FEATURE ARTICLES

STEM Pathways of Rural and Small-Town Students: Opportunities to Learn, Aspirations, Preparation, and College Enrollment

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Using the nationally representative High School Longitudinal Study of 2009 (HSLS:09), this study documents that rural and small-town students were significantly less likely to enroll in postsecondary STEM (science, technology, engineering, and mathematics) degree programs, compared with their suburban peers. This study also shows that schools attended by rural and small-town students offered limited access to advanced coursework and extracurricular programs in STEM and had lower STEM teaching capacity. Those opportunities to learn in STEM were linked to the widening geographic gaps in STEM academic preparation. Overall, our findings suggest that during high school rural and small-town students shifted away from STEM fields and that geographic disparities in postsecondary STEM participation were largely explained by students' demographics and precollege STEM career aspirations and academic preparation.

Keywords: adolescence; descriptive analysis; disparities; high schools; longitudinal studies; observational research; regression analyses; rural education; science education; survey research

In the United States, an increasing number of occupations require high levels of proficiency in science, technology, engineering, and mathematics (STEM) subjects, creating a pressing need to attract and retain young students from all backgrounds in STEM fields (National Science Board, 2020). To date, research and policy initiatives have addressed the underrepresentation of specific demographic groups such as women, racial/ethnic minorities, and persons with disabilities within STEM fields (National Science Foundation [NSF], 2019). However, little attention has been given to STEM participation among geographically defined populations, particularly rural and small-town students, who account for approximately 30% of the student population in the United States (National Center for Education Statistics [NCES], 2017) and face unique, geographically linked structural opportunities and barriers that shape their educational and occupational pathways (Agger et al., 2018; Hillman & Boland, 2019; Schmuck & Schmuck, 1993; Wells et al., 2019).

Rural and small-town students, who grow up outside of urban areas in places with lower population sizes and densities (NCES, n.d.), share similar social and educational experiences. In contrast to their city and suburban counterparts, rural and small-town students may encounter fewer college graduates, limited access to high-speed internet, and fewer job opportunities (Carr & Kefalas, 2009; Hunter et al., 2020) although they tend to benefit from close-knit relationships within families, schools, and communities (Byun et al., 2012; Lyson, 2002). Furthermore, prior research has documented that rural students tend to lack opportunities to learn (OTL) in STEM, including limited access to advanced math coursework (Anderson & Chang, 2011; Irvin et al., 2017; Reeves, 2012) and STEM-oriented career-advising support (Grimes et al., 2019). Although existing work has documented limited STEM OTL for rural students, it is still unclear how OTL in STEM are longitudinally associated with STEM career aspirations and postsecondary STEM degree enrollment for rural students. Current STEM education research has also neglected small-town students who face both similar and distinct challenges in their STEM OTL and pathways, compared with their rural peers.

The present study addresses these research gaps by systematically examining STEM OTL and pathways for rural and

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small-town students using the nationally representative High School Longitudinal Study of 2009 (HSLS:09). The first aim of this study is to determine geographical population-based estimates of STEM career aspirations, academic preparation, and college enrollment, which serve as key indicators for identifying differential STEM pathways for rural and small-town students. Building on the theoretical perspectives of OTL, the second aim of this study is to investigate geographic gaps in access to various in- and out-of-school STEM OTL (e.g., advanced math course offerings and after-school science programs). The third aim of this study is to explore whether disparities in STEM pathways among rural and small-town students can be explained by variations in individual characteristics and access to STEM-related OTL. The findings from this work are critical for informing policy and practice in addressing geographic disparities in STEM education and workforce development.

STEM Pathways: Aspirations, Preparation, and College Enrollment

Several prominent theories in psychology and sociology establish foundations for conceptualizing and analyzing the pathways to attaining a STEM career. Drawing on vocational psychology and life span developmental psychology perspectives (Vondracek et al., 1986), career development may be understood through an interdisciplinary, life span developmental, and contextual framework. Super (1980) describes career development as a function of one's vocational self-concept and multiple individual and contextual factors that shape lifelong career choices. Similarly, social cognitive career theory, which is widely used in studying STEM pathways (e.g., Chan et al., 2020; Grigg et al., 2018; Wang, 2013), underscores the critical roles of self-efficacy beliefs, expectations, interests, choice actions, and contextual supports and barriers (Lent et al., 2010). According to the social psychological model of status attainment (Blau & Duncan, 1967; Sewell et al., 1969), attaining a prestigious occupation—such as a high-skill and high-paying job in a STEM field—involves two major developmental processes: (1) the formation of educational and occupational aspirations and (2) academic preparation and educational attainment. Collectively, these theories suggest that STEM career aspirations and preparation, shaped by changing contexts, are important for STEM career pathways.

In the empirical literature on STEM career attainment, a substantial body of research has demonstrated that having *STEM career aspirations* in adolescence is one of the strongest determinants of completing a STEM college degree (Legewie & DiPrete, 2014; Tai et al., 2006), which is an important step toward pursuing a career in STEM fields. Intent to major in STEM while in high school—a proxy of STEM career aspirations—has a larger effect on STEM major enrollment than achievement scores and motivational factors in math and science subjects (Wang, 2013). Thus, the execution of STEM educational/occupational aspirations appears to be a central process in STEM pathways. STEM career aspirations, however, are quite volatile among adolescents over time (Mau, 2003; Sadler et al., 2012; Saw et al., 2018). Therefore, when examining geographic variation in STEM pathways, it is critical to explore changes in STEM career aspirations among adolescents across geographic areas and what factors are associated with these changes in various geographies.

