947)	(0.00933)	(0.0101)	(0.0147)	(0.0111)	(0.0186)	(0.0125)
FRPL Q2	-0.0149	-0.00761	0.0245	0.0384	-0.0278	-0.0323	-0.0779	-0.0120
	(0.0112)	(0.0128)	(0.0206)	(0.0288)	(0.0188)	(0.0201)	(0.0463)	(0.0259)
FRPL Q3	-0.0483***	-0.0438**	0.000881	0.0243	-0.0665***	-0.0494**	-0.0811	-0.0174
	(0.0113)	(0.0143)	(0.0252)	(0.0206)	(0.0174)	(0.0157)	(0.0506)	(0.0254)
FRPL Q4	-0.0609***	-0.0961***	-0.0189	0.000757	-0.112***	-0.0717**	-0.0391	0.00953
	(0.01000)	(0.0134)	(0.0169)	(0.0165)	(0.0299)	(0.0243)	(0.0431)	(0.0273)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	23,370	23,370	8,020	8,020	9,710	9,710	2,050	2,050
r2	0.0342	0.0416	0.0812	0.0943	0.0919	0.0999	0.115	0.0714

Note: Large districts are those with enrollment over 25,000. High spending districts have per-pupil annual spending over $12,000 using 2020 dollars. Urban and rural settings have suburban as base category. Teachers in each sample are those who teach at least one subject in the specified subject in grades 7 and above. Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

Results in Table 4 have some overlap with those from Table 3, though also show some differences. For example, as with Table 3, school enrollment size here in Table 4 is positive and statistically significant in most model specifications, though here it seems to be the only explanatory variable that has a strong association across models. Also, school FRPL levels are statistically significant in math and physical sciences, though these factors are not significant in biology or computer science. Charter schools show a significant negative association with math teacher qualifications, but this does not extend to other STEM fields. The higher-standard estimates (in the even columns) only appear to notably increase in magnitude in math (inspecting column 2 vs. 1); this pattern does not hold in other STEM fields. Combined, these results indicate that teacher qualifications and sorting patterns across schools are quite variable across STEM fields.

Conclusion

In this paper, we examined the characteristics and qualifications of the STEM teacher workforce in high-need schools and how they have evolved over nearly thirty years of national workforce surveys. Though many prior studies have examined teachers in high-need settings, including some that have focused on the STEM teacher workforce, we have little understanding about how the STEM workforce in high-need settings may be changing separate from other segments of the workforce. This scrutiny is especially warranted as demand for STEM content has increased in recent decades while the supply of teacher candidates into the field has simultaneously dwindled. Thus, we hypothesized that the STEM workforce in high-need settings may show hidden signs of deterioration over time that may otherwise be missed when assessing the workforce overall.

Yet, contrary to expectations, we found the STEM teacher workforce has been surprisingly resilient over time, not only maintaining qualifications levels but also modestly improving on several dimensions. Specifically, our results show STEM teachers in high-need settings are now more likely to have a master’s degree than they had in prior decades. Teachers in both math and physical sciences are now more likely to hold any degree in their aligned field than they had in the past, and are more likely to hold any field-aligned qualification in computer science. These gains are observed in high-need schools even as qualification levels in low-need schools stymy or retreat. Consequently, qualifications gaps on multiple dimensions between teachers in high- and low-poverty schools have been modestly shrinking over time. These gains are also evident in the most recent wave of survey collection, which occurred during pandemic recovery as many educators and policy experts have been anxious about widespread teacher shortages (e.g., Garcia, Kraft, and Schwartz 2022).

Not all our findings are optimistic. For example, we find some of the gains in field-aligned teachers over time are driven by those who are certified in-field only, which is a relatively weak qualification standard when considering the importance of subject matter knowledge. Also, the share of qualified teachers in biology in high-need schools have unambiguously declined, and gaps in comparison to low-need schools have thus increased in this subject. Despite these weak spots, the STEM workforce in high-need schools overall has proven to be more resilient to headwinds than we expected.

