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Alternative Routes: Alternative Teacher Certifications and STEM Classroom Environments

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Abstract: We use data from the High School Longitudinal Study of 2009 to examine the relationship between alternative teacher certification and student perceptions of the classroom learning environment. Our results show that students from marginalized communities are more likely to be taught by alternatively certified math and science teachers. Using student and subject fixed effects models, we find that, on average, there is no significant difference in classroom learning environments between alternatively certified teachers and traditionally certified teachers. Alternatively certified math teachers are less effective in enhancing some aspects of positive classroom learning environments, yet this evidence is limited. Our findings contribute to the ongoing conversation on teacher certification pathways and teaching effectiveness by providing empirical evidence on how students differentially perceive the classroom learning environment depending on the type of certification their mathematics and science teachers hold.

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Rutas alternativas: Certificaciones docentes alternativas y entornos de aula en STEM
Resumen: Utilizamos datos del *High School Longitudinal Study of 2009* para examinar la relación entre la certificación docente alternativa y las percepciones del estudiantado sobre el entorno de aprendizaje en el aula. Nuestros resultados muestran que el estudiantado de comunidades marginadas tiene mayor probabilidad de ser enseñado por docentes de matemáticas y ciencias con certificación alternativa. Mediante modelos de efectos fijos por estudiante y por asignatura, encontramos que, en promedio, no existen diferencias significativas en los entornos de aprendizaje en el aula entre docentes con certificación alternativa y docentes con certificación tradicional. Los docentes de matemáticas con certificación alternativa son menos efectivos en mejorar algunos aspectos de entornos de aprendizaje positivos en el aula; sin embargo, esta evidencia es limitada. Nuestros hallazgos contribuyen al debate en curso sobre las vías de certificación docente y la efectividad de la enseñanza al proporcionar evidencia empírica sobre cómo el estudiantado percibe de manera diferenciada el entorno de aprendizaje en función del tipo de certificación de sus docentes de matemáticas y ciencias.
Palabras-clave: formación docente; certificaciones docentes alternativas; educación STEM; entornos de aprendizaje en el aula

Caminhos alternativos: Certificações docentes alternativas e ambientes de sala de aula em STEM
Resumo: Utilizamos dados do *High School Longitudinal Study of 2009* para examinar a relação entre certificação docente alternativa e as percepções dos estudantes sobre o ambiente de aprendizagem em sala de aula. Nossos resultados mostram que estudantes de comunidades marginalizadas têm maior probabilidade de serem ensinados por professores de matemática e ciências com certificação alternativa. Utilizando modelos de efeitos fixos por estudante e por disciplina, verificamos que, em média, não há diferenças significativas nos ambientes de aprendizagem em sala de aula entre professores com certificação alternativa e professores com certificação tradicional. Professores de matemática com certificação alternativa são menos eficazes em promover alguns aspectos de ambientes de aprendizagem positivos em sala de aula; no entanto, essa evidência é limitada. Nossos achados contribuem para o debate em curso sobre as vias de certificação docente e a eficácia do ensino ao fornecer evidências empíricas sobre como os estudantes percebem de forma diferenciada o ambiente de aprendizagem em função do tipo de certificação de seus professores de matemática e ciências.
Palavras-chave: formação de professores; certificações docentes alternativas; educação STEM; ambientes de aprendizagem em sala de aula

Alternative Routes: Alternative Teacher Certifications and STEM Classroom Environments

The composition of the U.S. teacher workforce has changed considerably in recent years (Ingersoll & Merrill, 2017; Taie & Lewis, 2022), including a growing number of teachers entering through alternative route teacher preparation programs that enroll teachers who complete their preparation while serving as the teacher of record (U.S. Department of Education, 2016). In the 2007–08 school year, 18.3% of high school teachers were alternatively certified (U.S. Department of

Education, n.d.). By 2019–20, this share had risen to 30%, reflecting continued growth in the alternative certification sector (U.S. Department of Education, 2023).

Educators and policymakers have expressed both optimism and concern regarding how well alternatively certified teachers can support their students' academic and social development (Bowling & Ball, 2018; Boyd et al., 2007). This diversity of opinions reflects, in part, the variation in alternative route program designs, which range from fast-track online programs to university-based programs that share many features with traditional teacher preparation programs (Grossman & Loeb, 2008; Matsko et al., 2022). Allowing alternative routes into teaching can enhance teaching quality by removing barriers for a talented workforce to join the teaching profession (Boyd et al., 2007; Sass, 2015). The strongest evidence supporting this view comes from experimental and quasi-experimental studies of Teach For America (TFA), which tend to find consistently positive effects in secondary math and science (Chiang et al., 2017; Clark et al., 2013; Penner, 2021; Xu et al., 2011). Yet, TFA is not representative of alternative certification programs writ large, and many critics argue that certain alternative routes may compromise instructional quality by permitting underprepared teachers to work with students. Henry and colleagues (2014) show that alternatively prepared secondary math and science teachers are less effective than their traditionally prepared peers.

Meta-analytic evidence shows that the association between alternatively certified teachers and student achievement is heterogeneous (Whitford et al., 2018), but their relationship with students' perceptions of learning experiences remains understudied. The one exception is Lucksnat and colleagues (2024), which shows that differences in German ninth grade students' perceptions of teacher quality vary depending on whether their teacher was traditionally or alternatively prepared. The authors found no evidence of differences in student reports of classroom disruptions, student support, and cognitive activation. Although the findings are informative, the data come from Germany and may not generalize to the U.S. context. If we also find a null relationship between alternatively certified Science, Technology, Engineering, and Math (STEM) teachers and students' reports of the classroom environment, it would underscore how increasing access to the teaching profession may not necessarily jeopardize instructional quality, particularly among teachers with unique expertise, such as a STEM major. Further evidence is also needed because student reports of their classroom environment are correlated with other measures of teacher effectiveness, such as teacher value-added and observation scores (Kane et al., 2013). Such reports reveal otherwise unmeasured aspects of teacher quality (Balch, 2016; Schweig & Martínez, 2021) and reflect students' lived experiences in school.

Using the High School Longitudinal Study (HSLS: 2009), we investigate the relationship between alternative teacher certification and students' perceptions of the classroom learning environments in high school math and science courses. We start by describing the demographic characteristics of students taught by alternatively certified math and science teachers. To estimate differences in how students perceive the classroom learning environment based on the certification status of their teacher, we employ student and subject fixed effects. This approach adjusts for time-invariant differences across students and subjects, thus minimizing—though not eliminating—selection bias. We further focus on heterogeneity by testing whether these relationships vary by subject (math versus science) and teacher characteristics, including gender, race/ethnicity, STEM majors, and graduate degrees. Using the HSLS dataset that includes rich information on math and science teachers and their classroom learning environments, our findings offer valuable policy implications for teacher certification policies. We address the following research questions.

1. What are the demographic characteristics of students taught by alternatively certified math and science teachers?

2. To what extent are students' perceptions of the classroom learning environment in math and science courses associated with assignment to an alternatively certified teacher?
3. Do the relationships between alternative teacher certifications and students' perceptions of the classroom learning environment vary across subjects and teacher characteristics?