Although each individual may have their own unique pathway leading to a STEM career, *enrollment in a postsecondary STEM degree program* is an important defining milestone of STEM pathways and can be conceptually and empirically considered a "STEM entrance" (Chen & Weko, 2009). Academic preparation during secondary schooling is particularly crucial for enrolling in a postsecondary STEM degree program (Tyson et al., 2007; Wang, 2013). *STEM-focused academic preparation* in secondary schooling, as measured by the completion of advanced STEM coursework such as Advanced Placement (AP) and International Baccalaureate (IB) math and science courses, is associated with increased interest in STEM careers and likelihood of choosing a STEM major in college (e.g., Conger et al., 2021; Tyson et al., 2007; Warne et al., 2019). Academic achievement, specifically in math and science, represents another key measure of STEM academic preparation in secondary schooling that is positively related to STEM interest and career aspirations (Riegle-Crumb et al., 2011; Saw & Chang, 2018), college major choice in STEM (Wang, 2013), and STEM degree attainment (Xie & Killewald, 2012).

At the postsecondary level, the type of institution at which students begin their postsecondary education (i.e., 2- or 4-year institutions), could influence their STEM pathways (González Canché, 2017; Wang, 2015). At 2-year institutions, some STEM programs may be aligned with those at 4-year institutions, whereas some 2-year programs may focus more on developing career and technical skills and offer noncredit courses (Hagedorn & Purnamasari, 2012). In some cases, depending on the type of program in which a student is enrolled, beginning college at a 2-year institution could negatively affect later STEM baccalaureate success (Wang, 2015) and employment outcomes (González Canché, 2017). Given the fact that approximately 65% of rural students attend 2-year institutions at some point during their college careers (Byun et al., 2017), it is important to parse out how higher education opportunities tied to geography (Reyes et al., 2019) and college experience shape varying postsecondary STEM trajectories.

STEM Opportunities to Learn in Rural and Small-Town Areas

According to social cognitive career theory, interest in a choice action is a product of self-beliefs and learning experiences; therefore, STEM career intent and attainment is tied to not only STEM achievement and motivational factors but also STEM learning contexts and opportunities (Chan et al., 2020; Grigg et al., 2018; Lent et al., 2010; Wang, 2013). Compared with their city and suburban counterparts, rural and small-town students experience very different STEM learning environments and opportunities. Local labor markets and family contexts in rural and small-town areas could steer young students toward (or away from) particular industries or occupations (Petrin et al., 2014). The occupations that rural and small-town students are exposed to, and the information channels and social capital they experience, affect their educational and career aspirations and choices (Agger et al., 2018; Byun et al., 2012; Johnson, 2017; Saw, 2020; Wells et al., 2019).

For rural and small-town schools, being geographically remote may contribute to barriers and limited opportunities in terms of STEM-related teaching and learning. Students' educational and career outcomes are highly dependent on their OTL, or learning circumstances and resources in school, family, and community contexts (McDonnell, 1995; McPartland & Schnieder, 1996; Schmidt & Maier, 2009). OTL is a useful theoretical and empirical construct for quantifying and understanding the differences in STEM OTL. This is true across contexts and geographies and may help explain possible geographic variation in STEM aspirations, preparation, and postsecondary enrollment.

Course offerings are one prime dimension of OTL that is associated with student academic achievement (Gamoran, 1989; Lee et al., 1997). Many rural schools operate with reduced budgets that limit *advanced course offerings* and *extracurricular programs* in STEM (Anderson & Chang, 2011; Irvin et al., 2017; Peterson et al., 2015; Reeves, 2012), which may negatively affect students' motivation in STEM (Wang, 2015). A growing body of research has also reported that there are demographic disparities in access to out-of-school STEM learning opportunities, which are related to students' motivation, course taking, and college major choice in STEM (Chan et al., 2020; Saw et al., 2019; Saw et al., in press).

Instructional capacity is another important dimension of OTL and includes teachers' professional qualifications, experiences, and knowledge (Darling-Hammond, 2000; Hill et al., 2005). Teachers, especially those skilled in math and science, are a foundational school resource that play a key role in student outcomes (Clotfelter et al., 2010; Xie et al., 2015). However, structural barriers to recruiting and retaining qualified teachers in remote areas persist, namely, the remote locations of schools and uncompetitive salaries (Covay Minor et al., 2019; Peterson, 2017). Given the tight-knit nature of rural and small-town communities (Byun et al., 2012; Lyson, 2002), the opportunity to learn from highly skilled math and science teachers and role models may be critical to the persistence of rural and small-town students in STEM fields.

While there is a significant body of research dedicated to schooling and STEM education in rural areas (e.g., Peterson et al., 2015; Reeves, 2012; Tieken, 2014), those who live and attend school in small towns are often overlooked (Knox & Mayer, 2013). Building on and extending the existing, limited literature on STEM education in rural and small-town areas, this study examines three specific research questions (RQ):

Research Question 1: To what extent do STEM pathways—as measured by STEM career aspirations, academic preparation, and college enrollment—differ for rural and small-town students, compared with their suburban peers?

Research Question 2: To what extent do access to in- and out-of-school STEM OTL—as measured by advanced coursework offerings, instructional capacity, and extracurricular program offerings in STEM—differ for rural and small-town students, compared with their suburban peers?

Research Question 3: To what extent do variations in demographics and in access to in- and out-of-school STEM OTL explain the differences in STEM pathways for rural and small-town students, compared with their suburban peers?

Methods

Data and Sample

This study used data from the HSLS:09, conducted by the NCES, which was specifically designed to explore individual and contextual factors associated with student educational trajectories and outcomes, with a focus on STEM. HSLS:09 began with a nationally representative sample of ninth graders in fall 2009 and followed them through 11th grade (in spring 2012), high school graduation (in summer 2013), and postsecondary education and the labor market (in 2016). HSLS:09 is the most recent longitudinal study that can provide information on the STEM career aspirations, academic preparation, and postsecondary enrollment of a nationally representative sample of high school students across rural, small-town, suburban, and city areas. Another important benefit of HSLS:09 is its rich survey, transcript, and administrative data on students, teachers, and schools, which allows for examination of the extent to which an array of in-school and out-of-school STEM-OTL indicators explain possible geographic disparities in STEM pathways.

