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Summary

Historically, students took Algebra I in high school, but there has been a recent trend toward taking it in middle school (Domina, 2014). In the past two decades the proportion of middle school students taking Algebra I or more-advanced math courses has doubled (Domina, 2014). Success in Algebra I is important because it is a gateway course for advanced math (Star et al., 2015). Students who take and pass Algebra I are more likely to take and pass more-advanced math courses in high school (Snipes & Finkelstein, 2015). This trend has created a need for middle school teachers with more-advanced knowledge of math content, because prior research has suggested that teachers' knowledge of math content plays an important role in student achievement (National Mathematics Advisory Panel, 2008).

The current study examines associations between the qualifications of middle school Algebra I teachers and their students' math achievement. Specifically, the study focuses on teacher certifications to teach math, education background, and performance on certification exams, particularly those associated with math content knowledge.

Missouri Department of Elementary and Secondary Education staff might use the findings from this study when determining certification rules for middle school Algebra I teachers. The findings might also be useful to education leaders in other states as they consider which teacher qualifications are important for student achievement in Algebra I.

Key findings include:

- Teacher performance on math certification exams and years of experience teaching math were the qualifications most strongly associated with middle school students' Algebra I achievement.
- Teacher performance on math certification exams and years of experience teaching math were also strongly associated with Algebra I achievement for students in under-represented subgroups (Black students and Hispanic students) and disadvantaged subgroups (students receiving special education services and students eligible for the national school lunch program).

Contents

Figures

Tables

Why this study?

Success in advanced math courses gives students access to a wider variety of college and career options (National Mathematics Advisory Panel, 2008). Because students who fail Algebra I are less likely to enroll and succeed in advanced math courses (Snipes & Finkelstein, 2015), it is considered a gateway course for advanced math (Star et al., 2015). To increase the opportunity for students to take more-advanced math courses in high school, there has been a trend toward enrolling students in Algebra I in earlier grades. In the past two decades the proportion of middle school students taking Algebra I or more-advanced math courses has doubled (Domina, 2014).

Previous research has suggested that teachers' knowledge of math content may be associated with higher student math achievement. Teachers demonstrate their math content knowledge in a variety of ways, such as certifications to teach math; education background; and performance on direct assessments of math knowledge, including certification exams (Baldi, Warner-Griffith, & Tadler, 2015; Feistritzer, 2011; Goldhaber, Gratz, & Theobald, 2016; National Mathematics Advisory Panel, 2008). Teachers with secondary-level certifications are more likely to have higher performing students than are teachers with primary-level certifications (Darling-Hammond, 2010; Hill, 2007; Neild, Farley-Ripple, & Byrnes, 2009). Likewise, teachers who complete more math courses in college (Goe, 2007; National Mathematics Advisory Panel, 2008), as well as those who score higher on math certification exams (Clotfelter, Ladd, & Vigdor 2006; Goldhaber, 2007; Goldhaber & Hansen, 2010), are more likely to have students who perform better in math. However, little of this research has focused on middle school Algebra I, which is a critical milestone for student success in high school, college, and careers. The current study aims to fill that gap by focusing on the associations between the qualifications of middle school Algebra I teachers and their students' math achievement.

Middle school math certification in Missouri requires knowledge of content through basic algebra and basic geometry, whereas high school certification requires a higher level of math content knowledge for advanced courses (for example, Trigonometry and Calculus; Missouri Department of Elementary and Secondary Education, 2016). Thus, it may be more difficult for teachers certified in middle school math to help students make connections to higher level math and build a foundation for these more-advanced topics (Brown & Bergman, 2013; Howell, Faulkner, Cook, Miller, & Thompson, 2016).

The Regional Educational Laboratory Central's College and Career Readiness Research Alliance focuses on using research and evidence to ensure that students have access to highly qualified teachers, especially in gateway courses such as Algebra I. Through this study the alliance expects to better understand the associations between the qualifications of middle school Algebra I teachers and the success of their students. By examining the qualifications of middle school Algebra I teachers in Missouri, this report can inform alliance efforts to ensure that students have access to teachers who can support their success in Algebra I.

A broader review of the research on this topic as a rationale for this study is in appendix A, and key terms used in the report are defined in box 1.

Box 1. Key terms

Algebra I Missouri Assessment Program End-of-Course exam. The Algebra I Missouri Assessment Program (MAP) End-of-Course (EOC) exam comprises 10 subscales that cover topics considered essential to demonstrating mastery of Algebra I. Topics include the algebraic domains of arithmetic with polynomials and rational expressions; equations and inequalities; structure in expressions; and functions, statistics, and probabilities. The current report defines students' scores on the Algebra I MAP EOC exam as the measure of achievement in Algebra I.

Certification area. Missouri has two categories of secondary-level certification for math teachers: middle school and high school. A middle school math certification certifies teachers to teach math courses through the middle grades, typically up to Algebra I. A high school math certification certifies teachers to teach math courses through grade 12.

Certification exam. Certification exams are direct assessments of teachers' content or pedagogical knowledge. This study examined certification exams in math as well as in other topical areas, focusing on Praxis II academic skills and subject-specific content knowledge exams or the Missouri Educator Gateway Assessments (see box 3 later in the report).

Certification type. Certifications in Missouri are classified as initial, continuous, and lifetime. Initial certification is valid for four years. During this period teachers must teach for all four years, receive two years of mentoring, receive annual evaluations, participate in a Beginning Teacher Assistance program, complete a professional development plan, and participate in 30 contact hours of professional development. After the successful completion of the requirements for initial certification, teachers can obtain continuous certification. Teachers with continuous certification are required to complete a professional development plan and to complete 15 contact hours of professional development annually. Teachers are exempt from the 15 hour annual professional development requirement if they meet two of the following criteria: 10 years of teaching experience, a master's degree, or national board certification. A continuous certificate is valid for 99 years. Before 1988 teachers who met all requirements for continuous certification were issued a lifetime certificate. The lifetime certificate was no longer offered after 1988.

Education specialist degree. An education specialist degree is a terminal qualification that goes beyond the master's degree level. Programs that grant these degrees often focus on topics such as curriculum design, education policy, educator training, school psychology, or educational psychology.

Missouri Assessment Program. The Missouri Assessment Program (MAP) is the battery of state standardized student assessments. The MAP assessments evaluate students' progress toward mastery of curricular content. They consist of grade-level assessments for grades 3–8 and subject-specific, end-of-course assessments for topics commonly taught in high school.

Teacher certification. A teacher certification is the credential that makes an educator eligible to work in a K–12 setting. In Missouri, certification involves attaining at least a bachelor's degree, receiving passing scores on a certification exam, and completing a background check.

What the study examined

The study addressed three research questions:

- What are the qualifications (education background, certification, and scores on certification exams) of middle school Algebra I teachers in Missouri?
- Which teacher qualifications are most strongly associated with student performance on the Algebra I Missouri Assessment Program (MAP) End-of-Course (EOC) exam?
- How do specific teacher qualifications relate to achievement on the Algebra I MAP EOC exam for students in under-represented subgroups (Black students and Hispanic students) and disadvantaged subgroups (students receiving special education services and students eligible for the national school lunch program)? In particular, which qualifications are most strongly associated with success for students in these subgroups?

The Missouri Department of Elementary and Secondary Education provided data on teacher qualifications, including certifications obtained, education background and experience (for example, degree attained and years of teaching experience), and scores on certification exams. The department also provided scores on the Algebra I MAP EOC exam for middle school students who took the exam in the 2015/16 school year (the primary outcome measure for the study) and those students' scores on the MAP math exam in the prior year, as well as basic demographic information about students and teachers. Additional details about the data and analytical methods used in this study are provided in box 2 and appendix B.

Box 2. Data, sample, and methods

Data

The study used the following data at the student, teacher, school, and district level. All data were de-identified.

- Student-level data consisted of demographic characteristics (race/ethnicity, gender, English learner status, special education status, and national school lunch program eligibility); grade level; Algebra I Missouri Assessment Program (MAP) End-of-Course (EOC) exam scores; prior year grade-level MAP math exam scores; and the teachers, schools, and districts associated with the Algebra I MAP EOC exam scores, all provided by the Missouri Department of Elementary and Secondary Education.
- Teacher-level data consisted of years of teaching experience (total years and years teaching math), certification exam scores, certification levels and content areas, and highest degree obtained, all provided by the Missouri Department of Elementary and Secondary Education. Scores for four different certification exams are discussed in this report. These exams are described in box 3.
- School- and district-level data consisted of district and school configuration, aggregate student demographics (for example, percentage of the student body eligible for the national school lunch program, and school Title I status) and locale from the National Center for Education Statistics (U.S. Department of Education, n.d.), and school-level proficiency data for grade 6 and 7 state math exams from the Missouri Department of Elementary and Secondary Education data dashboard.

(continued)

Box 2. Data, sample, and methods *(continued)*

Sample

The analytic sample consisted of all middle school Algebra I teachers in Missouri during the 2015/16 school year: 429 teachers across 276 schools and 204 districts. The schools were located in city (n = 45), rural (n = 107), suburban (n = 70), and town (n = 54) locales. All teachers were linked to middle school students who took Algebra I during the 2015/16 school year. About 77 percent (n = 330) of the teachers were women. The mean years of experience teaching math courses was 12 (with a standard deviation of 7). The report refers to this sample simply as "teachers."