Our study contributes to the literature on teacher certification in four key ways. First, although prior administrative data studies (e.g., Boyd et al., 2012; Clotfelter et al., 2010; Kane et al., 2008) and national teacher-level analyses (Redding & Smith, 2016) have shown that alternatively certified teachers are more likely to work in schools serving higher concentrations of low-income students of color, the field still lacks national student-level evidence on this pattern. Our study fills this gap by leveraging a national dataset of high school students and their teachers, allowing for a better understanding of how teacher certification pathways relate to students' characteristics.

Second, we examine whether there are differences in how students perceive the classroom learning environments based on whether they are taught by an alternatively certified teacher, rather than focusing solely on test scores. Specifically, we construct a composite index on the degree to which students report that their teachers (a) have high expectations for all their students, (b) think mistakes are okay as long as all students learn, (c) make their subjects interesting, and (d) make their subjects easy to understand. By focusing on the classroom learning environment, this study deepens our understanding of whether alternatively certified teachers are associated with student learning opportunities in the classroom.

Third, we employ student fixed effects to compare classroom learning environments when students are taught by traditionally and alternatively certified teachers. As students from underserved communities are more likely to study with alternatively certified teachers (Redding & Smith, 2016), controlling for differences between students helps mitigate the selection bias associated with being in a classroom with an alternatively certified teacher.

Finally, we focus on alternatively certified math and science teachers. Many alternative teacher certification programs aim to recruit teachers who face severe shortages in these subjects (Brantlinger & Smith, 2013; Humphrey & Wechsler, 2007; Scribner & Akiba, 2010). By including math and science teachers, our study provides insights into the relationship between teacher preparation and teacher quality in STEM fields.

Literature Review

The Relationship Between Alternatively Teacher Certification and Student Outcomes

In 1984, New Jersey first adopted alternative teacher policy programs (Tamir, 2010). These programs spread to nearly every state by the 2010s (Redding, 2022), though a growing number of states have pulled back on alternative route teacher preparation programs in recent years, particularly those not based at an institution of higher education (U.S. Department of Education, 2023). The primary distinguishing feature of alternative certification is that it allows teacher candidates to become the teacher of record before completing all certification requirements (Constantine et al., 2009; Redding & Smith, 2016). Program credit hours, clinical supervision, and mentoring requirements are then completed "on the job" and can be coordinated by institutions of higher education, non-profit or for-profit organizations, and school districts (Humphrey & Wechsler, 2007; King & Yin, 2022; Yin & Partelow, 2020). Still, there can be significant variation in the design of alternative certification programs both within and across states (Boyd et al., 2012; Grossman & Loeb, 2008; Matsko et al., 2022; Nagro et al., 2023), spanning non-profit, mission-driven organizations (Teach For America [TFA]; TNTP Teaching Fellows), university-based alternative programs, and online programs (American Board for Certification of Teacher Excellence; Texas Teachers of Tomorrow). Given that alternative certification requirements can more closely resemble traditional certification requirements in some states, some researchers have pushed back on the utility of comparing traditionally and alternatively prepared teachers (Nagro et al., 2023). Despite this criticism, it remains important to compare alternatively and traditionally prepared teachers, given the evidence of sharp differences in the background characteristics of alternatively certified teachers and comprehensiveness of their preparation (Cohen-Vogel & Smith, 2007; Matsko et al., 2022; Redding & Smith, 2016).

A growing literature has examined the extent to which alternatively certified teachers are better or worse at improving student achievement than traditionally certified teachers. A meta-analysis of 12 rigorous studies showed that alternatively certified teachers had a small net effect on student achievement (0.03 *SD*) (Whitford et al., 2018). However, this overall finding masks considerable heterogeneity by school level, subject area, and type of alternative certification program. For instance, when looking specifically at high schools, sharp differences are observed depending on whether the alternatively certified teacher was part of TFA or another certification program. TFA teachers had a positive, significant effect on student achievement in math and science (0.05 to 0.06 *SD*) while other alternatively certified teachers had a negative impact on student achievement (-0.07 *SD*). This adverse impact is particularly concentrated among math and science instructors with alternative certification, with statistically significant findings mainly in science. Given that TFA represents a unique alternative certification program and most alternatively certified teachers are non-TFA (e.g., Boyd et al., 2009; Henry et al., 2014), the academic disadvantage faced by high school students assigned to such educators is concerning. Furthermore, given that students of color and students experiencing poverty are disproportionately likely to be taught by an alternatively certified teacher (Redding & Smith, 2016), these adverse outcomes warrant attention.

Within this growing body of research, it is noteworthy that the only U.S.-based studies examining non-achievement outcomes focus on TFA (Backes & Hansen, 2018, 2024; Glazerman et al., 2006). These studies are mixed regarding the extent to which TFA corps members impact non-achievement outcomes. Glazerman and colleagues' (2006) experimental evaluation shows no evidence of an effect in terms of grade retention, attending summer school, absenteeism, and disciplinary incidents, but TFA corps members report more serious problems with behavior and more interruptions to class related to student disruptions than teachers in the control group. Drawing on administrative data from Miami-Dade County Public Schools, Backes and Hansen (2018, 2024) show that students taught by TFA corps members were more likely to have an unexcused absence than students assigned to other teachers and that these relationships persist over time. As TFA teachers represent only a small fraction of alternatively certified teachers in the United States, the broader impact of alternatively certified teachers on classroom learning environments remains unclear. Moreover, as student perceptions can indicate teaching effectiveness and student learning opportunities, empirical evidence on how alternatively certified teachers influence students' perceptions of learning environments is needed.

Teacher Impacts on the Classroom Learning Environment

A growing body of research applying experimental and quasi-experimental research designs affirms what has long been implicit in models of teacher quality: that teaching is a social activity, and thus, providing a supportive classroom learning environment is critical for successful teaching (e.g., Davis, 2003). Though a supportive classroom learning environment can be defined across a number of domains (e.g., Kumar et al., 2018; Robinson, 2023), a few key focal areas have been of particular interest to researchers, including maintaining high student expectations, fostering a growth mindset where mistakes are considered part of the learning process, and ensuring that instructional material is engaging and easy to understand. Drawing on experimental data from the Measures of Effective Teaching project, Blazar and Kraft (2017) show how teachers can improve self-efficacy in math and student behavior in class. Building on this work, Kraft (2019) demonstrates that teachers influence both standardized test outcomes and competencies such as growth mindset, perseverance, and classroom effort. Importantly, these impacts appear to persist over time (Backes et al., 2022; Jackson, 2018; Liu & Loeb, 2021). As an example, the expectations held by 10th grade teachers have an impact on students' chances of college completion (Papageorge et al., 2020).