The HSLS:09 sample was generated through a two-stage sampling design with schools selected first and the students within those schools from the target population—ninth graders in the fall semester of the 2009–2010 school year—selected second (21,444 students from 944 schools participated in the 2009 base-year survey). In this study, the analytic sample was limited to the first-time ninth graders from the base-year sample (n = 20,242). It consisted of 33.7% suburban, 31.5% city, 23.4% rural, and 11.5% small-town students (weighted estimates).[1]

Measures

Students were identified as having *STEM career aspirations* if, in the first two waves of the HSLS:09 (in early ninth grade and late 11th grade), they reported that the occupation they expected to have at age 30 years was in life and physical sciences, engineering, mathematics, architecture, or information technology industries. Students' *STEM academic preparation* on entering high school was measured by their (a) math standardized test score in early ninth grade, (b) self-reported high school–level math course taken in eighth grade (i.e., algebra II, trigonometry, geometry, or precalculus), and (c) self-reported high school–level science course taken in eighth grade (i.e., biology, chemistry, physics, or pre-AP or pre-IB biology). Students' STEM academic preparation toward the end of high school was assessed by their (a) math standardized test score in late 11th grade, (b) earned credits in AP/IB math courses, and (c) earned credits in AP/IB science courses (based on the transcript data collected in 2014). *STEM college enrollment* was operationalized using the self-reported enrollment status in postsecondary STEM degree programs, surveyed in 2016.

A series of measures of *in-school and out-of-school STEM OTL*, based on school administrator and math/science teacher surveys administered in 2009, were examined in this analysis.[2] A first set of STEM-OTL indicators measured whether a school offered certain advanced math and science courses on-site, including (a) calculus; (b) AP calculus (AB); (c) AP calculus (BC); (d) IB calculus; (e) AP statistics; (f) advanced biology, biology II, AP, or IB; (g) advanced chemistry, chemistry II, AP, or IB; and (h) advanced physics, physics II, AP, or IB. A second set of STEM-OTL indicators served as proxies of math and science teaching capacity in a school, including (a) percentage of math/science teachers, (b) math teachers' perceived self-efficacy, (c) math teachers' perceived professional learning communities, (d) science teachers' perceived self-efficacy, (e) science teachers' perceived professional learning communities, and (f) required teacher professional development focused on how students learn math or science. A third set of STEM-OTL indicators assessed whether a school provided specific extracurricular learning opportunities in STEM—(a) holding schoolwide math/science fairs, workshops, or competitions; (b) informing students about regional or state math/science contests, websites, or blogs; (c) sponsoring a math/science after-school program; and (d) partnering with Mathematics Engineering Science Achievement or similar enrichment-model programs to provide math/science academic development activities and services to students.

The HSLS:09 collected a number of key measures on student *demographic characteristics*, including gender, race/ethnicity, socioeconomic status (SES), immigration generation, and disability status.[3] Online appendix Tables A1 and A2 (available on the journal website) present summary statistics for all variables and demographic characteristics by geographic locale.

Analytic Strategy

In the first set of analyses, we employed ordinary least squares models and linear probability models (LPM; for dichotomous outcomes)[4] to estimate the population (or raw) gaps in STEM career aspirations, academic preparation, postsecondary enrollment, and in- and out-of-school STEM OTL at the high school level (Y_i) by geographic locale:

$$Y_i = \beta_0 + \beta_1 Rural_i + \beta_2 Town_i + \beta_3 City_i + \varepsilon \qquad (1)$$

The coefficients of interest are β_1 and β_2, which can be interpreted as the geographic group differences in STEM measures for rural and small-town students (i), respectively, compared with their suburban counterparts (i.e., the reference group; the highest STEM participation group). City student samples were included in our analyses only for the purpose of improving the precision of estimation although they were not the group of interest, as they face different environment-specific opportunities and constraints in their STEM education and pathways.

In the second set of analyses, we employed block-entry hierarchical regression models to quantify the extent to which geographic disparities in STEM career aspirations and academic preparation in late high school (*STEMA/P*) can be explained by (a) demographic characteristics (*DEM*), (b) pre–high school STEM career aspirations and preparation (*preHS*), and (c) STEM OTL in high school (*HSOTL*). The full regression model is specified as:

$$STEMA/P_i = \beta_0 + \beta_1 Rural_i + \beta_2 Town_i + \beta_3 City_i + DEM_i\Gamma_1^{'} + preHS_i\Gamma_2^{'} + HSOTL_i\Gamma_3^{'} + \varepsilon \qquad (2)$$

In the third set of analyses, block-entry hierarchical regression models were used to estimate whether and to what extent the geographic gaps in postsecondary STEM degree enrollment can be explained by *DEM*, *preHS*, *HSOTL*, and *STEM-A/P*. The full regression model is specified as

$$STEM\ major_i = \beta_0 + \beta_1 Rural_i + \beta_2 Town_i + \beta_3 City_i + DEM_i\Gamma_1^{'} + preHS_i\Gamma_2^{'} + HSOTL_i\Gamma_3^{'} + STEMA/P_i\Gamma_4^{'} + \varepsilon \qquad (3)$$

In all block-entry hierarchical regression models, missing indicators were created and included in the models to account for missing data (Blake et al., 2020; Chiou et al., 2019).[5] Joint hypotheses tests (*F* tests) were conducted to determine whether a given block of predictors has explanatory power in predicting a specific outcome, net of baseline or restricted models (Wooldridge, 2019). All estimates were weighted by corresponding cross-sectional or longitudinal weights (i.e., W1STUDENT, W2W1STU, W3W1W2STUTR, and W4W1W2W3STU) provided by the HSLS:09, such that the results can be generalized to the population of first-time ninth graders in the United States in the fall of 2009. Standard errors estimates were adjusted using the balanced repeated replication method to account for HSLS:09's complex sampling design, including unequal selection probabilities, stratification, and clustering (Duprey et al., 2018). We caution against causal inferences of the coefficients on the geographic groups, which are not policy-manipulable (Holland, 1986; Johnson, 2001), and all other predictors, which we view as proxies for a broad set of individual and contextual factors.