The analytic sample included 11,708 students across grades 7 (n = 712) and 8 (n = 10,996). There were no grade 6 students with available data for the study. All students in the sample took an Algebra I course as well as the Algebra I MAP EOC exam. Female students accounted for 52 percent (n = 6,113) of the sample. Students in under-represented subgroups made up 12 percent of the sample: 7 percent (n = 785) of students were Black, and 5 percent (n = 530) were Hispanic. Students in disadvantaged subgroups made up 27 percent of the sample: 26 percent (n = 3,073) of the students were eligible for the national school lunch program, and 1 percent (n = 120) were receiving special education services. Fewer than 10 students in the sample were classified as English learner students.

Methodology

Descriptive statistics were used to address the first research question on teacher qualifications. The results provide information on the qualifications of middle school Algebra I teachers in Missouri—specifically, percentages, counts, and means related to teacher qualifications; for example, certification level (middle or high school), college major in math or other subject (nonmath), highest degree achieved, and Praxis II/Missouri Educator Gateway Assessments scores.

To address the second and third research questions on which teacher qualifications are most strongly associated with student achievement, a single dataset was created that combined information from the student-, teacher-, school-, and district-level datasets described above. These data were used to estimate a regression model to understand the relationship between teacher qualifications (for example, performance on certification exams) and student achievement on the Algebra I MAP EOC exam. The district- and school-level information, as well as the student prior year grade-level MAP math exam scores, enabled this relationship to be estimated while accounting for differences in prior student achievement and for other differences between the schools and districts in the study. Because the marginal value of an additional year of teaching experience may vary over the course of a teacher's career, the analysis included linear, quadratic, and cubic terms for this variable to capture possible nonlinearities in the relationship between teaching experience and student achievement on the Algebra I exam.

These models used elastic-net regression, an approach to regression modeling that helps distinguish the most important variables from a large set of candidate predictor variables. All variables were converted to the same scale before being used in the regression. Further details on data cleaning, data merging, model selection, and model fitting are in appendix B.

While teacher performance on certification exams, particularly those focused on math content knowledge, was a qualification of interest, teachers could have taken many different certification exams. Teachers in the sample took certification exams related to their math knowledge, other subject areas (for example, English language arts), and pedagogy and professional practices. In Missouri these exams included the Praxis CORE, Praxis II academic skills and subject-specific content knowledge exams, and Missouri Educator Gateway Assessments. A majority of teachers (65 percent) took one or two certification exams. A smaller share took more than three exams (18 percent). While teachers in the study sample took several different exams, this report discusses the results for the four most commonly taken exams (box 3). The demographic characteristics of teachers who took each exam and of their students are presented in table C1 in appendix C. About 17 percent of teachers did not have any available certification exam data.

Box 3. Teacher certification exams

This report discusses the results for the following four most commonly taken teacher certification exams.

Praxis II

Developed by Education Testing Services, the Praxis II battery serves as a series of content-specific educator certification exams. Prior to September 2014, Missouri required that all prospective educators pass Praxis II exams for all topical areas in which they planned to practice. The Praxis II exams assess content knowledge in many different subject areas, while pedagogy-focused exams evaluate knowledge of instructional approaches.

Praxis II Mathematics. This exam assesses the math knowledge of prospective educators who plan to teach grades 9–12. The exam has four content areas: high school math, college math, advanced math, and pedagogy and professional functions. This exam is an older version of the Praxis math assessments currently offered and has not been included in the certification process for more than a decade in Missouri.

Praxis II Mathematics: Content Knowledge. This exam is designed to assess the math knowledge necessary for a beginning teacher of high school math. It is typically taken by those who have completed a bachelor's program in math or math education. It covers number and quantity, algebra, functions, calculus, geometry, probability and statistics, and discrete math.

Praxis II Middle School Mathematics. This exam is designed to certify middle school math teachers. It is typically taken by those who have completed a bachelor's program in math, math education, or education. It covers arithmetic, algebra, geometry, and data.

Missouri Educator Gateway Assessments

The Missouri Educator Gateway Assessments battery includes 55 subtests focused on subject-specific areas for prospective elementary, middle, and high school teachers. Since 2014 all prospective educators in Missouri, including counselors, librarians, principals, and superintendents, have been required to take these exams for all the areas in which they seek certification (for example, middle school or high school math). The exams replaced all Praxis II exams and are aligned with state and national standards.

Missouri Educator Gateway Assessments Middle School Education: Mathematics. This exam consists of four parts: number and operations, algebra and functions, measurement and geometry, and statistics and probabilities. The exam is typically taken by prospective teachers planning to teach math in grades 5–9.

What the study found

This section describes the qualifications of teachers across Missouri who taught Algebra I courses at the middle school level during the 2015/16 school year. It also reports the associations between specific qualifications held by those teachers and the achievement of their students in Algebra I classes, for all students and for students in under-represented and disadvantaged subgroups.

As do many states, Missouri offers Algebra I at the middle school level to students identified as academically prepared for the subject. Schools may also offer Algebra I based on local priorities or curricula. As a result, the analytic sample is not representative of all students, schools, and districts. It is likely that a majority of students in the sample were given the chance to take Algebra I before high school because they had excelled in previous math courses. In addition, because this study is correlational, results cannot be given a causal interpretation.

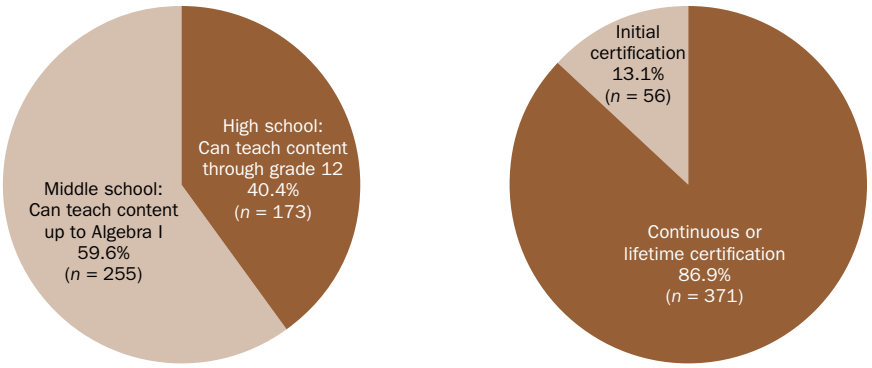
Roughly 40 percent of middle school Algebra I teachers held a certification that allowed them to teach content beyond Algebra I

All teachers in the analytic sample were certified in math, with 60 percent possessing a middle school math certification allowing them to teach math courses up to Algebra I (figure 1). A smaller share of teachers (40 percent) held a high school math certification allowing them to teach math courses through grade 12. High school certifications require more-advanced math content knowledge because teachers need to be prepared to teach courses such as Trigonometry and Calculus. About 87 percent of teachers held either a continuous or a lifetime certification.

About 62 percent of middle school Algebra I teachers held a graduate degree, and about 61 percent majored in math

All teachers in the analytic sample held at least a bachelor's degree, and 62 percent held a graduate degree (figure 2). About 61 percent of teachers majored in math for at least one of their college degrees. Nearly 98 percent of teachers with a graduate degree held a master's

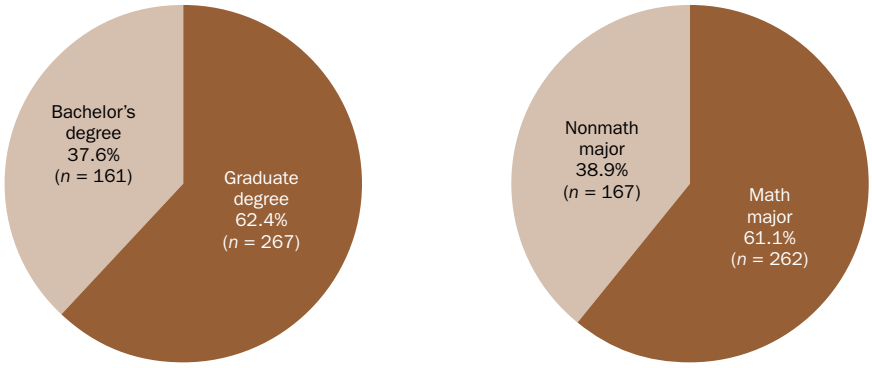
Figure 1. Most middle school Algebra I teachers in Missouri were certified to teach content up to Algebra I, and most held a continuous or lifetime certification



Note: One teacher was omitted from the analysis of the highest grade level for the teacher's math certification and two teachers were omitted from the analysis of certification type because of missing data.

Source: Authors' calculations based on data provided by the Missouri Department of Elementary and Secondary Education.

Figure 2. Most middle school Algebra I teachers in Missouri held a graduate degree, and most majored in math



Note: One teacher was omitted from the analysis of degree type because of missing data.

Source: Authors' calculations based on data provided by the Missouri Department of Elementary and Secondary Education.

degree, while education specialists and doctoral degree holders made up just over 2 percent of the sample. About 67 percent of teachers with a graduate degree had a middle school math certification, while 53 percent of teachers with only a bachelor's degree had a high school math certification.

Teachers with a middle school certification and teachers with a high school certification tended to have different education backgrounds

More teachers in the analytic sample with a high school certification (71 percent) than with a middle school certification (54 percent) majored in math (figure 3). But more teachers with a middle school certification (70 percent) than with a high school certification (50 percent) held a graduate degree.