Making course material interesting and relevant appears to be another way in which teachers establish a supportive classroom learning environment. This point is perhaps most explicit in the literature on culturally relevant education (CRE). The basis for CRE is the connection between the academic skills and concepts in class with the cultural referents that students bring into the classroom (Aronson & Laughter, 2016), which has been shown to impact student outcomes in the short- and long-term (Bonilla et al., 2021; Dee & Penner, 2017). Though research suggests the promise of merging CRE and inquiry-based math and science instruction (e.g., Aronson & Laughter, 2016; Brown, 2017), the success of such efforts often depends on teachers' knowledge and skills related to the translation of theory to practice (Brown et al., 2019). Scholars have raised concerns about whether the education sector has adequately invested in teacher quality to implement ambitious, equitable instruction (Aronson & Laughter, 2016; Castro & Edwards, 2021).

Concerns about the classroom learning environments of alternatively certified teachers are particularly salient given the ongoing increase in their numbers, many of whom enter the profession with limited or no preservice training (e.g., Redding & Smith, 2016). Although the existing literature offers an increasingly nuanced picture of how teachers shape classroom learning environments (e.g., Backes et al., 2022), researchers have paid limited attention to differences across policy-relevant teacher characteristics, such as entry pathways into teaching. Our study contributes to this literature by examining whether students' perceptions of classroom learning environments differ between traditionally certified and alternatively certified teachers and whether this association varies across teacher characteristics. The next section motivates competing conceptual perspectives on whether alternatively certified teachers help shape more positive or more negative classroom learning environments, underscoring the need to empirically address this important question.

Conceptual Framework

Informed by the literature on occupational licensing (Kleiner, 2000), competing arguments exist regarding the impact of alternative teacher certification on teacher quality. One perspective argues that alternatively certified teachers are less effective than traditionally certified ones, as professional standards for entry into teaching are designed to ensure that teachers possess the necessary skills to succeed in the classroom (Sass, 2015). Achieving this objective requires comprehensive pre-service preparation in teacher preparation programs (TPP). Certification standards often dictate that TPP graduates have met specific learning standards throughout coursework and clinical experiences. Having undergone training in a state-accredited TPP, educators are expected to have acquired the necessary pedagogical content knowledge (Darling-Hammond, 2013). Conversely, alternatively certified teachers may lack this preparation, which can reduce their ability to teach course material in ways that are engaging, clear, and relevant.

Other researchers have adopted a similar line of reasoning but argue that stringent certification requirements are meant to set the floor rather than the ceiling for teacher quality. That is, certification requirements act as a safeguard preventing individuals without adequate training and qualifications from becoming teachers (Leland, 1979; Sass, 2015). From this perspective, allowing alternatively certified teachers to become the teacher of record before completing their training risks placing them in classrooms without the requisite skills to create a supportive classroom environment. As preparation programs with lax recruitment standards have proliferated in many states, it is plausible that alternatively certified teachers will be unsuccessful in fostering supportive learning conditions for their students.

It is also plausible that alternatively certified teachers are more effective than traditionally certified teachers, as traditional certification requirements can restrict access for individuals who would otherwise be successful in the teaching profession. Abbreviating teacher preparation and alternatively certifying promising candidates can limit both real and opportunity costs of entering teaching (Humphrey & Wechsler, 2008; Redding, 2022; Walsh & Jacobs, 2007). Removing these barriers has enabled alternative certification programs to recruit higher proportion of male teachers, teachers of color, and teachers with specialized subject matter, particularly in math and science (Boyd et al., 2008, 2012; Grossman & Loeb, 2008; Redding, 2022). While it remains an open question whether these compositional changes in the teacher workforce contribute to differences in teacher quality (Master et al., 2018), there are reasons to believe that recruiting more teachers of color and academically talented individuals has been a beneficial development.

Research has increasingly recognized teacher racial/ethnic diversity as a critical element of teacher quality (Gershenson et al., 2021; Irvine, 1989; Ladson-Billings, 1994; Milner, 2011). Since alternative certification programs often recruit more teachers of color (Redding & Smith, 2016), expanding these programs could lead to classrooms where students experience more supportive learning environments given the growing body of research showing the positive impact of teachers of color (Bristol & Martin-Fernandez, 2019; Hwang et al., 2023, 2024; Redding, 2019). For instance, Black teachers bring unique contributions to the classroom, such as fostering growth mindset beliefs and providing supportive learning environments for Black students (Blazar et al., 2024). There may also be a role modelling effect, with students of color modifying their own expectations of their academic potential to reach the expectations set by the teacher (Redding, 2019). In short, alternative certification programs' role in diversifying the teaching profession may significantly contribute to creating a more positive classroom environment.

Recruiting academically talented teachers—often through selective programs such as TFA or TNTP—has been effective in attracting individuals with strong academic backgrounds who may not have entered teaching otherwise. As discussed earlier, TFA teachers tend to have generally positive effects on secondary science and math achievement, and, to a lesser degree, on non-academic outcomes. It is plausible that these alternatively certified teachers play a role in creating a more positive learning environment for their students.

In summary, there are competing conceptual perspectives on whether alternatively certified teachers are associated with more positive or negative classroom learning environments. While we do not posit a directional hypothesis, we examine whether students report more favorable perceptions of the classroom when taught by alternatively certified teachers with characteristics often linked to higher quality, such as having a graduate degree, a STEM major, or greater teaching experience.

Data

To address our research questions, we use data from the High School Longitudinal Study of 2009 (HSLS)—a national study of high school students. The HSLS dataset includes approximately

21,000 ninth grade students[1] from 940 schools in 2009 and followed them into 11th grade in 2012 and beyond into postsecondary years. Alongside student surveys, the HSLS dataset includes information about students' parents, math and science teachers, school administrators, and school counselors. Our sample comes from the 2009 base year of HSLS:09. We use restricted-use HSLS:09 data because they include school identifiers, which are necessary to account for the nesting of students within schools. Our main analyses, which use student and subject fixed effects models, include 10,110 unique students across 810 schools to examine the relationship between alternatively certified teachers and classroom learning environments.

We use the teacher survey that asks whether a teacher started their teaching career with an alternative teaching certificate, the key independent variable in our main models. The specific survey question is "Did you enter teaching through an alternative certification program?"[2] The HSLS dataset also includes other teacher characteristics, such as teacher gender, race/ethnicity, years of teaching experience, whether a teacher has a graduate degree, and whether a teacher has a bachelor's degree in a STEM major. We use these variables as controls in our main analysis. Additionally, we investigate whether the associations between an alternatively certified teacher and classroom learning environments vary across these teacher characteristics. Our student fixed effects estimate leverage within-student, cross-subject variation in teacher certification. Among students with data on both math and science teachers, 34.6% (N = 4,657) experience mixed-certification exposure and provide the identifying variation for the models.

In our sample, half of students are female, and the other half are male. White students make up the largest portion of racial/ethnic groups (57%), yet our sample includes a sizable percentage of Hispanic (16%), Black (9%), Asian (8%), and students of other race/ethnicity backgrounds (10%). A substantial percentage of teachers entered the teaching profession through an alternative certification program, with 19% and 29% of math and science teachers, respectively (Appendix Table 1).