Results

Geographic Disparities in STEM Career Aspirations, Academic Preparation, and College Enrollment

The first purpose of this study was to investigate differences in STEM pathways among students across geographic locations, using indicators of students' career aspirations, academic preparation, and postsecondary enrollment in STEM. Our results showed that considerable differences in STEM pathways by geographical locations existed, particularly when comparing rural and small-town high school students with their suburban peers (see Table 1). Whereas rural and suburban students reported similar percentages of interest in STEM careers (11.6% vs. 11.7%) on entering high school, evidence indicates that a rural–suburban gap in STEM career aspirations emerged by the end of 11th grade (8.9% rural vs. 10.5% suburban—statistically significant at the critical level of 10%). In contrast, an

Table 1
Geographic Disparities in STEM Career Aspirations, Academic Preparation, and College Enrollment

	Suburban (reference group)		Rural vs. Suburban		Small Town vs. Suburban		City vs. Suburban	
STEM Pathway	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Pre-/early HS aspirations and preparation								
STEM career aspirations in early 9th grade	.117	(.006)	−.001	(.009)	−.025*	(.010)	.002	(.010)
Math achievement in early 9th grade	.053	(.032)	−.094*	(.046)	−.247***	(.068)	−.095	(.060)
HS-level math taken in 8th grade	.051	(.005)	−.024*	(.010)	−.031***	(.007)	.001	(.009)
HS-level science taken in 8th grade	.055	(.007)	−.010	(.012)	−.031**	(.009)	.002	(.010)
Late HS aspirations and preparation								
STEM career aspirations in late 11th grade	.105	(.006)	−.016†	(.009)	−.007	(.011)	−.002	(.010)
Math achievement in late 11th grade	.694	(.035)	−.134*	(.053)	−.283***	(.060)	−.099	(.075)
Earned credits in AP/IB math	.208	(.017)	−.071*	(.028)	−.112***	(.025)	.020	(.030)
Earned credits in AP/IB science	.232	(.016)	−.100***	(.027)	−.165***	(.023)	.015	(.027)
Postsecondary STEM degree enrollment								
2-year college	.032	(.005)	−.001	(.006)	−.005	(.009)	.011	(.008)
4-year college	.134	(.009)	−.038**	(.013)	−.030†	(.017)	−.024†	(.014)
2- and 4-year college	.166	(.009)	−.040**	(.014)	−.035*	(.017)	−.013	(.015)

Note. Each row reports results from a regression model estimating the mean differences across geographic groups (without controlling for demographic characteristics). Standard errors were computed using the balanced repeated replication method. Data were weighted to be generalizable to the population of first-time ninth graders in the United States in the fall of 2009. HS = high school; STEM = science, technology, engineering, and mathematics; AP = Advanced Placement; IB = International Baccalaureate; β = coefficient.
†$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

opposite trend emerged between small-town and suburban students. While small-town students reported significantly lower percentages of interest in a STEM career than their suburban counterparts (9.2% vs. 11.7%) in early 9th grade, the small-town–suburban gap narrowed substantially and was no longer statistically significant toward the end of high school.

Compared with their suburban peers, both rural and small-town students appeared to be relatively academically underprepared in STEM subjects at the beginning and toward the end of high school. In early ninth grade, rural and small-town students, respectively, scored 0.094 and 0.247 standard deviations lower than their suburban counterparts on math assessment tests. The rural–suburban and small-town–suburban gaps in math achievement widened to 0.134 and 0.283 standard deviations by the end of 11th grade. Compared with suburban students (5.1%), fewer rural (2.4%) and small-town (3.1%) students reported having taken a high school–level math course when in eighth grade.[6] Small-town students also reported lower percentages of completing a high school–level science course when in 8th grade, compared with their suburban counterparts (2.4% vs. 5.5%). By the end of high school, while suburban students earned, on average, 0.208 and 0.232 credits in AP/IB math and science, respectively, rural students only earned, on average, 0.137 and 0.132 credits in the two subjects. Small-town students earned, on average, even fewer credits in AP/IB math (0.096 credits) and science (0.067 credits).

When surveyed in 2016, about 3 years after high school graduation for most HSLS:09 respondents, approximately 16.6% of suburban students reported enrolling in a postsecondary STEM degree program at either a 2- or 4-year college, as opposed to only 12.6% and 13.1% of rural and small-town students, respectively (an approximately 3.5% to 4.0% geographic gap). The geographic disparities in postsecondary STEM degree enrollment were predominantly observed at 4-year colleges, not at 2-year colleges, where less than one quarter of undergraduate students were pursuing a postsecondary STEM degree (please see online appendix Table A3, available on the journal website, for results from multinomial logistic regression models estimating the likelihood of enrolling in a STEM or non-STEM degree program at 2- and 4-year colleges). Additionally, results from supplementary models controlling for key demographic characteristics (please see online appendix Table A4, available on the journal website) show similar patterns to the primary findings shown in Table 1, although the magnitudes of geographic gaps in most indicators of STEM pathways were slightly reduced.