Over 40 percent of teachers had either 4–6 or 19 or more years of experience teaching math

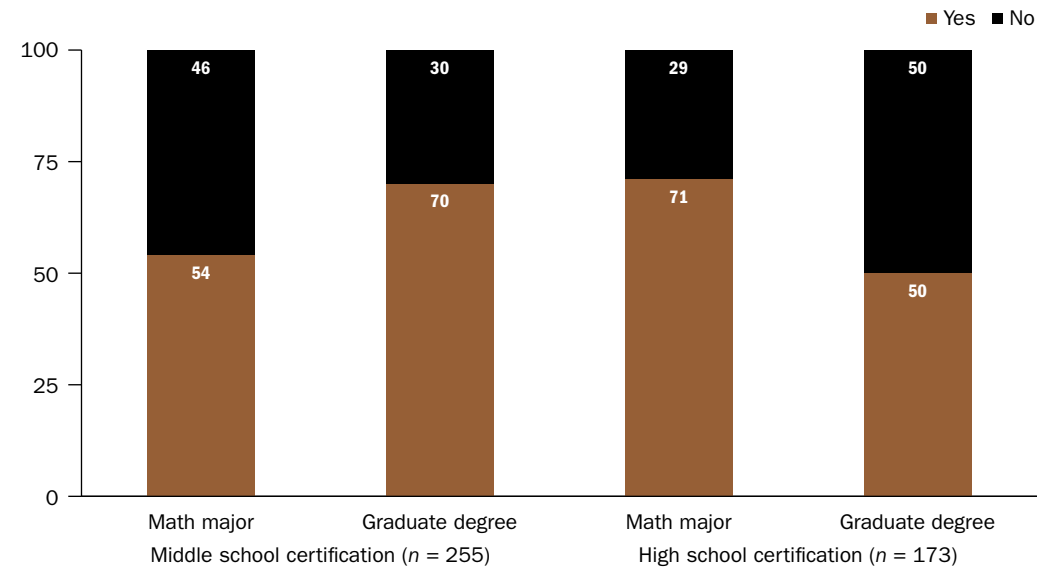
Experience teaching math among the teachers in the analytic sample ranged from 1 to 29 years. The two most frequently observed categories were teachers with 4–6 years of experience teaching math (21 percent) and teachers with 19 or more years of experience teaching math (20 percent; figure 4). Teachers with 1–3 years of experience teaching math (11 percent) and 16–18 years of experience teaching math (9 percent) were the smallest categories.

The most frequently taken exam in the certification process was the Praxis II Middle School Mathematics exam, which most teachers passed

About 78 percent of teachers in the analytic sample took one of the two Praxis II math exams during their certification process (Praxis II Middle School Mathematics or Praxis II Mathematics: Content Knowledge). The remaining teachers either had no data available (12 percent) or took another math exam (10 percent).

About 53 percent of teachers took the Praxis II Middle School Mathematics exam during their certification process. About 96 percent achieved a passing score of 158 or higher on a scale of 100–200 (figure 5). Teachers could take the exam multiple times, and teachers who did not pass could have received a passing score on another math certification exam.

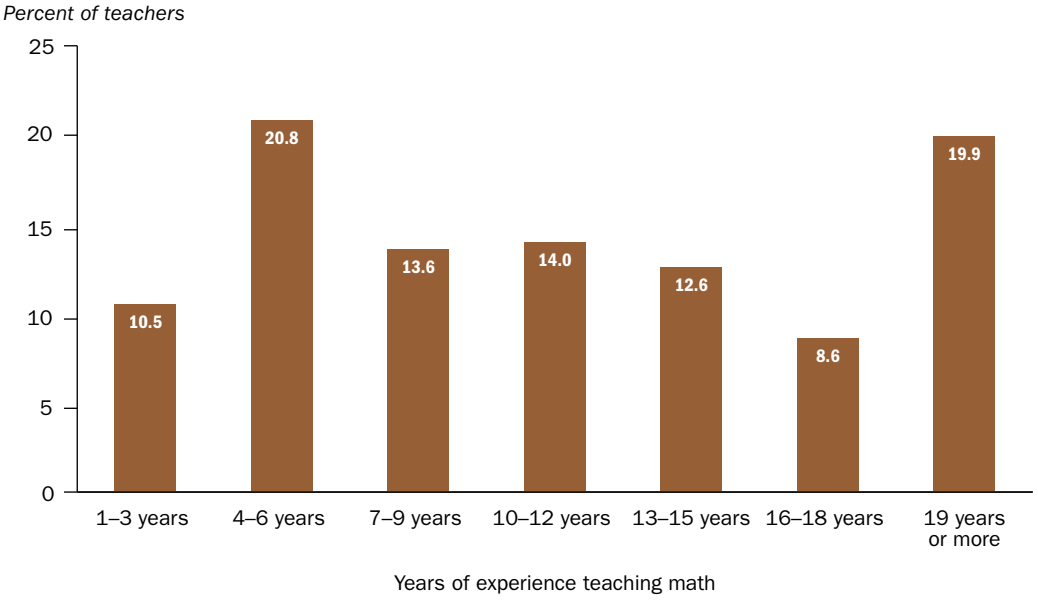
Figure 3. A smaller proportion of middle school Algebra I teachers in Missouri with a middle school certification majored in math, but a larger proportion held a graduate degree compared with teachers with a high school certification



Note: One teacher was omitted from the analysis because of missing data on the highest grade level for the teacher's math certification.

Source: Authors' calculations based on data provided by the Missouri Department of Elementary and Secondary Education.

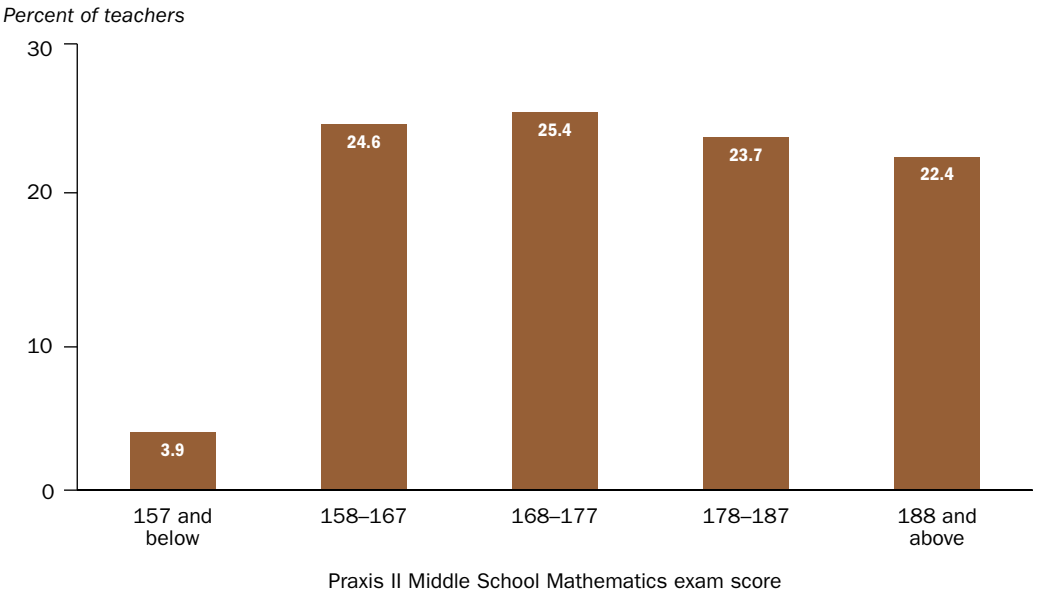
Figure 4. The two largest categories of years of experience teaching math among middle school Algebra I teachers in Missouri were 4–6 years and 19 or more years



Note: *n* = 428. One teacher was omitted from the analysis because of missing data on years of experience teaching math.

Source: Authors' calculations based on data provided by the Missouri Department of Elementary and Secondary Education.

Figure 5. Most teachers who took the Praxis II Middle School Mathematics exam achieved a passing score



Note: *n* = 228. A passing score is 158 or higher on a scale of 100–200.

Source: Authors' calculations based on data provided by the Missouri Department of Elementary and Secondary Education.