This optimistic conclusion, however, is not a ringing endorsement of the STEM workforce. Indeed, need-based gaps are evident on every qualification we considered and have persisted for nearly three decades; thus, the modest shrinking we observe on some of these dimensions must be taken in context of a long history of unequal access to qualified teachers. Further, our analysis presented in Figure 3 shows that the majority of teachers leading physical sciences and computer science courses in 2020 in both high- and low-need settings are either unqualified to teach the field or are weakly qualified with field-certification only and no academic degree. Math teachers are modestly better on these metrics, though more than 20% of them in both high- and low-need settings have no aligned qualifications. These facts have discouraging implications for the quality of and access to robust STEM instruction for students across all school settings.

These findings naturally lead to a set of follow-on questions into why the STEM workforce in high-need settings is so unexpectedly resilient. How is the STEM workforce in high-need settings being sustained despite the growing constellation of pressures? Are some other shifts in school staffing practices occurring under the surface? Have loan forgiveness or other recruitment policies for teachers in high-need subjects helped to plug leaks in the teacher pipeline? Alternatively, what roles have independent initiatives specifically aimed to support STEM teacher training programs (e.g., the Robert S. Noyce Program sponsored by the National Science Foundation) played in supporting and enhancing access to STEM instruction across these high-need settings? Though these questions are beyond the scope of the current study, we aim to address some of these in follow-on analyses. New evidence on these issues will help to inform policy and practice responses that can be deployed to support this important, but often overlooked, segment of the teacher workforce.

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Appendix

Teacher sample definition and demographics

Our sample is comprised of teachers from the 1993-94, 1999-2000, 2003-04, 2007-08, and 2011-12 School and Staffing Survey waves and the 2015-16, 2017-18, and 2020-21 National Teacher and Principal Survey waves. We only select those who teach 7th grade or above that teach in a departmentalized instruction format. The variables on course coverage, specifically the different subjects taught during periods throughout the week are only reported for teachers who teach in this format (elementary subject specialists also report this information, but since we are focusing on secondary level teachers, we do not include them in this sample). 83.4% of teachers for grade 7 and above in SASS and NTPS teach in a departmentalized instruction format and have the subject-related information that allow us to conduct our analysis. This amounts to a total of 172,020 observations for all waves.

We use CCD data as the main source for free and reduced-price lunch (FRPL) eligibility. This data can only be merged onto the 1999-00 SASS and posterior teacher sample waves. Prior to 1998 the CCD only reports free lunch student eligibility. For this reason, we use the share of students eligible for FRPL documented in responses to the school questionnaire for SASS data as of the 1993-94 school year. To maximize the number of observations for our analysis we also replace missing student poverty counts (due to not merging with CCD) for 1999-00 SASS to 2017-18 NTPS waves with the FRPL values in the corresponding school questionnaires. Teacher observations that did not merge with the SASS/NTPS school-level data or the CCD school-level data are dropped from the sample since student poverty is a key metric in this analysis. This drop decreases our sample from 172,020 to 166,200 observations. We also merge district level information from the CCD on spending and enrollments onto our analysis file. This brings our sample to the final count of 161,230 observations.

In the section where we focus on teacher qualifications aligned with the specific subjects they teach; we are only able to use survey waves starting in 2003-04 due to the significant alteration of the items associated with the subject/s a teacher is certified to teach. Before this wave, teachers were asked if they were certified in the subject that is their main teaching field (or other fields they teach in following questions), after 2003-04, the question allows respondents to choose from any field from a selection (e.g., Table 3 for SASS 2003-04). Another change in this item is the shift from asking for additional fields of certification a teacher has in the state in which they teach or any other state (17a – 1999-00) to a specific focus on the state in which they teach starting in 2003-04 (30b).

Measuring school poverty

Since student poverty counts vary by year and are constantly increasing, we construct quartiles based on the percentage of FRPL-eligible students in a teacher's school on a year-by-year basis. These quartiles are constructed at the teacher level, meaning that for a given year, the 25% of teachers who teach in the highest need schools are assigned to quartile 4. Throughout the paper, as we reference high-need and low-need schools, FRPL quartile 1 teachers are those in “low-need” school and those in quartile 4 are in “high-need” schools.