Geographic Disparities in STEM Opportunities to Learn in High School

The second purpose of this study was to update and extend previous work on the geographic disparities in STEM OTL, which may help explain the differences in STEM pathways—STEM career aspirations, academic preparation, and postsecondary enrollment—of students from different geographic locations. Consistent with prior evidence, our results indicate that rural high school students had significantly fewer opportunities to take advanced math and science courses, compared with their suburban counterparts (see Table 2). For example, rural students were about 20 percentage points less likely to have access to a calculus course on-site compared with their suburban peers

Table 2
Geographic Disparities in STEM Opportunities to Learn in High School

STEM Opportunities	Suburban (reference group) β	Suburban (reference group) *SE*	Rural vs. Suburban β	Rural vs. Suburban *SE*	Small Town vs. Suburban β	Small Town vs. Suburban *SE*	City vs. Suburban β	City vs. Suburban *SE*
Courses offered on-site								
Calculus	.829	(.027)	–.202**	(.061)	–.110	(.071)	–.047	(.046)
AP calculus (AB)	.855	(.028)	–.240***	(.060)	–.113	(.069)	–.054	(.052)
AP calculus (BC)	.526	(.040)	–.281***	(.076)	–.311**	(.088)	–.142*	(.065)
IB calculus	.077	(.023)	–.047	(.028)	–.057*	(.026)	.034	(.033)
AP statistics	.605	(.038)	–.336***	(.062)	–.389***	(.055)	–.118†	(.067)
Advanced biology, biology II, AP, or IB	.742	(.035)	–.235***	(.065)	–.205**	(.076)	.021	(.061)
Advanced chemistry, chemistry II, AP, or IB	.705	(.032)	–.232***	(.065)	–.367***	(.075)	–.020	(.060)
Advanced physics, physics II, AP, or IB	.631	(.036)	–.372***	(.052)	–.530***	(.051)	–.151*	(.073)
Teaching capacity								
Percentages of math/science teachers	.259	(.003)	–.004	(.010)	–.020**	(.007)	–.009	(.009)
Math professional learning communities	.071	(.050)	–.049	(.090)	–.210†	(.110)	–.106	(.079)
Math teacher's self-efficacy	.106	(.056)	–.073	(.094)	–.122	(.120)	–.203*	(.099)
Science professional learning communities	–.055	(.052)	.093	(.096)	.037	(.115)	.135	(.093)
Science teacher's self-efficacy	.065	(.047)	–.064	(.100)	–.276**	(.092)	–.018	(.092)
Professional development in math/science	.629	(.041)	–.122†	(.069)	–.079	(.077)	–.032	(.080)
Extracurricular programs/activities								
Math/science fairs/workshops/competitions	.466	(.037)	–.140*	(.060)	–.144†	(.079)	–.070	(.058)
Math/science contests/websites/blogs	.755	(.032)	–.174*	(.073)	–.159*	(.079)	–.033	(.061)
Math/science after-school programs	.574	(.037)	–.141*	(.061)	–.034	(.081)	.031	(.068)
Math/science enrichment programs	.240	(.030)	–.088†	(.045)	–.077	(.065)	.102	(.075)

Note. Each row reports results from a regression model estimating the mean differences across geographic groups (without controlling for demographic characteristics). Standard errors were computed using the balanced repeated replication method. Data were weighted to be generalizable to the population of first-time ninth graders in the United States in the fall of 2009. STEM = science, technology, engineering, and mathematics; AP = Advanced Placement; IB = International Baccalaureate; β = coefficient.
†$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

(62.7% vs. 82.9%). The rural–suburban disparities in course offerings, favoring suburban students, were also observed in AP calculus (AB/BC), AP statistics, and advanced biology, chemistry, and physics courses (ranging from 23.2 to 37.2 percentage point gaps). Our analysis adds new evidence to the literature by showing that small-town students, similar to their rural peers, generally had less access to advanced math and science courses in high school. Specifically, compared with their suburban counterparts, significantly fewer schools attended by small-town students offered AP calculus (BC), IB calculus, AP statistics, and advanced science courses in biology, chemistry, and physics (ranging from 5.7% to 53.0 percentage point gaps).

Our analyses also provide a new set of empirical evidence showing that rural and small-town high school students had less OTL in STEM in terms of teaching capacity and extracurricular programs/activities in STEM (see Table 2). Schools attended by rural students were less likely to require their teachers to participate in professional development focused on how students learn math or science (a 12.2 percentage point gap—statistically significant at the critical level of 10%). Schools attended by small-town students tended to have lower percentages of math and science teachers (a 2 percentage point gap), lower levels of perceived professional learning communities among math teachers (a 21.0 percentage point gap—statistically significant at the critical level of 10%), and lower levels of self-efficacy reported by science teachers (a 27.6 percentage point gap), compared with schools attended by suburban students. Furthermore, compared with schools in suburban areas, schools located in both rural and small-town settings were less likely (ranging from 14.0 to 17.4 percentage point gaps) to hold math or science fairs, workshops, or competitions; inform students about math or science contests, websites, blogs, or other online programs; and sponsor a math or science after-school program.

Explaining Geographic Disparities in STEM Career Aspirations, Academic Preparation, and College Enrollment

The results of the previous sections demonstrate that substantial geographic gaps in STEM career aspirations, academic preparation, and college enrollment existed, as well as disparities in STEM OTL at the high school level. Our last set of analyses, which employed hierarchical regression models, explored the extent to which high school STEM OTL, along with demographic characteristics and pre–high school factors, explained the geographic differences in the STEM pathways from high

Table 3
Explaining Geographic Disparities in STEM Career Aspirations and Academic Preparation in Late High School