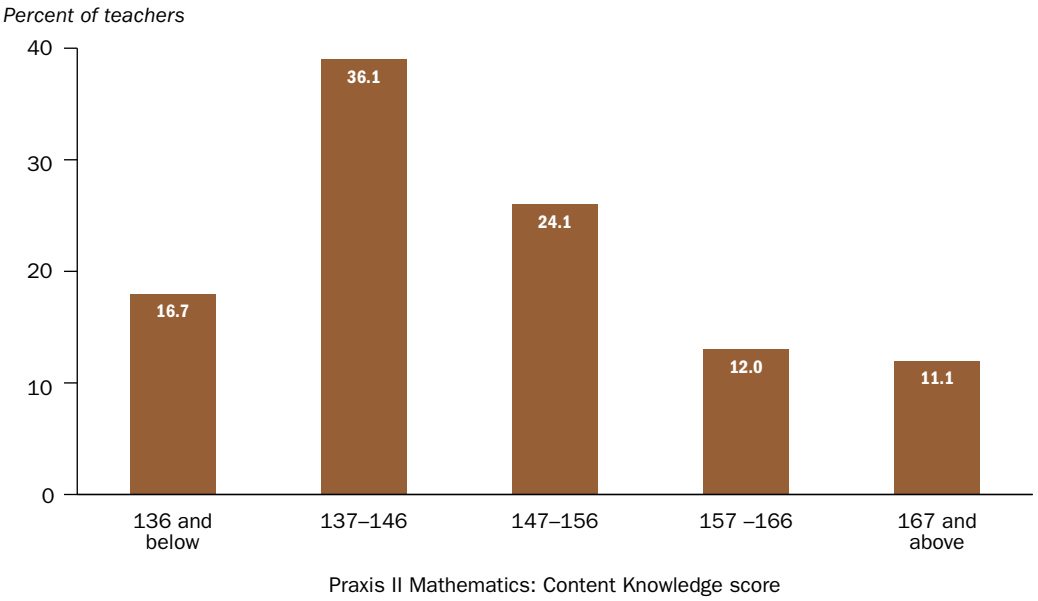
The second most frequently taken exam in the certification process was the Praxis II Mathematics: Content Knowledge exam, which most teachers passed

About 25 percent of teachers took the Praxis II Mathematics: Content Knowledge exam during their certification process. About 83 percent achieved a passing score of 137 or higher on a scale of 100–200 (figure 6). Teachers could take the exam multiple times, and teachers who did not pass could have received a passing score on another math certification exam.

The teacher qualification most strongly associated with Algebra I achievement for all middle school students was performance on math certification exams, followed by years of experience teaching math

Overall, performance on the Praxis II Middle School Mathematics exam was the teacher qualification that had the strongest association with middle school students' Algebra I achievement (see table B2 in appendix B). Years of experience teaching math had the second strongest association, and performance on the Praxis II Mathematics exam had the third strongest association. Because only teachers with 12–28 years of experience teaching math took the Praxis II Mathematics exam, the relationship between taking the exam and Algebra I achievement might appear to be partially driven by math teaching experience. However, the analysis also accounted for math teaching experience, so this alternative explanation is unlikely. While years of experience teaching math was associated with higher student performance, overall years of teaching experience was not (table 1). (See appendix B for additional information on how to interpret regression coefficients.)

Figure 6. Most teachers who took the Praxis II Mathematics: Content Knowledge exam achieved a passing score



Note: *n* = 108. A passing score is 137 or higher on a scale of 100–200.

Source: Authors' calculations based on data provided by the Missouri Department of Elementary and Secondary Education.

Teacher performance on at least one math certification exam was strongly associated with middle school students' Algebra I achievement for all students in under-represented and disadvantaged subgroups

Teacher performance on at least one math certification exam was strongly associated with middle school students' Algebra I achievement for each of the four under-represented and disadvantaged subgroups. In particular, the Praxis II Middle School Mathematics exam was the teacher qualification most strongly associated with Algebra I achievement for students receiving special education services and students eligible for the national school lunch program (see table 1). Performance on the Praxis II Mathematics: Content Knowledge exam (which covers knowledge of high school math) was more strongly associated with Algebra I achievement for Black students than was the Praxis II Middle School Mathematics exam. Performance on the Missouri Educator Gateway Assessments Middle School Education: Mathematics exam was associated with Algebra I achievement for Hispanic students.

Years of experience teaching math was strongly associated with middle school students' Algebra I achievement for Hispanic students and students eligible for the national school lunch program

Years of experience teaching math was strongly associated with Algebra I achievement for Hispanic students and students eligible for the national school lunch program (see table 1). For Hispanic students the association between teaching experience and Algebra I achievement was stronger for teachers with either very little or a lot of experience teaching math. For students eligible for the national school lunch program, each additional year of experience teaching math was associated with an expected gain in Algebra I achievement. For

Table 1. Variables related to middle school teacher qualifications that were strongly associated with Algebra I achievement for all students and for students in under-represented and disadvantaged subgroups in Missouri in 2015/16

Teacher qualification	All students	Students in under represented and disadvantaged subgroups
Certification exam		
Praxis II Middle School Mathematics	Yes	Students receiving special education services, students eligible for the national school lunch program
Praxis II Mathematics	Yes	
Praxis II Mathematics: Content Knowledge		Black students
Missouri Educator Gateway Assessment Middle School Education: Mathematics[a]		Hispanic students
Background		
Years of experience teaching math[b]	Yes	Hispanic students, students eligible for the national school lunch program
Education specialist degree[c]		Black students, Hispanic students
Certification		
Math certification type = continuous		Students eligible for the national school lunch program

Note: Cells with content indicate teacher qualifications with a positive regression coefficient of 0.20 standard deviation or higher for either the linear or the cubic term. Empty cells indicate teacher qualifications with a regression coefficient of less than 0.20 standard deviation. See appendix B for information on how to interpret regression coefficients. The full table of regression coefficients is in table B2 in appendix B. The teacher qualifications listed were the strongest predictors of student Algebra I achievement in addition to other qualifications included in the model.

a. A small proportion of teachers took the Missouri Educator Gateway Assessment Middle School Education: Mathematics exam (n = 12).

b. The regression analysis included both linear and cubic terms for years of experience teaching math to account for the possibility that the strength of the relationship between experience and student achievement varies across teachers' careers. A quadratic term was also included in the analysis, but the coefficient was zero in all models.

c. A small proportion of teachers included in the study sample held an education specialist degree (n = 8).

Source: Authors' analysis of data provided by the Missouri Department of Elementary and Secondary Education.

Hispanic students, however, the magnitude of the expected gain for each additional year of experience was similar across the range of teacher experience.

When taught by a teacher with a continuous certification, middle school students who were eligible for the national school lunch program had higher Algebra I achievement

In general, teacher certification type was not associated with middle school students' Algebra I achievement, with one exception. For students eligible for the national school lunch program there was a positive relationship between Algebra I achievement and instruction by teachers with a continuous certification.

When taught by a teacher with an education specialist degree, both Black and Hispanic middle school students had higher Algebra I achievement

Black and Hispanic middle school students who were taught by a teacher with an education specialist degree tended to have higher Algebra I achievement than students taught

by a teacher without an education specialist degree. However, holding a master's degree or a doctorate was not associated with higher achievement among under-represented or disadvantaged students. This finding should be interpreted with caution since only eight teachers in the study sample held an education specialist degree.

Implications of the study findings

This study found that, after a variety of other student-, teacher-, and school-level characteristics were accounted for, teacher performance on a math certification exam was the teacher qualification most strongly associated with students' Algebra I achievement, as measured by students' Algebra I MAP EOC exam scores. This finding held true for the overall student sample and for students in under-represented subgroups (Black students and Hispanic students) and disadvantaged subgroups (students receiving special education services and students eligible for the national school lunch program). These results suggest that gateway assessments (such as the Praxis II Middle School Mathematics exam) are not merely a compliance feature of the teacher-certification process but that these exams may meaningfully differentiate a teacher's ability to support student success through Algebra I. Policymakers and state and local education administrators may want to consider performance on certification exams when determining minimum qualifications for teaching Algebra I. Furthermore, the findings may discourage the placement of teachers with poor gateway assessment scores in middle school Algebra I classrooms. This implication should be interpreted with caution, however, because teachers could respond to a new policy associated with using exam scores for placement by retaking the exam until they achieve a desirable score, which could reduce the strength of the association.

In addition, after a variety of other student-, teacher-, and school-level characteristics were accounted for, Algebra I students of teachers with more math teaching experience tended to perform better on the Algebra I MAP EOC exam. This result held true for the overall student sample and for Hispanic students and students who were eligible for the national school lunch program. This finding suggests that schools and districts might give preference to teachers with more experience teaching math when selecting Algebra I teachers, especially in schools with higher populations of under-represented or disadvantaged students. Because Algebra I serves as a gateway to more-advanced math topics, schools and districts might consider the benefit of staffing Algebra I classes with more experienced teachers.

Unlike prior research, this study did not find positive links between teacher certification levels and student achievement in math, after student and school characteristics as well as other teacher qualifications were accounted for (see appendix A). In particular, teacher qualifications to teach courses beyond middle school (teachers with a high school math certification) were not associated with students' Algebra I achievement. Because of this misalignment with previous research, further research is needed to determine what other factors associated with levels of teacher certification might be more strongly associated with middle school Algebra I achievement. The study also found that, in addition to other characteristics, the education attainment of teachers was not associated with Algebra I achievement for students overall or for students in under-represented or disadvantaged subgroups. The one exception was for teachers with an education specialist degree, whose Black and Hispanic students tended to perform better on the Algebra I MAP EOC exam. This finding is consistent with prior research, which suggests that education attainment is not associated with student achievement (Clotfelter et al., 2006).

With a larger set of teachers and more information about college course-taking, other qualifications might have been identified that were more strongly associated with student Algebra I achievement than the qualifications examined in the study. Other qualifications that were not included in the study may be more strongly associated with middle school student achievement in Algebra I, such as assessments based on classroom observation. Therefore, education organizations with access to these data might leverage them to examine the associations between additional teacher qualifications and middle school students' Algebra I achievement.