Defining STEM teachers and alignment between subjects taught and qualifications

Appendix Table A1 presents the subjects by which we identify STEM teachers (column 2), and our method for aligning subjects across different course assignments, and degree and certification fields. Our STEM and subject-specific field categorization builds from Chart 1 in Ingersoll (2003) and includes fields within Mathematics, Science and Computer Science.

Using 2020-21 NTPS questionnaire as an example, assigned courses are categorized based on the Subject Matter Code from Table 1, degrees based on Table 2, and certifications based on Table 3. STEM classes are those listed under the “Mathematics and Computer Science” and “Natural Sciences” subheadings. Fields under the Social Sciences and Career and Technical Education subheadings are not considered STEM classes or related qualifications in our analysis, even if they deal with STEM-related content. Other survey waves have analogous categorizations in their teacher questionnaires, which we likewise employ for categorizing STEM courses from the course list.

We define STEM teachers as those who report teaching a STEM subject for at least one of their assignments and non-STEM teachers as those with course assignments not shown in Table A1. STEM and non-STEM degrees or certifications are defined analogously. For example, a teacher who teaches biology, may have a degree in mathematics and a certification in chemistry and be considered as a STEM teacher with both a STEM degree and certification. However, this teacher would be considered unqualified when focusing on field-aligned qualifications.

To further align teacher course assignments with their qualifications we consider mathematics, computer science, biology, and physical science teachers individually. A teacher can be considered for more than one of these subjects (if they teach classes in algebra and chemistry for example, they would be categorized as a math and a physical science teacher and have their qualifications treated separately for each case). For this approach, we consider teachers that have their qualifications aligned with the subjects they are teaching if they follow the categorizations in appendix Table 1. For example, a mathematics teacher with an aligned background could have a degree in engineering and a certification in statistics and probability. A physical sciences teacher could teach chemistry, have a degree in physics and a certification in earth sciences and be considered as having an in-field degree and certification.

Table A1. Categorizing STEM teachers' courses, degrees, and certification fields.

Subject fields	(1) Main teaching field	(2) Course assignment fields	(3) Major, Minor or MA fields	(4) Certification Fields
Mathematics	Algebra I, algebra II, algebra III, algebra advanced, algebra elementary, algebra intermediate, basic and general mathematics, Business and applied math, Calculus and pre-calculus, Geometry, Mathematics, Pre-algebra, Statistics and probability, Trigonometry	Algebra I, algebra II, algebra III, algebra advanced, algebra elementary, algebra intermediate, Analytic geometry/math analysis, Basic and general mathematics, Business and applied math, Business math, Calculus, Calculus and pre-calculus, General mathematics, Geometry, Integrated math, Other mathematics, Physics, Pre-algebra, Pre-calculus, Probability/statistics, Trigonometry	Engineering, mathematics, mathematics education, statistics, statistics and probability, physics	Mathematics, Statistics and probability
Science	Biology/life science, Chemistry, earth sciences/geology/space science, Engineering, General and all other science, General science, integrated science, Other natural sciences, Physical science, Physics	Biology/life science, Chemistry, Earth sciences, Engineering, General science, Geology/earth science/space science, Integrated science, Other natural science, Other physical science, Physical science, Physics	Biology/life sciences, chemistry, earth science/geology, engineering, other natural sciences, other physical sciences, physics, science education	Biology/Life sciences, Chemistry, Earth sciences, Other natural sciences, Physical science, Physics, Science, general
Biology	Biology/life science	Biology/life science	Biology/life sciences	Biology/Life sciences
Physical science	Chemistry, earth sciences/geology/space science, Engineering, Physical science, Physics	Chemistry, Earth sciences, Engineering, Geology/earth science/space science, Other physical science, Physical science, Physics	chemistry, earth science/geology, engineering, other physical sciences, physics	Chemistry, Earth sciences, Physical science, Physics
Computer science	Computer science	Computer programming, Computer science, Other computer science	computer science, computer and information science	Computer science