To measure math and science classroom learning environments—our outcome variables—we use a student survey that asks about math and science teachers. Specifically, the survey asks "How much do you agree or disagree with the following statements about your math/science teacher? Your math/science teacher (a) thinks every student can be successful; (b) thinks mistakes are okay as long as all students learn; (c) makes math/science interesting; (d) makes math/science easy to understand. Students responded to these questions on a 4-point scale ranging from 1 (strongly agree) to 4 (strongly disagree). We reversed the coding so that a higher score indicates a more positive classroom learning environment. Students generally tend to evaluate classroom learning environments positively, yet variations exist. For math teachers, the mean ratings for the four items are 3.33 (SD = 0.66), 3.20 (SD = 0.70), 2.75 (SD = 0.94), and 2.91 (SD = 0.87), respectively. For science teachers, the corresponding mean ratings are 3.29 (SD = 0.67), 3.12 (SD = 0.71), 2.89 (SD = 0.93), and 2.85 (SD = 0.96).

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[1] The HSLS dataset includes approximately 21,000 ninth graders. However, due to missing data, our analytic sample is smaller. We use listwise deletion to handle the missing data, resulting in a sample size that varies depending on the model. The missing data primarily arise from incomplete teacher survey and the absence of student evaluations when students do not take math or science courses. As a robustness check, we also estimate models using multiple imputation (Appendix Table 3), and the main findings remain consistent.
[2] Our reference group includes non-alternatively certified teachers, both traditionally prepared and uncertified. Although our data do not allow us to distinguish between these two subgroups, we use the term *traditionally prepared teachers* as the reference group because they comprised the vast majority of teachers during the No Child Left Behind era.

Based on these four items—Successful, Mistakes, Interesting, and Easy—we created a composite index by averaging the standardized scores of the items. The resulting composite index has a mean of 0 and a standard deviation of 1 for both math and science. The Cronbach's alpha values are 0.836 for math and 0.842 for science, indicating high internal consistency. While each individual item captures a specific aspect of the classroom learning environment associated with alternatively certified teachers, using a composite index minimizes the risk of multiple comparisons that can inflate false positives and provides a more reliable and parsimonious measure.

Table 1 shows the differences in characteristics between traditionally and alternatively certified teachers. In terms of math teachers, the percentage of female teachers is smaller among alternatively certified teachers relative to traditionally certified teachers (51% versus 63%). While math teachers are predominantly White regardless of certificate type, there is a higher percentage of alternatively certified teachers of color. Specifically, 10% of traditionally certified math teachers are teachers of color, whereas 19% of alternatively certified math teachers belong to racial/ethnic minority groups. The proportion of math teachers holding graduate degrees is lower among alternatively certified teachers (45% versus 52%), whereas the percentage of teachers holding STEM bachelor's degree is higher (56% versus 37%). Additionally, alternatively certified math teachers tend to have fewer years of teaching experience (7.2 versus 11.0).

Table 1

Teacher Characteristics by Certificate Type (Alternative versus Traditional)

Math Teacher Characteristics	Alternative	Traditional	Difference
Female	0.51	0.63	-0.12**
White	0.81	0.90	-0.09***
Black	0.07	0.03	0.05***
Hispanic	0.07	0.03	0.04***
Asian	0.03	0.02	0.00
Other race/ethnicity	0.02	0.01	0.00
Graduate degree	0.45	0.52	-0.07***
STEM BA degree	0.56	0.37	0.20***
Teaching experience	7.17	11.04	-3.87***
Science Teacher Characteristics			
Female	0.58	0.55	0.03**
White	0.83	0.90	-0.07***
Black	0.08	0.03	0.05***
Hispanic	0.05	0.03	0.02***
Asian	0.02	0.02	0.00
Other race/ethnicity	0.02	0.02	0.00
Graduate degree	0.52	0.58	-0.07***
STEM BA degree	0.79	0.49	0.30***
Teaching experience	7.52	12.21	-4.7***

Source. High School Longitudinal Study of 2009 (HSLS:09). ** $p<0.01$ *** $p<0.001$

Note. The analyses include 10,110 unique student–teacher observations from 810 U.S. schools.

The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements.

STEM = science, technology, engineering, and mathematics.

For science teachers, similar patterns emerge when comparing traditionally and alternatively certified teachers. Alternatively certified science teachers tend to be more racially diverse (e.g., 8% versus 3% Black teachers) and are more likely to hold STEM bachelor's degrees (79% versus 49%). They also tend to have fewer years of teaching experience (7.52 versus 12.21). Unlike math teachers, however, the percentage of male teachers is slightly higher among alternatively certified science teachers (58% versus 55%).

Methods

Regression Analysis of Alternatively Certified Teachers

To investigate the associations between student characteristics and alternatively certified teachers, we run Ordinary Least Squares (OLS) regression analyses. We first conduct bivariate analyses to show the associations without controls, then conduct multivariate analyses by including other student characteristics. Additionally, we add school fixed effects to estimate the associations within schools. The following equation (1) represents our bivariate OLS models:

$$Alt_i = \beta_0 + \boldsymbol{X_i}\beta_1 + \theta_s + \varepsilon_i \quad (1)$$

Alt_i denotes whether a student has a teacher with an alternative certificate. $\boldsymbol{X_i}$ denotes student characteristics, including race/ethnicity, family SES, and achievement levels (math test scores in 9th grade). θ_s denotes a school fixed effect and ε_i is the error term. The key parameter of interest is $\boldsymbol{\beta_1}$, which captures the association between a student's characteristics and having a teacher with an alternative certificate. By adding other control variables and school fixed effects, we also examine this relationship while controlling for additional factors. Separate models are run for math and science teachers.

Fixed Effects Analysis of Classroom Learning Environments

Next, we employ a student fixed effect strategy to estimate the relationship between assignment to an alternatively certified teacher and the classroom learning environment. Because teachers are not randomly assigned to students, it is important to address potential selection into assignments of teachers with different certificate types. Our student fixed effects approach compares student reports of the classroom learning environment across traditionally and alternatively certified teachers while accounting for time-invariant differences between students, yielding more precise estimates. However, these models do not account for time-varying factors, which limits causal interpretation.

Although HSLS:09 is nationally representative, our unweighted fixed-effects estimates are designed to capture within-student comparisons across teachers rather than produce national estimates. We follow Sansone (2017, 2019) in estimating student fixed-effects models, leveraging the HSLS data, which include each student's evaluations of both math and science teachers by each student,[3] as shown in Equation (2). While our fixed effects approach does not adjust for unequal

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[3] Because our identification strategy relies on student fixed effects, when both math and science teachers hold both traditional certificates or both hold alternative certificates, they do not contribution to our estimates. Our data shows that 34.6% of ninth grade students have teachers of different certificate types (alternative versus traditional) across subjects, contributing to our estimates. Additionally, we compare our full sample and sample from models using student and subject fixed effects. Appendix Table 1 show that our full sample and estimation sample are mostly similar, but students in our fixed effects model tend to come from higher SES backgrounds and exhibit higher levels of achievement.

sampling probabilities, it relies on the assumption that sampling is independent of the regression error conditional on observed covariates. We consider this assumption plausible in the HSLS:09 context, given the extensive set of covariates and the inclusion of student and subject fixed effects.

$$Y_{is} = Alt_{is}\emptyset + X_{is}\beta_1 + \pi_i + \delta_s + \varepsilon_{is} \qquad (2)$$

Y_{is} denotes student *i*'s classroom learning environments in subject *s*. The outcome captures a student's evaluation of the classroom learning environment, indicating the degree to which a teacher (a) thinks every student can be successful, (b) thinks mistakes are okay as long as all students learn, (c) makes the subject interesting, and (d) makes the subject easy to understand. We construct a composite measure by averaging the standardized scores of these four items.