Appendix A. Expanded literature review

Success in advanced math courses gives students access to a wider variety of college and career options (National Mathematics Advisory Panel, 2008). Because students who fail Algebra I are less likely to enroll in and succeed in advanced math courses (Snipes & Finkelstein, 2015), it is considered a gateway course for advanced math (Star et al., 2015). To increase the opportunity for students to take more-advanced math courses in high school, there has been a trend toward enrolling students in Algebra I in earlier grades. In the past two decades the proportion of middle school students taking Algebra I or more-advanced math courses has doubled (Domina, 2014). However, middle schools may have fewer teachers on staff who are well prepared to teach Algebra I.

Previous research has indicated that differences among teachers can explain a substantial amount of the variance in students' gains in math achievement (Nye, Konstantopoulos, & Hedges, 2004). One difference among teachers is their knowledge of the math content they teach. The National Mathematics Advisory Panel (2008) examined empirical research on the association between preK–8 teachers' math knowledge and student outcomes. The review focused on literature that used at least one of three identified measures of teachers' math knowledge: certifications to teach math, education background, and performance on direct assessments of teachers' math knowledge, including certification exams. The National Mathematics Advisory Panel concluded that "teachers must know in detail the math content they are responsible for teaching and its connections to other important math, both prior to and beyond the level they are assigned to teach" (p. 37). The relationships between student achievement and teachers' certification, coursework in math, and performance on math certification exams are described in greater detail below.

Teacher certifications and student outcomes

As discussed in the National Mathematics Advisory Panel (2008) review of research related to preK–8 teachers, certification plays a key role in teachers' knowledge of the math content they teach, which in turn is related to student outcomes. However, there is wide variation in the certification process across the United States, especially for middle school teachers. When a middle school certification is not required, middle school teachers often choose between a primary and high school certification (Baldi et al., 2015).

Researchers across several studies have found a positive association with student achievement for teachers with a high school certification compared with teachers with a primary school certification (Darling-Hammond, 2010; Hill, 2007; Neild et al., 2009). Researchers have suggested that the math content knowledge needed to receive a high school certification gives these teachers an advantage in classroom instruction over peers with a primary school certification (Darling-Hammond, 2010).

However, this positive relationship has not been corroborated by all studies examining certification and student achievement. For example, Kane, Rockoff, and Staiger (2008) found no relationship for New York City public schools between teachers having a primary or high school certification and student achievement in grades 4–8. In addition, Clotfelter et al. (2006) found that more qualified teachers, including those with a high school certification, were more likely to serve higher performing and more affluent students in grade 5. As a result, the authors posited that much of the research reporting a positive relationship

between high school certification and student achievement has been influenced by selection bias because teachers with better qualifications served students who were already higher performing.

Education background and student outcomes

The National Mathematics Advisory Panel (2008) literature review also identified courses taken by math teachers as a measure of content knowledge. Findings suggest that teachers with more math education have a positive influence on student achievement due to their greater content knowledge. Specifically, based on a synthesis of previous research, the National Comprehensive Center for Teacher Quality found that teachers who had taken more math courses positively influenced student achievement in math compared with teachers who had taken fewer math courses (Goe, 2007).

A review of the research, however, reveals a more nuanced relationship between teachers' coursework and student achievement. Some researchers who examined college coursework among math teachers identified a negative relationship with student achievement (Clotfelter et al., 2006), while others found positive associations (Wenglinsky, 2002). Neither of these studies focused primarily on middle school student success in Algebra I, however. Clotfelter et al. (2006) examined the relationship for grade 5 teachers, while Wenglinsky (2002) examined teachers in grades 3–8. Some scholars have suggested that the positive associations between teachers' college coursework and student achievement are driven largely by teachers' desires for the better working conditions and higher salaries that come with serving at more affluent schools (Clotfelter et al., 2006).

These results suggest that the education background of teachers with more math coursework might not have been a benefit to students but rather gave the teachers more options when selecting teaching assignments, including serving at more affluent schools with higher performing students. In that case, these results do not support the claims of a positive association made by Goe (2007) and the National Mathematics Advisory Panel (2008).

Performance on math certification exams and student outcomes

The National Mathematics Advisory Panel (2008) review also indicated that teachers' performance on math certification exams has a positive relationship with their students' achievement. A majority of the research on this topic focused on primary grades rather than middle grades and Algebra I. The studies tend to rely on state-developed teacher subject matter assessments and commercially developed exams such as Praxis II, a licensure exam developed by Educational Testing Service (2017).

In addition, researchers have found modest positive correlations between teachers' scores on math certification exams and their elementary school students' achievement (Clotfelter et al., 2006; Goldhaber, 2007; Goldhaber & Hansen, 2010). However, these studies do not focus on the key period in students' academic careers when they attempt to master the skills needed to be successful in Algebra I, a gateway for later success in high school and college math courses (Star et al., 2015).

To date, the Regional Educational Laboratory (REL) Central is aware of only two studies that have examined the relationship between teachers' scores on math certification exams and student achievement beyond the elementary grades, though neither study focused primarily on success in Algebra I. In both cases the studies found results similar to those of studies conducted at the primary level: higher teacher scores were positively associated with student achievement in secondary grades (Clotfelter et al., 2006; Goldhaber et al., 2016).

More research needed, especially at the middle school level

In sum, more research is needed, especially at the middle school level, on teacher qualifications that have been used as proxies for math content knowledge (certifications, education background, and performance on math certification exams). The literature reviewed here shows mixed findings on the association between teacher qualifications and student achievement in math. Furthermore, little of the research has focused specifically on middle school student success in Algebra I. That issue is of interest to REL Central's College and Career Readiness Research Alliance because it is associated with taking more-advanced math courses in high school and achieving success in college and career later in life.

Appendix B. Data preparation and the regression model

Data preparation

Data from several sources were combined to create the final student-level dataset used in the regression models. Student-, teacher-, school-, and district-level files provided by the Missouri Department of Elementary and Secondary Education were merged with information on school and district locales obtained from the Common Core of Data of the National Center for Education Statistics (U.S. Department of Education, n.d.) (table B1).

The teacher-level data contained variables for a large number of Missouri Educator Gateway Assessments (MEGA) and Praxis II exams, but most exams were taken by just a handful of teachers. The resultant problem of missing data was handled as follows. The valid scores for each MEGA or Praxis II exam were standardized to *z*-scores, and the standard deviation was computed based on all teachers with a valid score on a given exam that appeared in the dataset. Because of the wide variation in the number of Algebra I teachers who had taken each exam, the standard deviations are based on very different sample sizes—from as few as 5 test-takers to more than 200. This difference was unavoidable because of the nature of the dataset. After *z*-scores were computed for each MEGA or Praxis II exam, teachers with missing exam data were given a value of 0 for the exam in question. Finally, an indicator variable was created that equaled 1 if a teacher did not take the exam and 0 otherwise.

This coding scheme ensured that the partial correlation of the valid *z*-scores with student Algebra I Missouri Assessment Program (MAP) End-of-Course (EOC) exam performance was not affected by the missing values. The scheme also enabled looking separately at the predictive power of a teacher having taken a certain exam and the predictive power of relative performance on the exam. Other variables with missing teacher-level data were handled in the same way. After missing teacher-level data were addressed, the teacher-level data were merged with the student-level data.

All student-level predictor variables were recoded into two different variables: a teacher-level mean for the predictor and a student-level predictor that was centered on the teacher mean. This coding scheme allowed separate estimation of, for example, the contextual effect of attending a class with a large number of Hispanic students and the individual-level influence of being Hispanic in a particular class. The percentage of students who scored "below basic" or "basic" on the grade 6 and 7 math exams during the 2014/15 school year were also included in the sample to account for school-level effects.

Model fitting procedures for elastic-net regressions

Due to the large number of correlated predictor variables, it made sense to use a regularized regression modeling approach that would both select variables and estimate regression coefficients for the selected variables. Elastic-net regression was chosen for this purpose. The regression models included all relevant student-, teacher-, school-, and district-level variables in order to best understand the predictive power of teacher qualification variables in addition to other measures included in the models.

For the final student-level dataset, all predictor variables were standardized to *z*-scores before being used in the elastic-net regressions. This standardization occurred at the student level,

Table B1. Teacher- and student-level data used in the analysis of the relationship between the qualifications of middle school Algebra I teachers in Missouri and middle school students' Algebra I achievement

Data type	Description
Teacher-level data	
Teaching certification	Certification grade level (middle or high school) Certification type (initial, continuous, or lifetime)
Education background and demographics	Degrees attained Advanced math courses taken Major/content area Years of teaching experience (total, math-related, within Missouri, and within current district) Gender
Certification exams	Math subtest scores on Missouri Educator Gateway Assessments for teachers certified during 2014 or later (at the elementary, middle, or high school level) Praxis II exam scores for teachers certified before 2014 (at the elementary, middle, or high school level)
Student-level data	
Demographic information	Race/ethnicity, Black or Hispanic[a] English learner status Special education status National school lunch program status Grade Gender
Missouri Assessment Program performance	Proficiency levels on the Algebra I Missouri Assessment Program End-of-Course exam for all students who took Algebra I in the 2015/16 school year Scaled scores on the Algebra I Missouri Assessment Program End-of-Course exam for all students who took Algebra I in the 2015/16 school year Previous year scaled scores on the Missouri Assessment Program math exam (taken by all students in Missouri) from the same cohort of students
Institutional identifiers	Teacher/classroom identifier School identifier Locale (for example, city or rural) School configuration (for example, K–8 or K–12)

a. To protect student anonymity, all other racial/ethnic categories, such as Native American, Alaska Native, Asian/Pacific Islander, Asian/Hawaiian, and multiracial, were collapsed into a single category because of the small sample size of each group.