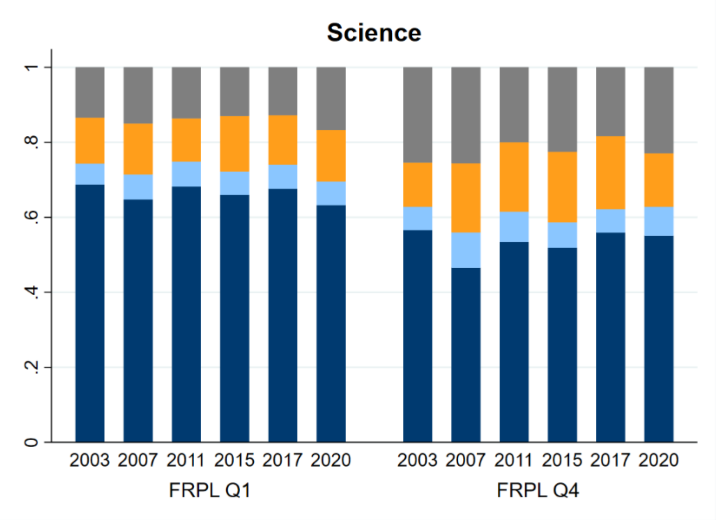
Table A2. Teacher qualification regressions only with indicators for urbanicity and percent of students eligible for free or reduced-price lunch.

	(1) Experienced (>3 years)	(2) Masters	(3) Fully licensed	(4) STEM degree	(5) STEM degree or certification	(6) STEM degree and certification
Urban	-0.00555	0.00426	-0.0228*	0.0367***	0.0114	0.0347**
	(0.00765)	(0.00954)	(0.00861)	(0.00897)	(0.00747)	(0.00995)
Rural	0.00428	-0.0689***	-0.00257	-0.0247***	-0.0258**	-0.0196**
	(0.00510)	(0.00919)	(0.00486)	(0.00651)	(0.00825)	(0.00715)
FRPL Q2	0.00109	-0.0466***	0.00686	-0.0201	-0.0125	-0.0129
	(0.00465)	(0.0128)	(0.00514)	(0.0108)	(0.00821)	(0.0101)
FRPL Q3	-0.0263***	-0.0722***	-0.0211***	-0.0671***	-0.0478***	-0.0620***
	(0.00639)	(0.00789)	(0.00546)	(0.0104)	(0.0122)	(0.0108)
FRPL Q4	-0.0623***	-0.0872***	-0.0471***	-0.110***	-0.0779***	-0.117***
	(0.00815)	(0.0137)	(0.00849)	(0.0151)	(0.00860)	(0.0155)
State FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
N	39,710	39,710	39,710	39,710	39,710	39,710
r2	0.0163	0.111	0.0297	0.0287	0.0192	0.0271

Note: Urban and rural settings have suburban as base category. Teachers in each sample are those who teach at least one STEM subject in grades 7 and above. Standard errors in parentheses. * p < 0.05, ** p < 0.01, *** p < 0.001.

Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

Figure A1. Science teacher



Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.

Table A3. Science teacher subject-aligned qualification regressions

	(1) Science degree or certification	(2) Science degree and certification
Large district	-0.00191	0.00559
	(0.0117)	(0.0164)
High-spending district	-0.0110	0.00929
	(0.0134)	(0.0127)
Urban	0.00257	0.0219
	(0.00912)	(0.0149)
Rural	0.0146	0.0264*
	(0.00892)	(0.0106)
Charter	0.00276	-0.0341
	(0.0167)	(0.0270)
School enrollment (log)	0.0655***	0.0954***
	(0.00830)	(0.0157)
FRPL Q2	-0.00203	-0.000383
	(0.0115)	(0.0150)
FRPL Q3	-0.0228	-0.0401**
	(0.0133)	(0.0143)
FRPL Q4	-0.0519***	-0.0636***
	(0.0123)	(0.0145)
State FE	Yes	Yes
Year FE	Yes	Yes
N	18,620	18,620
r2	0.0395	0.0519

Note: Large districts are those with enrollment over 25,000. High spending districts have per-pupil annual spending over $12,000 using 2020 dollars. Urban and rural settings have suburban as base category. Teachers in sample are those who teach at least one science subject in grades 7 and above. Standard errors in parentheses.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Source: National Center for Education Statistics' Schools and Staffing Survey, National Teacher and Principal Survey and Common Core of Data.