	Suburban (reference group)		Rural vs. Suburban		Small Town vs. Suburban		City vs. Suburban		Joint Hypotheses Test
STEM Pathway	β	SE	β	SE	β	SE	β	SE	*F*
STEM career aspirations (late 11th grade)									
M1: without controls	.105	(.006)	−.016†	(.009)	−.007	(.011)	−.002	(.010)	
M2: M1 + demographic controls	.170	(.009)	−.015†	(.009)	−.002	(.011)	.006	(.009)	25.14***
M3: M2 + pre-HS controls	.120	(.008)	−.012	(.008)	.007	(.011)	.004	(.008)	37.56***
M4: M3 + HS-OTL controls	.124	(.025)	−.011	(.009)	.010	(.011)	.003	(.008)	1.11
Math achievement (late 11th grade)									
M1: without controls	.694	(.035)	−.134*	(.053)	−.283***	(.060)	−.099	(.075)	
M2: M1 + demographic controls	.998	(.037)	−.108**	(.038)	−.190***	(.044)	−.009	(.048)	166.36***
M3: M2 + pre-HS controls	.763	(.027)	−.062*	(.028)	−.070†	(.037)	.001	(.029)	663.93***
M4: M3 + HS-OTL controls	.659	(.093)	−.067*	(.029)	−.068†	(.035)	.007	(.029)	1.60†
Earned credits in AP/IB math									
M1: without controls	.208	(.017)	−.071*	(.028)	−.112***	(.025)	.020	(.030)	
M2: M1 + demographic controls	.236	(.020)	−.047†	(.025)	−.066**	(.025)	.035	(.025)	31.32***
M3: M2 + pre-HS controls	.149	(.019)	−.030	(.022)	−.029	(.024)	.033	(.023)	41.33***
M4: M3 + HS-OTL controls	−.054	(.069)	−.016	(.023)	−.011	(.024)	.041†	(.022)	1.22
Earned credits in AP/IB science									
M1: without controls	.232	(.016)	−.100***	(.027)	−.165***	(.023)	.015	(.027)	
M2: M1 + demographic controls	.231	(.019)	−.072**	(.025)	−.110***	(.022)	.032	(.022)	30.99***
M3: M2 + pre-HS controls	.155	(.017)	−.057*	(.023)	−.077***	(.020)	.031	(.021)	33.14***
M4: M3 + HS-OTL controls	−.014	(.069)	−.041†	(.022)	−.057**	(.019)	.033	(.021)	1.94*

Note. Each panel reports results of regression models predicting a specific indicator of STEM aspiration and preparation with increasing sets of controls and indicators of missing data that were created to account for missing patterns of various predictors. Standard errors were computed using the balanced repeated replication method. Data were weighted to be generalizable to the population of first-time ninth graders in the United Stataes in the fall of 2009. STEM = science, technology, engineering, and mathematics; M = model; HS = high school; OTL = opportunity-to-learn; β = coefficient; AP = Advanced Placement; IB = International Baccalaureate.
†$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

school to college. As shown in Table 3, the marginal gap in STEM career aspirations between rural and suburban students by the end of 11th grade can partially be explained by an extensive set of demographic, pre–high school, and high school STEM-OTL factors. The geographic differences in math achievement in late high school can partially be explained by demographic characteristics and pre–high school factors (slightly more than half of the rural–suburban gap and three quarters of the small-town–suburban gap). However, high school STEM OTL factors cannot further explain the residual geographic gaps in math performance (the joint test was not statistically significant).

On one hand, the geographic disparities in earned credits in AP/IB math were also mostly explained by demographic and pre–high school factors. The joint test of OTL variables was not statistically significant, indicating that high school OTL factors do not help explain the differences in the number of earned credits in AP/IB math among students across geographic areas. On the other hand, all included demographic, pre–high school, and high school STEM-OTL measures only accounted for some but not all of the geographic differences in earned credits in AP/IB science. One possible explanation for this discrepancy between earned math and science credits is that our models controlled for math test scores assessed in early ninth grade, not science test scores, which were not available in the HSLS:09 data (although the highest science course completed in eighth grade was included).

Table 4 reports results from a series of hierarchical regression models that attempted to identify which factors explained the geographic disparities in STEM college enrollment. After accounting for demographic characteristics (Model 2), the suburban–rural gap in postsecondary STEM degree enrollment reduced by about 30% (from 4.0 to 2.8 percentage points), whereas the suburban–small-town gap reduced by approximately 71% (from 3.5 to 1.0 percentage points) and became not statistically significant. The suburban–rural gap in postsecondary STEM degree enrollment can also be partially explained by pre- and early high school factors, including math and science courses taken in eighth grade, math ability, and STEM career aspirations in early ninth grade (Model 3). Interestingly, the extensive set of high school STEM-OTL factors included in this study did not *directly* help explain the suburban–rural disparities in postsecondary STEM degree enrollment, net of demographic characteristics, and pre–high school preparation and aspirations in STEM (Model 4). Our final model demonstrated that STEM career aspirations and academic preparation assessed at the end of high school helped explain the remaining suburban–rural gap in postsecondary STEM degree enrollment (Model 5). Taken together, the disparities in

Table 4
Explaining Geographic Disparities in Postsecondary STEM Degree Enrollment

	Suburban (reference group)		Rural vs. Suburban		Small Town vs. Suburban		City vs. Suburban		Joint Hypotheses Test
STEM Pathway	β	*SE*	β	*SE*	β	*SE*	β	*SE*	*F*
STEM degree enrollment									
M1: without controls	.166	(.009)	–.040**	(.014)	–.035*	(.017)	–.013	(.015)	
M2: M1 + demographic controls	.219	(.013)	–.028*	(.013)	–.010	(.016)	–.003	(.014)	25.65***
M3: M2 + pre-HS controls	.171	(.013)	–.022†	(.012)	.006	(.016)	–.006	(.013)	37.99***
M4: M3 + HS-OTL controls	.201	(.041)	–.022†	(.012)	.003	(.017)	–.008	(.013)	1.15
M5: M4 + HS-A/P controls	.147	(.047)	–.011	(.010)	.007	(.016)	–.015	(.013)	41.44***