Source: Authors' construction.

so the mean and standard deviation were computed based on the students in the dataset with nonmissing values for the predictor in question. When fewer than five teachers in the dataset had taken a given MEGA or Praxis II exam, that variable was discarded from the dataset prior to fitting the regressions described below. Finally, dummy variables were created for each of the 429 teachers in the dataset and included in all statistical models. Regularized regression models were fitted using elastic-net regression as implemented in the glmnet package in R (Friedman, Hastie, & Tibshirani, 2010). Elastic-net regression is a type of penalized regression model that combines features of ridge regression and lasso regression. Specifically, elastic-net regression solves the following minimization problem (Zou & Hastie, 2005):

$$\min_{\beta_0,\beta} \frac{1}{N}\sum_{i=1}^{N} l(y_i, \beta_0, + \beta^T x_i) + \lambda[\frac{(1-\alpha)\|\beta\|_2^2}{2} + \alpha\|\beta\|_1]$$

where $l(.)$ stands for the negative of the normal log-likelihood function, y_i is the value of the dependent variable for individual i, x_i is a vector of predictor variable values for

individual *i*'s, $\|.\|_1$ is the l_1 norm of its argument (the sum of the absolute values), $\|.\|_2$ is the l_2 norm of its argument (the sum of the squared values), α is a mixing parameter, and λ is a tuning parameter (see below). Ridge regression models tend to shrink the coefficients of correlated predictors, whereas lasso models tend to pick one of the correlated predictors and set the other coefficients to zero. Elastic-net regression combines features of both through a mixing parameter, α. When $\alpha = 0$, elastic-net regression reduces to ridge regression, and when $\alpha = 1$, elastic-net regression reduces to lasso regression. Given the large number of correlated predictors in the model, and in order to obtain a more tractable solution, the study team wanted a substantial number of parameters to be shrunk to zero, while also retaining some features of ridge regression. After exploring a variety of models with different mixing parameters, the study team found that an $\alpha = 0.75$ mixing parameter tended to give interpretable solutions.

In addition to the elastic-net mixing parameter, the regression fit is determined by the size of a tuning parameter, λ. The appropriate value of λ was chosen using the cv.glmnet function in the glmnet package, with the default values. This function performs 10-fold cross-validation and chooses the λ value that minimizes the mean cross-validated error of the cross-validated predictions.

Benefits of using a penalized regression model

Penalized regression models are an improvement on older methods for variable selection (such as stepwise regression), particularly with a large number of collinear predictors, as in this dataset. Stepwise regression with collinear predictors can lead to very different solutions depending on the order in which variables are entered into the stepwise regression. On the other hand, elastic-net regression yields a unique solution, which is optimal for a given choice of α and the tuning parameter λ.

For those familiar with ordinary least square (OLS) or multilevel regression (MLR) models, it may seem odd to fit a regression model with both teacher-level predictors and teacher-level dummy variables (often called teacher-level fixed effects in an OLS or MLR context). In OLS or MLR models the teacher-level fixed effects seemingly model away all teacher-level variance, leaving no additional variance to be predicted by other teacher-level variables. However, elastic-net parameter estimates do not behave in the same way. Tibshirani (1996) shows that the lasso regression estimate is equivalent to the Bayesian posterior mode under independent Laplace priors for the β coefficients. Similarly, ridge regression estimates are Bayesian posterior modes under normal priors (Zou & Hastie, 2005). Finally, as noted in Greenland (2000) and elsewhere, MLR models can be interpreted as Bayesian solutions to the regression problem with normal priors on the random effects and flat (improper) priors on the fixed effects. Encompassing all these perspectives, the elastic-net solution that includes teacher-level predictors and teacher dummy variables is similar to an MLR solution with teachers as a "level" in the model and teacher-level predictors. The difference is that the elastic-net solution puts a mixture of normal and Laplace priors on all of the parameters, and the MLR solution puts a flat prior on the fixed effects and a normal prior on the random effects.

The complete results from the elastic-net regressions are reported in table B2. Predictors that were set to 0 by the estimation algorithm for all models are reported separately in table B3. Separate models were run for the overall student population and for each student subgroup of interest.

Table B2. Complete elastic-net regression coefficients predicting middle school students' Algebra I achievement based on teacher qualifications in Missouri

Variable	Overall	Under represented subgroup		Disadvantaged subgroup	
		Black	Hispanic	Special education	National school lunch program
Optimal λ chosen by cross-validation	0.04	0.57	0.53	2.07	0.17
Teacher qualifications					
Certification exam					
Praxis II Middle School Mathematics	0.70	0.00	0.00	1.72	0.84
Praxis II Mathematics	0.27	0.00	0.00	0.00	0.00
Missouri Educator Gateway Assessments Professional Knowledge: Middle School	0.19	0.00	0.01	na	0.13
Praxis Core Battery Professional Knowledge	0.12	0.00	0.00	0.00	0.00
Praxis II Principles of Learning and Teaching: Grades 5–9	0.13	0.00	0.00	0.00	0.00
Missouri Educator Gateway Assessments Middle School Education: Mathematics	0.05	0.00	0.23	0.00	0.00
Praxis II Education of Exceptional Students: Mild to Moderate Disabilities	0.04	0.00	0.00	na	0.00
Praxis II Education of Exceptional Students	0.03	0.00	0.00	na	0.01
Praxis II Business Education (101)†	0.01	0.00	na	na	0.00
Missouri Educator Gateway Assessments Mathematics	0.00	0.00	0.00	–0.46	0.00
Praxis II Principles of Learning and Teaching: Grades 7–12	0.00	–0.15	0.04	na	0.00
Praxis II School Leaders Licensure (6011)†	0.00	0.00	–0.07	na	–0.05
Praxis II Mathematics: Content Knowledge	0.00	0.24	0.00	0.00	0.00
Praxis II Social Studies: Content Knowledge (81)†	0.00	–0.07	0.00	0.00	0.00
Praxis II Physical Education: Content Knowledge	0.00	0.00	0.00	0.00	–0.13
Praxis II Physical Education	–0.04	0.00	0.03	na	0.00
Missouri Educator Gateway Assessments Physical Education	–0.08	0.00	0.13	na	0.00
Praxis II Business Education (100)†	–0.37	0.00	0.00	0.00	–0.11
Did not take Praxis II Elementary Education (10)†	0.17	0.00	0.00	0.00	0.00
Did not take Missouri Educator Gateway Assessments Middle School Education: Mathematics	0.16	0.00	0.00	0.00	0.23
Did not take Praxis II Mathematics	0.11	0.00	0.00	0.00	0.00
Did not take Praxis II Business Education (101)†	0.08	0.00	na	na	0.00
Did not take Missouri Educator Gateway Assessments Mathematics	0.00	0.53	1.36	–0.37	0.00
Did not take Praxis II Elementary Education: Curriculum, Instruction, and Assessment (11)†	0.00	0.47	0.00	0.00	0.00
Did not take Praxis II Middle School English Language Arts: Content Knowledge (49)†	0.00	0.00	0.37	0.00	0.00
Did not take Praxis Core Battery Professional Knowledge	0.00	0.00	0.17	0.00	0.00
Did not take Praxis II Mathematics: Content Knowledge	0.00	0.00	–0.39	0.00	0.00
Did not take Praxis II Physical Education: Content Knowledge	0.00	0.00	0.10	0.00	0.10
Did not take Praxis II Physical Education	0.00	0.00	–0.01	na	–0.02
Did not take Praxis II Middle School Social Studies: Content Knowledge (89)†	–0.01	0.00	–0.11	0.00	0.00
Did not take Missouri Educator Gateway Assessments Physical Education	–0.03	0.00	–0.27	na	–0.01

(continued)

Table B2. Complete elastic-net regression coefficients predicting middle school students' Algebra I achievement based on teacher qualifications in Missouri *(continued)*