The main parameter of interest is $\emptyset$, which indicates the extent to which classroom learning environments vary based on whether teachers are alternatively certified. In other words, $\emptyset$ shows how different types of teacher certifications in math and science (such as having an alternatively certified math teacher versus a traditionally certified science teacher, or vice versa) is associated with ninth graders' evaluations of classroom learning environments.

X_{is} indicates teacher characteristics of student *i* (i.e., teacher gender, teacher race/ethnicity, whether the teacher had a graduate degree, whether the teacher has a bachelor's degree in a STEM major, and the years of teaching experience), π_i indicates a student fixed effect, δ_s is a subject fixed effect, and ε_{is} is the error term. The HSLS surveyed students' class evaluation for math and science teachers separately, allowing us to employ student and subject fixed effects to estimate differences in students' perceptions of the classroom learning environments depending on the teacher's entry pathway.

To test whether this relationship varies across teacher characteristics, we add interaction terms between certification status and each teacher characteristic to our model. The following equation (3) expresses our student fixed effects model with interaction effects:

$$Y_{is} = Alt_{is}\emptyset + X_{is}\beta_1 + (TeaCha_{is})\,\beta_2 + (Alt_{is} * TeaCha_{is})\,\beta_3 + \pi_i + \delta_s + \varepsilon_{is} \quad (3)$$

These interaction terms (β_3) indicates whether there are heterogenous relationships across teachers who differ in gender, race/ethnicity, possession of a graduate degree, STEM major, teaching experience, subject that they teach, and math course taking.[4] Given the nested structure of the data, all models account for within-school dependence by clustering standard errors at the school level. This approach adjusts for the non-independence of students within the same school and yields more accurate estimates and standard errors.

The HSLS:09 collected data from a nationally representative sample of U.S. high school students. Although researchers can use sampling weights to produce estimates that are generalizable to the U.S. population, we estimated our main models without weights. Our identification strategy in the second set of analyses uses student and subject fixed effects to control for all time-invariant differences between students and subjects. Therefore, our estimates reflect within-student variation rather than population-level averages. Because the goal of these analyses is to obtain less biased estimates using student and subject fixed effects, the application of sampling weights is not appropriate (Sansone, 2019; Solon et al, 2009). However, for our first set of analyses—examining

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[4] The math course-taking variable is categorized into three levels: remedial courses (review or remedial math, including basic, business, consumer, functional, or general math, and pre-algebra), regular courses (Algebra I and Integrated Math I), and advanced courses (geometry, Algebra II, trigonometry, statistics, Integrated Math II, analytic geometry, and other advanced courses such as pre-calculus or calculus).

overall patterns in alternatively certified teacher assignments—we apply the appropriate math and science teacher weights as a robustness check and report these results in Appendix Table 2.

Results

Student Characteristics and Alternatively Certified Teachers

Table 2 shows the associations between student characteristics and teacher certification. Columns 1 through 5 focus on alternatively certified math teachers, and Columns 6 through 10 focus on alternatively certified science teachers. Column 1 shows that Black, Hispanic, and other race/ethnicity students are more likely to be assigned to alternatively certified math teachers, relative to White students. Columns 2 and 3 indicate that students from lower family SES (bottom and middle terciles) and lower academic achievement (bottom and middle terciles based on 9th grade math test scores) are more likely to be assigned to alternatively certified math teachers. A model that includes student race/ethnicity, family SES, and academic achievement variables continues to show that students from racial/ethnic minority groups, lower SES, and lower achievement levels are more likely to be assigned to alternatively certified math teachers (Column 4). Finally, to examine whether disparities in access to traditionally certified teachers persist within schools, we add school fixed effects to the model. Column 5 in Table 3 reveals that Hispanic students, students from other racial/ethnic groups, and students with lower achievement (bottom tercile) have a higher likelihood of being assigned to alternatively certified math teachers, even within schools.

Columns 6 through 10 in Table 2 show disparities in access to traditionally certified teachers in science. Columns 6 and 7 indicate that student race/ethnicity and family SES are not significantly associated with being assigned to alternatively certified science teachers. Conversely, lower student achievement levels (bottom and middle terciles) are significantly associated with a higher likelihood of being assigned to alternatively certified science teachers (Column 8). The association between lower student achievement level and alternatively certified science teachers continues to be statistically significant even after controlling for student race/ethnicity and family SES levels (Column 9). However, with the inclusion of school fixed effects, the association between student achievement levels and being assigned to alternatively certified science teachers is no longer significant (Column 10). In the model with school fixed effects, Black students have a lower likelihood of being assigned to alternatively certified science teachers. The model fit (R^2) improved substantially when school fixed effects were included (from 1% to 45% in math and from 0.2% to 53% in science) highlighting the explanatory power gained by including school fixed effects.[5]

[5] Although our school fixed effects models account for all time-invariant differences between schools, they do not adjust for HSLS's complex survey design. As a sensitivity check, we applied the Taylor-series linearization approach (using W1MATHTCH for math and W1SCITCH for science) with the restricted-use HSLS:09 data, which include school identifiers. Some estimates change in Appendix Table 2 under this alternative specification. For example, whereas Table 2 showed that lower-SES and lower-achieving students were more likely to be assigned to an alternatively certified math teacher, we no longer find significant evidence for this pattern in Appendix Table 2. However, the models with and without weights produce consistent results regarding racial disparities: students of color are more likely to be assigned to an alternatively certified teacher. This pattern is more evident in math than in science.

Table 2

Student Characteristics and Teachers with Alternative Certifications

Student Characteristics	Math Teachers					Science Teachers				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Black	0.059**			0.048*	-0.006	0.031			0.023	-0.030*
	(0.021)			(0.021)	(0.011)	(0.023)			(0.023)	(0.012)
Hispanic	0.087***			0.075***	0.018*	0.030			0.025	-0.010
	(0.019)			(0.019)	(0.009)	(0.018)			(0.019)	(0.009)
Asian	-0.008			0.000	0.001	0.006			0.014	-0.016
	(0.015)			(0.015)	(0.012)	(0.020)			(0.020)	(0.014)
Other race/ethnicity	0.032***			0.028*	0.024**	0.005			0.003	-0.016
	(0.013)			(0.013)	(0.009)	(0.016)			(0.016)	(0.011)
SES (bottom tercile)		0.061***		0.030*	0.003		0.021		0.001	0.008
		(0.014)		(0.013)	(0.008)		(0.018)		(0.017)	(0.009)
SES (middle tercile)		0.030**		0.018	0.002		0.009		-0.001	0.000
		(0.010)		(0.010)	(0.007)		(0.013)		(0.013)	(0.008)
Achievement (bottom tercile)			0.055***	0.031*	0.027**			0.042**	0.039**	0.015
			(0.013)	(0.012)	(0.010)			(0.016)	(0.015)	(0.010)
Achievement (middle tercile)			0.028**	0.016	0.008			0.024**	0.023*	0.017
			(0.010)	(0.010)	(0.008)			(0.012)	(0.011)	(0.009)
School FE					X					X
N (unique student)	15960	15960	15960	15960	15960	14580	14580	14580	14580	14580
R^2	0.007	0.004	0.003	0.010	0.451	0.001	0.000	0.001	0.002	0.531