Note. Each panel reports results of regression models predicting postsecondary STEM degree enrollment with increasing sets of controls and indicators of missing data that were created to account for missing patterns of various predictors. Standard errors were computed using the balanced repeated replication method. Data were weighted to be generalizable to the population of first-time ninth graders in the United States in the fall of 2009. STEM = science, technology, engineering, and mathematics; M = model; HS = high school; OTL = opportunity-to-learn; A/P = STEM aspiration and preparation; β = coefficient.
†$p < .1$. *$p < .05$. **$p < .01$. ***$p < .001$.

postsecondary STEM degree enrollment across geographic areas can largely be explained by students' demographic characteristics and a limited number of key precollege measures on STEM career aspirations and academic preparation.[7]

Discussion

Previously Unreported Underrepresentation of Rural and Small-Town Students in Postsecondary STEM Degree Programs

Analyzing a nationally representative, longitudinal sample of high school students, our study makes several unique contributions to the research and policy literature on rural and small-town education and STEM education and diversity. This study is the first to present national population-based estimates of the underrepresentation of rural and small-town students in postsecondary STEM degree programs (12.6% and 13.1%, respectively, compared with 16.6% for their suburban counterparts), calling attention to a previously unreported issue in STEM access and equity. Considering that STEM occupations are projected to grow nationally by 8.0% by 2029, compared with 3.4% growth for non-STEM occupations (U.S. Bureau of Labor Statistics, 2021), and many rural economies rely on STEM-heavy fields such as agriculture, mining, and manufacturing (Housing Assistance Council, 2012; U.S. Department of Agriculture, 2015), our findings suggest that students living in rural and small-town areas represent an important source for broadening participation in STEM fields and a population deserving of equitable access to STEM education and employment opportunities.

Novel Insights Into STEM Opportunities to Learn and STEM Pathways of Rural and Small-Town Students

Another major contribution of this study is that it presents the first set of national evidence documenting relatively fewer STEM OTL for rural and small-town students in terms of science course offerings, math and science teaching capacity, and STEM extracurricular programs, in addition to previously studied math course offerings. Consistent with several prior studies using national data from the previous decade (Anderson & Chang, 2011; Irvin et al., 2017; Reeves, 2012), our findings indicate that rural high school students in the 2010s continued to have limited access to advanced math courses. Our study extends this body of research by showing that schools attended by both rural and small-town students were less likely to offer advanced science coursework and extracurricular programs in STEM and tended to have lower levels of teaching capacity in math and science, as measured by the percentages of math and science teachers, teacher self-efficacy, and professional development and learning communities. Investigating the geographic disparities in these areas of STEM OTL is important because prior studies have shown that critical antecedents of students' STEM achievement and career pursuit include advanced STEM course completion (Conger et al., 2021; Tyson et al., 2007; Warne et al., 2019), quality of math and science teachers (Clotfelter et al., 2010; Xie et al., 2015), and out-of-school time STEM learning (Chan et al., 2020; Saw et al., 2019).

The rural environment represents a rich context to learn about science, yet rural students' STEM learning opportunities often do not align with the structures and systems of traditional U.S. schools (Avery, 2013; Avery & Kassam, 2011). In our study, the identified lack of STEM OTL for rural students partially explained their relatively lower STEM preparation toward the end of high school, which in turn explained their underenrollment in postsecondary STEM degree programs. Our analyses also indicated that the math achievement gap favoring suburban over rural students substantially widened over time in high school. Collectively, this set of findings suggests that rural students are shifting away from STEM fields somewhere along the high school trajectory with respect to their STEM preparation, which may be a result of a lack of STEM OTL in both formal and informal education contexts throughout their K–12 schooling.

Our study also provides the first national evidence on, and novel insights into, the educational opportunities and STEM pathways of small-town students, a largely understudied group in the literature. Although much diversity exists in their histories and economies, many small towns, like many rural places, developed as market towns or as small manufacturing towns in the industrial era but then shifted due to changing technologies and outsourcing in the late 20th century (Knox & Mayer, 2013). Similar to rural areas, the unique geographies and industries of many small towns make STEM learning particularly relevant; yet as we find, small-town schools have fewer aspects of STEM OTL, compared with suburban schools. Similar to their rural peers, small-town students were also underrepresented in postsecondary STEM degree programs, an underrepresentation which was fully explained by demographic characteristics and pre- and early high school factors.

Limitations and Future Research Directions

There are several limitations to this study, which future research should address. First, this study used the four large and encompassing NCES geographic categories of rural, small town, suburban, and urban, which does not fully account for heterogeneity across and within locations. We recognize the vast diversity in rural and small-town areas and argue that future research should attend to more specific geographic regions as the resources, industries, and cultures present in those regions are distinct. Second, in this current study, we did not examine intersections of geography, race/ethnicity, gender identity, and SES because of a lack of statistical power for those intersectional subgroups. Understanding the STEM experiences of students of color across locales, for example, is particularly important for future research, given the individual and institutional structural racism present in STEM spaces (McGee, 2020). In future work with a larger diverse sample of rural and small-town students, it is vital to include analyses of STEM pathways that attend to students' intersectional identities, particularly those with multiple marginalized identities (Saw et al., 2018).

Third, in our models, the rural– and small-town–suburban gaps in earned credits in AP/IB science were not fully explained, even with an inclusion of an extensive set of predictors. There may be other important influences on these geographic gaps in science education. Future research should examine how other individual and contextual factors can further explain the gaps in science course taking across geographic areas. Fourth, although one important set of findings is that geographic gaps in postsecondary STEM enrollment can be largely explained by students' STEM career aspirations and course completion toward the end of high school (in addition to demographic characteristics), we acknowledge that these motivational and academic preparation factors are endogenous variables of a broad set of individual and contextual factors throughout childhood and adolescence. Future research should identify earlier indicators of student, family, school, and community factors that promote or inhibit rural and small-town students' educational pathways to and through STEM fields.