Variable	Overall	Under-represented subgroup		Disadvantaged subgroup	
		Black	Hispanic	Special education	National school lunch program
Did not take Praxis II Principles of Learning and Teaching: Grades 5–9	–0.23	0.00	0.00	0.00	–0.07
Did not take Praxis II School Leaders Licensure (6011)†	–0.30	0.00	0.00	na	0.00
Did not take Praxis II Health Education	–0.34	0.00	–0.02	0.00	0.00
Background					
Years of experience teaching math (linear term)	0.59	0.00	0.00	0.00	0.44
Years of experience teaching math (cubic term)	0.03	0.00	0.53	0.00	0.09
Education specialist degree	0.04	0.54	0.44	0.00	0.15
Teacher missing data for math experience variable	0.04	0.00	na	na	0.03
Highest degree = bachelor's degree	0.00	0.00	–0.14	0.00	0.00
Certification					
Has social studies certification	0.07	0.00	0.00	0.00	0.00
Has math certification	0.05	na	0.00	na	0.01
Math certification type = continuous	0.01	0.00	0.00	0.00	0.51
Math certification type = lifetime	0.00	–0.60	0.00	–0.66	0.00
Math certification source = college math major	0.00	0.00	0.00	0.00	0.02
Teacher missing data on highest grade certified to teach	–0.10	na	0.00	na	–0.12
Math certification source = college math coursework	–0.26	0.00	–0.39	0.00	0.00
Math certification type = initial	–0.41	0.00	0.00	0.00	0.00
Teacher demographics					
Female	0.69	0.00	0.00	0.00	0.51
Teacher missing data on gender	0.17	na	na	0.00	0.20
Student characteristics (centered at teacher mean)					
Pretest	7.18	6.66	6.84	6.94	7.31
Grade 7	0.48	0.00	0.00	0.00	0.21
Asian/Pacific Islander	0.38	na	na	1.74	0.15
Female	0.24	0.44	0.13	0.05	0.36
Limited English proficient more than 1 year	0.09	–0.01	0.00	0.52	0.00
Hawaiian/Pacific Islander	0.05	na	na	0.00	0.10
Hispanic	0.00	na	na	0.00	0.25
At school less than 1 year	0.00	–0.11	0.00	0.00	–0.31
White	0.00	na	na	–0.65	0.00
American Indian or Alaska native	–0.05	na	na	0.00	0.00
Multiracial	–0.15	na	na	0.00	0.00
In district less than 1 year	–0.19	–0.71	0.00	–0.72	–0.15
Special education designation	–0.20	–0.28	0.00	na	–0.14
Black	–0.51	na	na	0.00	–0.48
Eligible for the national school lunch program	–0.65	0.00	0.00	0.00	na
Student characteristics (aggregated to teacher level)					
Grade-level pretest mean	7.54	10.64	8.40	10.22	8.20
Percent of students identified as Asian/Pacific Islander	0.52	0.05	0.24	0.00	1.12
Percent of students identified as multiracial	0.12	0.00	0.86	0.00	0.09

(continued)

Table B2. Complete elastic-net regression coefficients predicting middle school students' Algebra I achievement based on teacher qualifications in Missouri *(continued)*

Variable	Overall	Under-represented subgroup		Disadvantaged subgroup	
		Black	Hispanic	Special education	National school lunch program
Percent of students identified as limited English proficient	0.03	0.12	0.00	–0.42	0.00
Percent of students identified as Black	0.00	0.00	–0.92	0.00	0.00
Percent of students identified as Hawaiian/Pacific Islander	0.00	0.24	0.00	0.00	0.00
Percent of students with special education designation	0.00	0.00	0.00	0.00	–0.13
Percent of students who are female	–0.01	0.00	0.00	0.00	–0.28
Percent of students identified as American Indian or Alaska native	–0.09	0.00	0.00	0.00	–0.38
Percent of students at school less than 1 year	–0.13	–0.31	0.00	–0.30	–0.31
Percent of students eligible for the national school lunch program	–1.01	0.00	0.00	–1.23	–1.05
School and district characteristics					
Number of students in school eligible for the national school lunch program	0.67	0.10	0.00	0.00	0.31
School is missing information on student proficiency	–0.18	0.00	–0.08	0.00	0.00
School is in small city locale	0.07	0.00	0.03	na	0.28
School is in distant rural locale	0.00	–0.04	–0.02	0.00	0.00
Number of students in school eligible for the national school lunch program	0.00	–1.21	0.00	0.00	–0.20
School is in large suburb locale	0.01	0.00	0.00	0.86	0.74
School is in midsize city locale	0.00	–0.55	0.00	0.00	0.00
School student/teacher ratio	0.00	0.00	0.00	1.37	0.00
School is in suburb locale	0.00	0.00	0.00	1.05	0.33
School is in remote rural locale	–0.02	0.00	0.00	0.00	0.00
School is in town locale	–0.19	0.00	0.00	0.00	0.00
School is in distant town locale	–0.45	0.00	0.00	0.00	0.00
District is in large city locale	0.10	0.00	0.00	0.00	0.00
District is in suburb locale	0.04	0.00	0.00	0.00	0.00
District is in large suburb locale	0.02	0.00	1.43	0.00	0.00
District is in city locale	0.00	0.00	0.00	–0.81	0.00
District is in fringe town locale	0.00	0.03	0.00	0.00	0.00
District is in rural locale	0.00	0.00	0.00	0.84	0.00
District is in small city locale	0.00	0.00	0.61	na	0.00
District is in midsize city locale	–0.24	0.00	–0.92	0.00	–0.59
District is in distant town locale	–0.38	0.00	0.00	0.00	–0.50
District is in town locale	–0.61	0.00	–0.04	–0.04	0.00
District is in distant rural locale	–0.65	–0.16	–0.09	0.00	–0.35

† Numbers in parentheses are Missouri Department of Elementary and Secondary Education test codes, which can be used to distinguish certification exams that share the same name (generally newer and older versions of an exam or paper and computer-based versions of the same exam).

na indicates that the variable was constant for the particular subgroup in question. For instance, no one who taught a special education student took the Praxis II Business Education exam, every teacher who taught Black students had a math certification, and no special education students took Algebra I in schools located in small cities.

Note: Elastic-net regressions used a 0.75 mixing parameter. All predictor variables were standardized to *z*-scores before running the elastic-net model-fitting procedure. All models include dummy variables (fixed effects) for teachers. Only variables with a nonzero coefficient in at least one model are reported in this table. Variables with zero coefficients for all models are reported in table B3.

Source: Authors' analyses of data provided by the Missouri Department of Elementary and Secondary Education. Data on locales are from the National Center for Education Statistics (U.S. Department of Education, n.d.).

Table B3. Additional variables included in elastic-net regressions predicting middle school students' Algebra I achievement based on teacher qualifications in Missouri (zero coefficient estimates for all models)

Data type	Description
Teacher-level variables	
Teaching certification	• Business education • Early childhood education • Elementary education • General sciences • Gifted students education • Language arts • Physical education • Principal • Social sciences • Highest grade certified to teach • Highest grade certified to teach math
Education background	• Highest degree is doctorate • Highest degree is master's • Total years of teaching experience • Total years of teaching experience (quadratic term) • Total years of teaching experience (cubic term) • Total years of math teaching experience (quadratic term)
Certification exams	• Praxis II Elementary Education (10)† • Praxis II School Leaders (1011)† • Praxis II Elementary Education: Curriculum, Instruction, and Assessment (11)† • Praxis II Middle School Science: Content Knowledge • Praxis II Middle School English Language Arts: Content Knowledge (49)† • Praxis II Health Education • Praxis II Middle School Social Studies: Content Knowledge (89)† • Did not take Missouri Educator Gateway Assessments Professional Knowledge: Middle School • Did not take Praxis II Business Education (100)† • Did not take Praxis II School Leaders (1011)† • Did not take Praxis II Education of Exceptional Students • Did not take Praxis II Middle School Science: Content Knowledge • Did not take Praxis II Principles of Learning and Teaching: Grades 7–12 • Did not take Praxis II Education of Exceptional Students: Mild to Moderate Disabilities • Did not take Praxis II Middle School Mathematics • Did not take Praxis II Social Studies: Content Knowledge (81)†
Aggregated student-level variables	• Percent of students in grade 6 or 7 • Percent of students in district less than 1 year • Percent of students identified as Hispanic • Percent of students identified as White
Student-level data	
Demographic information	None
Missouri Assessment Program pretest	None
School-level data	
Performance information	Percent of grade 6 and 7 students below proficient in math on state test
Demographic information	Number of students in school Number of teachers in school

(continued)

Table B3. Additional variables included in elastic-net regressions predicting middle school students' Algebra I achievement based on teacher qualifications in Missouri (zero coefficient estimates for all models) *(continued)*

Data type	Description
Locale information	School is in city locale
	School is in fringe rural locale
	School is in fringe town locale
	School is in large city locale
	School is in remote town locale
	School is in rural locale
	School is in small suburb locale
District-level data	
Demographic information	District is K–8 district
Locale information	District is in fringe rural locale
	District is in remote rural locale
	District is in remote town locale
	District is in small suburb locale

† Numbers in parentheses are Missouri Department of Elementary and Secondary Education test codes, which can be used to distinguish certification exams that share the same name (generally newer and older versions of an exam or paper and computer-based versions of the same exam).

Source: Authors' construction.

Interpreting regression coefficients estimated by elastic-net regression

Regression modeling is a technique for predicting the value of some variable of interest (generally referred to as the dependent variable) from a set of predictor variables (generally referred to as independent variables). In this study the dependent variable is a student's score on the Algebra I MAP EOC exam, while teacher qualifications are the main independent variables of interest.

A regression coefficient for a given predictor variable indicates the average change in the dependent variable associated with a unit change in the predictor variable if all other variables in the model are set to a fixed value. The size of a regression coefficient is influenced by the scale of the variable with which it is associated, which is related to how spread out measurements are for that variable or its standard deviation. All other things equal, a predictor variable with a larger standard deviation will have a smaller estimated regression coefficient.

To address the research questions, the study team needed to compare the size of different regression coefficients to understand which variables are the strongest predictors of student differences on the Algebra I MAP EOC exam. Therefore, it was necessary to rescale the predictor variables to ensure that they had the same standard deviation before comparing regression coefficients. All predictor variables were rescaled to have a standard deviation of 1.

For example, in table B2 the regression coefficient associated with Praxis II Middle School Mathematics is 0.70, and the regression coefficient associated with years of experience teaching math is 0.59. This pattern of findings supports the conclusion that, for the general student population, performance on a math certification exam and years of experience teaching math are the strongest teacher qualification predictors of students' Algebra I MAP EOC exam scores.