Source. High School Longitudinal Study of 2009 (HSLS:09). * $p<0.05$ ** $p<0.01$ *** $p<0.001$

Note. Standard errors in parentheses at the school level. The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements. Achievement = Math Achievement in 9th grade. SES = socioeconomic status. ATC = alternative teacher certificate. STEM = science, technology, engineering, and mathematics. FE = fixed effects.

Alternatively Certified Teachers and Classroom Learning Environments

Table 3 presents the associations between alternatively certified teachers and students' perceptions of the classroom learning environment. We first examine the relationship between certification type (alternatively certified versus traditionally certified) and each dimension of the learning environment, controlling for teacher characteristics as well as student and subject fixed effects. Columns 1 through 4 show that teacher certification status is not significantly associated with students' perceptions that (1) their teachers believe every student can be successful; (2) their teachers consider mistakes acceptable as long as all students learn; (3) their teachers make the subject interesting; and (4) their teachers make the subject easy to understand. Using a composite measure of the classroom learning environment (Column 5) yields a similar result, with no statistically significant association. Overall, the findings provide little evidence that students perceive differences in their classroom learning environment based on whether their teacher entered the profession through an alternative or traditional certification pathway.

Table 3

Relationship between Alternative Teacher Certificates and Classroom Learning Environments with Student and Subject Fixed Effects

Variables	Successful	Mistakes	Interesting	Easy	Composite Variable
	(1)	(2)	(3)	(4)	(5)
ATC	-0.001	0.029	-0.013	-0.019	-0.001
	(0.020)	(0.021)	(0.039)	(0.033)	(0.039)
Student FE	X	X	X	X	X
Subject FE	X	X	X	X	X
Teacher Controls	X	X	X	X	X
N (student-subject)	19930	20000	20042	20070	20210
R^2	0.643	0.639	0.565	0.569	0.606
Within R^2	0.002	0.008	0.007	0.005	0.007

Source. High School Longitudinal Study of 2009 (HSLS:09)
Note. The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements. All outcomes are based on student evaluations. Successful = Teachers think all students can be successful. Mistakes = Teachers think mistakes are okay as long as all students learn. Interesting = Teachers make subject interesting. Easy = Teachers make subject easy to understand. ATC = alternative teacher certificate. FE = fixed effects. Teacher Controls include teacher gender, race/ethnicity, graduate degree, STEM degree, and teaching experience. Standard errors in parentheses at the school level. The dependent variable of column (5) is a composite index created by averaging standardized scores across the four perception items (i.e., Successful, Mistakes, Interesting, and Easy).

Alternatively Certified Teachers and Classroom Learning Environments across Teacher Characteristics

Next, we examine whether the association between alternatively certified teachers and classroom learning environments varies across teacher characteristics. Table 4 presents results testing whether the relationship between teacher certification type and students' perceptions of the classroom learning environment differs by teacher gender, race/ethnicity, graduate degree, STEM major, teaching experience, subject taught, and math course level. Columns 1 through 5 show that the associations between certification type and classroom learning outcomes do not differ by teacher gender, race/ethnicity, graduate degree, STEM major, or teaching experience. Additionally, Column

7 indicates that the relationship between teacher certification type and classroom learning environment does not vary by academic tracking, as measured by math course level.

Table 4

Relationship between Alternative Teacher Certificates and Classroom Learning Environments across Teacher Characteristics with Student and Subject Fixed Effects

Variables	Classroom Learning Environments						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ATC	0.021	-0.024	0.058	0.043	-0.027	-0.073	0.071
(ref. traditional)	(0.061)	(0.042)	(0.056)	(0.068)	(0.054)	(0.049)	(0.076)
ATC * Female teacher	-0.041						
	(0.074)						
ATC * Teacher of color		0.158					
		(0.094)					
ATC * Graduate degree			-0.114				
			(0.069)				
ATC * STEM				-0.066			
				(0.079)			
ATC * Experience					0.003		
					(0.005)		
ATC * Math						-0.177**	
(ref. science)						(0.063)	
ATC * Math Course (Regular)							-0.065
(ref. remedial)							(0.082)
ATC * Math Course (Advanced)							-0.101
							(0.091)
Student FE	X	X	X	X	X	X	X
Subject FE	X	X	X	X	X	X	X
Teacher Controls	X	X	X	X	X	X	X
N (student-subject)	20210	20210	20210	20210	20210	20210	20210
R^2	0.606	0.606	0.606	0.606	0.606	0.607	0.606
Within R^2	0.007	0.007	0.008	0.007	0.007	0.008	0.007

Source. High School Longitudinal Study of 2009 (HSLS:09) ** p<0.01

Note. The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements. All outcomes are based on student evaluations. ATC = alternative teacher certificate. FE = fixed effects. Teacher Controls include teacher gender, race/ethnicity, graduate degree, STEM degree, and teaching experience. Standard errors in parentheses at the school level. The dependent variable (classroom learning environments) is a composite index created by averaging standardized scores across the four perception items (i.e., Successful, Mistakes, Interesting, and Easy).

One interaction term that reaches statistical significance is between alternative teacher certification and math subject (Column 6). This result suggests that the association between teacher certification type and classroom learning environments varies by subject area. Specifically, alternatively certified math teachers are associated with less positive classroom learning environments compared with alternatively certified science teachers. Although we find some suggestive evidence of subject-specific variation, the associations between teacher certification type and classroom learning environments do not differ significantly across other teacher characteristics.

Alternative Model Specifications

We conduct several alternative models to assess the robustness of our findings. First, we re-estimate our models using 20 multiple imputations (MI), shown in Appendix Table 3, which address missing data by generating plausible values and reduce potential bias compared with listwise deletion. Overall, the results remain largely consistent with our main findings, although the interaction between teacher certification and subject is not statistically significant in the MI models.

Second, we apply a propensity score method using inverse probability weighting (IPW) as a robustness check to examine the associations between alternative teacher certification and classroom learning environments. IPW helps reduce bias from observed confounding by balancing covariates across treatment groups but cannot account for unobserved variables that may still affect the outcomes (Austin, 2011; Rosenbaum & Rubin, 1983). We also run models on subsamples defined by teacher gender, race/ethnicity, graduate degree, STEM major, subject, and academic tracking (math course level) as subgroup analyses. Appendix Table 4 shows that the findings remain consistent (i.e., null overall relationship between teacher certification and student perceptions of the classroom learning environment, with some evidence of a more negative relationship in math classrooms).