Research and Policy Implications

Despite these limitations, our findings have important research and policy implications. This study contributes to the literature on vocational psychology and status attainment models in sociology by demonstrating that the levels of career aspirations in STEM *change across individuals and geographic groups over time*. We argue that future research should conceptualize and analyze STEM career aspirations as *dynamic* motivational factors to better understand and monitor the individual and group differences in STEM educational and career trajectories (Mau, 2003; Sadler et al., 2012; Saw et al., 2018). Our study also broadens the research literature on OTL in rural and small-town areas by documenting the geographic disparities in science course offerings, math and science instructional capacity, and STEM extracurricular activities, in addition to previously reported disparities in math course offerings. Future research should explore access to other types of in-school and out-of-school STEM OTL, such as STEM learning opportunities on the internet, place-based learning opportunities within rural and small-town families and communities, and how these OTL facilitate the STEM pathways of geographically diverse students.

In late spring 2021, a bipartisan group of U.S. senators reintroduced the Rural STEM Education Act, which would provide federal support for improving STEM education and research in rural schools (U.S. Senate Committee on Commerce, Science, and Transportation, 2021). Thus, the findings of this national longitudinal study are timely and policy relevant. A key finding from this study was that the geographic gaps in postsecondary STEM degree enrollment essentially disappeared with the inclusion of precollege covariates in addition to demographics. This can help inform appropriate policy and program initiatives that target students' malleable motivational beliefs and academic preparation. Moreover, our findings indicate that the offering of advanced math courses is a larger issue in rural schools, whereas the offering of advanced science courses is a larger challenge in small-town schools. Therefore, *subject-specific* programs and support structures may be beneficial for rural and small-town students. Last, we find that geographic disparities in STEM achievement and course taking toward the end of high school were largely explained by pre–high school factors, suggesting that STEM interventions focused on broadening STEM participation in rural and small-town schools must consider implementation efforts aimed at students in elementary and middle school.

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[1]Suburban, city, rural, and town designations are defined by the NCES based on U.S. Census Bureau definitions that consider how close locales are to urbanized areas (NCES, n.d.).

[2]All variables of in- and out-of-school STEM learning opportunities were measured at the school level, except four teaching capacity variables—math teacher's self-efficacy, math professional learning communities, science teacher's self-efficacy, and science professional learning communities. These were assessed at the teacher level and linked to individual students.

[3]Demographic characteristics are defined by gender identity (1 = *female*, 0 = *male*), race/ethnicity (i.e., White, Black, Hispanic/Latinx, Asian, and other race [including multiracial and Native Americans]), and SES (a composite score constructed by combining measures of parental education, occupations, and income). Based on the self-reported data on the birth country of respondents and their parents, a series of immigration generation indicators were constructed for identifying (a) first-generation immigrants (who were born outside of the United States), (b) second-generation immigrants (who were born in the United States and whose parents were not born in the United States), (c) 2.5-generation immigrants (who were born in the United States and who had one parent that was born in the United States and the other parent who was foreign born), and (d) third-and-higher-generation immigrants (who were born in the United States and whose parents were also born in the United States). To identify students with disabilities, this study used multiple survey items and transcript data from the HSLS:09. First, we used a base-year survey question that asked parents "Has a doctor, health care provider, teacher, or school official ever told you that [your ninth grader] has any of the following conditions?" The response options included seven broad types of disability as defined by the Individuals with Disabilities Education Act (IDEA), including "autism, Asperger's disorder, pervasive developmental disorder, or other autism," "hearing problems or vision problems," "attention deficit disorder (ADD) or attention deficit hyperactive disorder (ADHD)." Second, we used another base-year parental survey question that asked "Does [your ninth grader] currently receive special educational services?" The third piece of information was the high school transcript record on the number of special education credits earned by the students. By combining this information, a set of four indicators for disability status was created, including (a) never (no records of any types of disability), (b) past (who had a past record of disability but was not receiving special educational services in high school), (c) moderate (who received special educational services but did not receive any special education credits in high school), and (d) severe (who received any special education credits [and were placed in special education classrooms] in high school).

[4]The use of LPMs rather than logit or probit models has several advantages. Unlike logit or probit models, which are nonlinear transformations of linear regressions, LPMs require weaker distributional assumptions (Wooldridge, 2019). Nonetheless, additional analyses showed that the results were not sensitive to selection among logit, probit, and LPM (results available on request). While the binary response models may violate the heteroskedasticity assumption, the issue can be addressed by computing robust standard errors in LPMs but not in logit or probit models. More important, coefficients of LPMs are easier and more straightforward to interpret, especially when comparing estimates across models. This advantage of LPMs is particularly critical for this study as one of the research goals is to compare the estimates across locale groups.

[5]Additional analyses using a multiple imputation approach for handling missing values showed similar results (please see online appendix Tables A5 and A6, available on the journal website).

[6]An additional set of analyses classifying algebra I as high school–level math course yielded the same conclusion that fewer rural and small-town students completed high school–level math course by the end of eighth grade, compared with their suburban counterparts.

[7]Considering that rural and small-town high school graduates were less likely to immediately enroll in college and more likely to attend a 2-year college, instead of a 4-year university, compared with their suburban counterparts (National Student Clearinghouse Research Center, 2018), our estimates on geographical gaps in postsecondary STEM degree enrollment may be overestimated. In an additional set of analyses, we limited our sample to those (a) who ever attended a college by 2016 and (b) who ever attended a 4-year college by 2016; the conclusions remained the same although the estimates are less precise due to smaller sample sizes (please see online appendix Table A7, available on the journal website).

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