This report seeks to make relevant and actionable suggestions related to identifying teachers who are well prepared to instruct Algebra I courses at the middle school level. As a result, the report focuses on positive predictors of Algebra I student achievement with coefficients that were larger than 0.20. This decision was made for three reasons. First, positive associations are more relevant and interpretable to the Regional Educational Laboratory Central's College and Career Readiness Research Alliance members as they make strategic staffing decisions based on teacher qualifications that are associated with middle school student success in Algebra I. As noted, Algebra I marks a critical milestone for student success in math, which can lead to greater success in high school, college, and career. Ensuring college and career success is the primary objective of the alliance. Second, negative coefficients associated with teacher qualifications were generally smaller in absolute value and less policy relevant than were positive coefficients, and the alliance has not expressed a need to identify teachers who might be poorly prepared to instruct Algebra I middle school students.

Limitations of the model

A note of caution is in order regarding how to interpret the standardized regression coefficients reported in this study. These coefficients are interpretable as the expected change in the dependent variables given a standard deviation change in the independent variable. The report refers to variables with larger coefficients as stronger predictors of Algebra I MAP EOC exam scores. However, a strong predictor is not necessarily a more practically relevant predictor. For instance, the standard deviation of the years of experience teaching math variable is about 7, which implies that it would take seven years for a teacher to move one standard deviation on this variable. The standard deviation of the continuous certification variable is about 0.4. Since teachers can move from initial certification to continuous certification after only four years, it may be easier to achieve a standard deviation change in the continuous certification variable than in the years of experience teaching math variable.

However, the above analysis may also be misleading. Many teachers with an initial certification will leave the profession before achieving a continuous certification. Similarly, not all teachers with five years of experience will remain teachers until they have 20 years of experience. These compositional changes in the types of teachers who achieve a certain numerical level for a given variable may drive results more than actual changes in individual teachers. Ultimately, estimated coefficients must be interpreted as predictions for the population as currently constituted. They cannot be interpreted as predicted causal effects should one of the variables be manipulated in order to change the constitution of the current population of teachers.

Appendix C. Demographic characteristics of teachers and students, by teacher certification exam

The demographic characteristics of teachers who took each type of exam and their students are presented in table C1.

Table C1. Characteristics of middle school Algebra I teachers and their students in Missouri, by certification exam taken

		Teachers					Students (percent of total)				
Certification exam	Number of observations	Average years of experience	Percent eligible to teach up to grade 12	Percent with graduate education degree	Percent with specialist education degree	Average number of students taught	Black	Hispanic	White	Special education	National school lunch program
Praxis II Middle School Mathematics	228	M = 9.1 SD = 6.2	24.6	55.7	2.6	28.9	7.5	4.6	80.1	0.92	29.9
Praxis II Mathematics	22	M = 18.7 SD = 5.0	100.0	68.2	0.0	22.2	6.1	1.8	86.3	0.44	28.9
Praxis II Mathematics: Content Knowledge	108	M = 7.8 SD = 5.5	86.1	48.2	0.9	20.5	6.0	3.5	84.5	0.62	32.6
Missouri Educator Gateway Assessments Middle School Education: Mathematics	12	M = 4.8 SD = 5.2	66.7	41.7	0.0	22.4	1.9	6.3	84.5	0.17	35.5

M is mean. *SD* is standard deviation.

Note: Because some teachers took more than one certification exam, an individual teacher may contribute data to multiple rows. Specifically, 117 of the 429 teachers took two or three of the exams listed in the table.

Source: Authors' compilation based on analysis described in appendix B.

Note

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References

Baldi, S., Warner-Griffin, C., & Tadler, C. (2015). *Education and certification qualifications of public middle grades teachers of selected subjects: Evidence from the 2011–12 Schools and Staffing Survey* (NCES No. 2015–815). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics. Retrieved May 18, 2018, from https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2015815.

Brown, S., & Bergman, J. (2013). Preservice teachers' understanding of variable. *Investigations in Mathematics Learning, 6*(1), 1–17. https://eric.ed.gov/?id=EJ1052931.

Clotfelter, C. T., Ladd, H. F., & Vigdor, J. L. (2006). Teacher-student matching and the assessment of teacher effectiveness. *Journal of Human Resources, 41*(4), 778–820. https://eric.ed.gov/?id=EJ750956.

Darling-Hammond, L. (2010). Teacher education and the American future. *Journal of Teacher Education, 61*(1–2), 35–47. https://eric.ed.gov/?id=EJ879281.

Domina, T. (2014). The link between middle school mathematics course placement and achievement. *Child Development, 85*(5), 1948–1964.

Educational Testing Service. (2017). *Core academic skills for educators: Mathematics* (*Praxis* Study Companion). Princeton, NJ: Author. Retrieved May 18, 2018, from https://www.ets.org/s/praxis/pdf/5732.pdf.

Feistritzer, C. E. (2011). *Profile of teachers in the U.S. 2011*. Washington, DC: National Center for Education Information. Retrieved May 18, 2018, from https://www.edweek.org/media/pot2011final-blog.pdf.

Friedman, J., Hastie, T., & Tibshirani, R. (2010). Regularization paths for generalized linear models via coordinate descent. *Journal of Statistical Software, 33*(1), 1–22. Retrieved May 18, 2018 from, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2929880/.

Goe, L. (2007). *The link between teacher quality and student outcomes: A research synthesis*. Washington, DC: National Comprehensive Center for Teacher Quality. Retrieved May 18, 2018, from https://eric.ed.gov/?id=ED521219.

Goldhaber, D. (2007). Everyone's doing it, but what does teacher testing tell us about teacher effectiveness? *Journal of Human Resources, 42*(4), 765–794.

Goldhaber, D., Gratz, T., & Theobald, R. (2016). *What's in a teacher test? Assessing the relationship between teacher licensure test scores and student STEM achievement and course-taking* (CALDER Working Paper No. 158). Washington, DC: American Institute for Research, National Center for Analysis of Longitudinal Data in Education Research. Retrieved May 18, 2018 from, http://www.caldercenter.org/publications/what%E2%80%99s-teacher-test-assessing-relationship-between-teacher-licensure-test-scores-and.

Goldhaber, D., & Hansen, M. (2010). Race, gender, and teacher testing: How informative a tool is teacher licensure testing? *American Educational Research Journal, 47*(1), 218–251. https://eric.ed.gov/?id=EJ883788.

Greenland, S. (2000). Principles of multilevel modelling. *International Journal of Epidemiology, 29*(1), 158–167.

Hill, H. C. (2007). Mathematical knowledge of middle school teachers: Implications for the No Child Left Behind policy initiative. *Educational Evaluation and Policy Analysis, 29*(2), 95–114. https://eric.ed.gov/?id=EJ782317.

Howell, P. B., Faulkner, S. A., Cook, C. M., Miller, N. C., & Thompson, N. L. (2016). Specialized preparation for middle level teachers: A national review of teacher preparation programs. *RMLE Online, 39*(1), 1–12. https://eric.ed.gov/?id=EJ1132959.

Kane, T. J., Rockoff, J. E., & Staiger, D. O. (2008). What does certification tell us about teacher effectiveness? Evidence from New York City. *Economics of Education Review, 27*(6), 615–631.

Missouri Department of Elementary and Secondary Education. (2016). *Core Data & Missouri Student Information System: Reference manual: 2016–2017.* Jefferson City, MO: Author. Retrieved May 18, 2018, from https://dese.mo.gov/data-system-management/manuals.

National Mathematics Advisory Panel. (2008). *Foundations for success: The final report of the National Mathematics Advisory Panel.* Washington, DC: U.S. Department of Education. Retrieved May 18, 2018, from https://www2.ed.gov/about/bdscomm/list/mathpanel/report/final-report.pdf.

Neild, R. C., Farley-Ripple, E. N., & Byrnes, V. (2009). The effect of teacher certification on middle grades achievement in an urban district. *Educational Policy, 23*(5), 732–760. https://eric.ed.gov/?id=EJ852121.

Nye, B., Konstantopoulos, S., & Hedges, L. V. (2004). How large are teacher effects? *Educational Evaluation and Policy Analysis, 26*(3), 237–257.

Snipes, J., & Finkelstein, N. (2015). *Opening a gateway to college access: Algebra at the right time* (Research Brief). San Francisco, CA: Regional Educational Laboratory West at WestEd. Retrieved May 18, 2018, from https://www.wested.org/resources/algebra-at-the-right-time/.

Star, J. R., Foegen, A., Larson, M. R., McCallum, W. G., Porath, J., & Zbiek, R. M. (2015). *Teaching strategies for improving algebra knowledge in middle and high school students* (NCEE No. 2015–4010). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance. Retrieved May 18, 2018, from https://ies.ed.gov/ncee/wwc/PracticeGuide/20.

Tibshirani, R. (1996). Regression shrinkage and selection via the lasso. *Journal of the Royal Statistical Society. Series B, 58*(1): 267–288.

U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics. (n.d.). *Common core of data*. Retrieved May 18, 2018, from https://nces.ed.gov/ccd/.

Wenglinsky, H. (2002). How schools matter: The link between teacher classroom practices and student academic performance. *Education Policy Analysis Archives, 10*(12), 1–30.

Zou, H., & Hastie, T. (2005). Regularization and variable selection via the elastic net. *Journal of the Royal Statistical Society, Series B, 67*(2), 301–320.

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