Third, we run models including interaction effects between teacher certification and teacher characteristics, using each learning environment dimension as a separate outcome. Appendix Table 5 shows that teacher certification is generally not associated with student perceptions that teachers believe all students can succeed or that mistakes are acceptable, and these associations do not vary by teacher characteristics. One interaction effect reaches marginal significance: Column 9 suggests that the association varies slightly by teacher race. Appendix Table 6 focuses on engaging learning environments (teachers make the subject interesting and easy to understand) and shows that, consistent with our main models using a composite variable, the association between teacher certification and learning environments varies by the subject taught. These results suggest that the association between alternative certification and positive classroom learning environments is weaker in math than in science.

Discussion

We use a national dataset of U.S. high school students to examine alternatively certified teachers and the classroom learning environment. Our results show that students from underserved communities, including students from racial/ethnic minority groups, students from lower family SES, and students who tend to struggle academically, are more likely to be assigned to alternatively certified math teachers. These patterns are consistent both across and within schools. While we also find disparities in the likelihood of being assigned to alternatively certified science teachers, these disparities are much less pronounced than in math. Students with lower achievement levels are more likely to be assigned to science teachers with alternative certificates across schools; however, these associations do not persist within schools. Our findings align with previous studies showing that alternatively certified teachers are more likely to work in schools enrolling higher concentrations of students from underserved communities (e.g., Redding & Smith, 2016).

Our study is less conclusive when examining whether students report different perceptions of their classroom learning environment when taught by traditionally versus alternatively certified teachers. Models with student and subject fixed effects, along with sensitivity analyses using propensity score matching, indicate that, on average, student perceptions of their classroom learning environments do not vary by teacher certification pathway. This pattern aligns with results from Lucksnat and colleagues (2024), who found no evidence of differences in ninth-grade students' perceptions of how well their mathematics teachers managed classroom disruptions or supported students. Additionally, contrary to our expectations, the association between alternative certification and student perceptions of the learning environment does not vary across most teacher characteristics, including gender, race/ethnicity, graduate degree, STEM major, and teaching experience.

The only significant estimate related to our third research question was for alternatively certified mathematics teachers, whose students rated the classroom learning environment less favorably than those of alternatively certified science teachers. This aligns with meta-analytic evidence showing that non-TFA alternatively certified high school math teachers had lower math achievement (Whitford et al., 2018). Though we do not view this finding as definitive—particularly as it was not statistically significant across all sensitivity analyses—we see the need for future research on alternatively certified mathematics teachers, given their inequitable distribution and the importance of high-quality mathematics teachers for students' academic and career pathways, especially in STEM (Shaw & Barbuti, 2010; Wang et al., 2015).

Our study contributes to the literature on alternative teacher certification, yet it has a few limitations. First, although teaching effectiveness can considerably vary across types of alternative certificates (Matsko et al., 2022; Whitford et al., 2018), we were not able to test the extent to which the observed relationships varied across different alternative teacher certification program types due to insufficiently detailed information. Second, given that alternative route programs have continued to evolve since HSLS:09 was conducted, including more teachers entering through these routes (U.S. Department of Education, 2023), our findings may not reflect student perceptions of teachers with current alternative certifications. Third, although our main models account for all time-invariant differences between students and subjects, our analyses rely on cross-sectional data, which remain susceptible to omitted variable bias. Fourth, although the data are nationally representative, only 34% of students with alternatively certified teachers in math or science contribute to the student fixed effects estimates. Consequently, our findings may not generalize to other contexts and should not be interpreted as nationally representative. Finally, the effects of alternatively certified teachers can vary across school levels (Whitford et al., 2018), yet our study with data from a sample of U.S. high school students was not able to test whether the findings hold true in elementary and middle school contexts. Future studies addressing these limitations will provide a more comprehensive and nuanced understanding of how individuals entering the teaching profession via alternative routes shape students' learning opportunities.

Conclusion

This study builds on prior research on alternatively certified teachers and student outcomes by focusing on students' perceptions of their teachers. Our findings provide a nuanced view regarding the ability of alternatively certified teachers to foster a supportive classroom environment. On the one hand, our overall null findings align with a larger body of research on alternatively certified teachers that has shown few overall differences between traditional and alternatively certified teachers (Whitford et al., 2018). On the other hand, we find some evidence indicating that alternatively certified math teachers are associated with less supportive learning environments. Given the increasing prevalence of alternatively certified teachers and their prominent role in STEM education, it is important to prioritize efforts that ensure these teachers have adequate knowledge and training. This includes strengthening teacher preparation programs and expanding ongoing professional development opportunities to support their instructional practice.

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APPENDICES

Appendix Table 1

Descriptive Statistics

Variables	Full Analytic Sample Mean	Analytic Sample Mean with Student and Subject Fixed Effects
Student		
Female	0.50	0.50
White	0.57	0.60
Black	0.09	0.08
Hispanic	0.16	0.14
Asian	0.08	0.08
Other race/ethnicity	0.10	0.10
Family SES	0.07	0.15
Math Achievement (Grade 9)	0.02	0.14
Math Teacher		
Alternative certificate	0.19	0.18
All students can be successful	3.34	3.35
Mistakes are okay	3.21	3.22
Make the subject interesting	2.75	2.76
Make the subject easy	2.92	2.92
Science Teacher		
Alternative certificate	0.29	0.28
All students can be successful	3.29	3.31
Mistakes are okay	3.12	3.13
Make the subject interesting	2.90	2.90
Make the subject easy	2.85	2.85

Source. High School Longitudinal Study of 2009 (HSLS:09).

Note. The data include data from ninth graders in HSLS:09. SES = socioeconomic status.

Appendix Table 2

Student Characteristics and Teachers with Alternative Certifications with Sampling Weights

Student Characteristics	Math Teachers				Science Teachers			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Black	0.127***			0.114***	0.054			0.049
	(0.029)			(0.030)	(0.044)			(0.041)
Hispanic	0.139***			0.128***	0.068*			0.064*
	(0.022)			(0.023)	(0.026)			(0.026)
Asian	0.061			0.067*	0.012			0.018
	(0.031)			(0.032)	(0.026)			(0.026)
Other race/ethnicity	0.029			0.022	0.002			-0.001
	(0.024)			(0.023)	(0.023)			(0.023)
SES (bottom tercile)		0.082***		0.023		0.037		0.008
		(0.017)		(0.017)		(0.021)		(0.019)
SES (middle tercile)		0.044**		0.023		0.026		0.015
		(0.015)		(0.013)		(0.017)		(0.018)
Achievement (bottom tercile)			0.068**	0.035			0.035	0.020
			(0.022)	(0.023)			(0.030)	(0.028)
Achievement (middle tercile)			0.022	0.006			0.031	0.023
			(0.015)	(0.015)			(0.017)	(0.016)
N (unique student)	21370	21370	21370	21370	21230	21230	21230	21230

Source. High School Longitudinal Study of 2009 (HSLS:09) * *p*<0.05 ** *p*<0.01 *** *p*<0.001

Note. Standard errors in parentheses at the school level. The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements. Achievement = Math Achievement in 9th grade. SES = socioeconomic status. ATC = alternative teacher certificate. STEM = science, technology, engineering, and mathematics. FE = fixed effects.

Appendix Table 3

Association Between Alternative Teacher Certification and Classroom Learning Environments across Teacher Characteristics Using Multiple Imputations

Variables	Classroom Learning Environments							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ATC	-0.000	0.016	-0.010	0.056	0.056	-0.001	-0.054	0.104
(ref. Traditional)	(0.044)	(0.066)	(0.047)	(0.065)	(0.079)	(0.060)	(0.065)	(0.119)
ATC * Female teacher		-0.029						
		(0.080)						
ATC * Teacher of color			0.065					
			(0.116)					
ATC * Graduate degree				-0.110				
				(0.080)				
ATC * STEM					-0.088			
					(0.089)			
ATC * Experience						0.000		
						(0.005)		
ATC * Math							0.094	
							(0.077)	
ATC * Math Course (Regular)								-0.107
(ref. Remedial)								(0.122)
ATC * Math Course (Advanced)								-0.116
								(0.133)
Student FE	X	X	X	X	X	X	X	X
Subject FE	X	X	X	X	X	X	X	X
Teacher Controls	X	X	X	X	X	X	X	X
N (student-subject)	36590	36590	36590	36590	36590	36590	36590	36590

Source. High School Longitudinal Study of 2009 (HSLS:09)

Note. Standard errors in parentheses at the school level. The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements. The outcome is a composite measure based on four items: (1) teachers believe all students can be successful, (2) teachers view mistakes as acceptable as long as students learn from them, (3) teachers make the subject interesting, and (4) teachers make the subject easy to understand. Teacher-level controls include gender, race/ethnicity, graduate degree, STEM degree, and teaching experience.

Appendix Table 4

Association between Alternative Teacher Certification and Classroom Learning Environments Using Propensity Score Matching with Inverse Probability Weights across Teacher Characteristics and Math Tracks

Teacher Subgroups	Coefficients
All teachers	-0.021
	(0.017)
Female teachers	-0.017
	(0.024)
Male teachers	-0.019
	(0.026)
Teachers of color	0.040
	(0.047)
White teachers	-0.028
	(0.019)
Teachers with graduate degree	-0.008
	(0.024)
Teachers without graduate degree	0.037
	(0.025)
Teachers with STEM major	-0.039
	(0.021)
Teachers without STEM major	0.022
	(0.030)
Math teachers	-0.099**
	(0.027)
Science teachers	0.028
	(0.023)
Remedial math course	0.057
	(0.088)
Regular math course	0.002
	(0.023)
Advanced math course	-0.056
	(0.030)

Source. High School Longitudinal Study of 2009 (HSLS:09) ** $p<0.01$

Note. Standard errors in parentheses at the school level. We applied inverse probability weighting to estimate the association between alternative teacher certification and classroom learning environments. The outcome is a composite measure based on four items: (1) teachers believe all students can be successful, (2) teachers view mistakes as acceptable as long as students learn from them, (3) teachers make the subject interesting, and (4) teachers make the subject easy to understand. Teacher-level controls include gender, race/ethnicity, graduate degree, STEM degree, and teaching experience.

Appendix Table 5

Associations Between Alternative Teacher Certification and Classroom Learning Environments across Teacher Characteristics

Variables	All Students can be Successful							Mistakes are Okay as Long as Students Learn						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
ATC	0.025	-0.013	0.036	0.018	-0.042	0.022		0.022	0.014	0.060	0.032	0.001	0.053*	-0.009
(ref. traditional)	(0.031)	(0.022)	(0.030)	(0.035)	(0.027)	(0.026)		(0.033)	(0.023)	(0.031)	(0.036)	(0.030)	(0.027)	(0.056)
ATC * Female teacher	-0.046							0.013						
	(0.040)							(0.042)						
ATC * Teacher of color		0.084							0.111*					
		(0.049)							(0.051)					
ATC * Graduate degree			-0.071							-0.060				
			(0.037)							(0.040)				
ATC * STEM				-0.027							-0.002			
				(0.043)							(0.045)			
ATC * Experience					0.005							0.003		
					(0.003)							(0.003)		
ATC * Math						-0.053							-0.056	
(ref. science)						(0.034)							(0.038)	
ATC * Math Course (regular)							-0.019							0.062
(ref. remedial)							(0.049)							(0.060)
ATC * Math Course (advanced)							-0.016							0.010
							(0.051)							(0.064)
Student FE	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Subject FE	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Teacher Controls	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N (student-subject)	19930	19930	19930	19930	19930	19930	19930	20000	20000	20000	20000	20000	20000	20000

Source. High School Longitudinal Study of 2009 (HSLS:09). * $p<0.05$

Note. Standard errors in parentheses at the school level. The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements. Achievement = math achievement in 9th grade. SES = socioeconomic status. ATC = alternative teacher certificate. STEM = science, technology, engineering, and mathematics. FE = fixed effects.

Appendix Table 6

Associations Between Alternative Teacher Certification and Classroom Learning Environments across Teacher Characteristics

Variables	Teachers Make Subject Interesting							Techers Make Subject Easy to Understand						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
ATC	0.015	-0.021	0.030	0.035	-0.008	0.059	0.106	-0.004	-0.039	0.024	0.023	-0.018	0.054	0.062
(ref. Traditional)	(0.058)	(0.042)	(0.055)	(0.066)	(0.052)	(0.048)	(0.082)	(0.052)	(0.035)	(0.047)	(0.054)	(0.046)	(0.042)	(0.068)
ATC * Female teacher	-0.052							-0.027						
	(0.071)							(0.063)						
ATC * Teacher of color		0.058							0.144					
		(0.103)							(0.091)					
ATC * Graduate degree			-0.083							-0.083				
			(0.066)							(0.060)				
ATC * STEM				-0.071							-0.063			
				(0.075)							(0.064)			
ATC * Experience					-0.000							-0.000		
					(0.005)							(0.004)		
ATC* Math						-0.169**							-0.175**	
(ref. science)						(0.061)							(0.054)	
ATC * Math Course (Regular)														-0.091
							-0.112							
(ref. remedial)							(0.086)							(0.072)
ATC * Math Course							-0.159							-0.082
(Advanced)														
							(0.094)							0.081
Student FE	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Subject FE	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Teacher Controls	X	X	X	X	X	X	X	X	X	X	X	X	X	X
N (student-subject)	20040	20040	20040	20040	20040	20040	20040	20070	20070	20070	20070	20070	20070	20070

Source. High School Longitudinal Study of 2009 (HSLS:09). * p<0.05 ** p<0.01

Note. Standard errors in parentheses at the school level. The observation numbers have been rounded to the nearest 10 to meet disclosure risk requirements. Achievement = math achievement in 9th grade. SES = socioeconomic status. ATC = alternative teacher certificate. STEM = science, technology, engineering, and mathematics. FE = fixed effects.