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STEM Teacher Characteristics and Mobility: Longitudinal Evidence From the American Midwest, 2010 Through 2023

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ABSTRACT

This study examines the demographics, qualifications, and turnover of STEM teachers in Kansas and Missouri—two contiguous, predominantly rural states in the Midwestern region of the United States. The existing literature lacks detailed insights regarding U.S. STEM teachers, especially with recent economic and social changes over the COVID-19 pandemic, and there is particularly limited evidence regarding STEM teachers in the U.S. Midwest. Utilizing large-scale administrative longitudinal data, we filled part of this gap by documenting the characteristics and turnover patterns of STEM teachers in Kansas and Missouri over a 13-year period, from 2010 through 2023. Our analysis shows declining trends among young and early-career STEM teachers, STEM certification, and rising STEM teacher turnover, especially post-COVID-19. We found particularly high turnover rates in urban schools and schools with the highest shares of students of color and poverty. We also found numerous factors of STEM teacher turnover, including salary and employment in schools serving high percentages of minoritized and low-income students, as well as differential turnover patterns among school geographical circumstances. This work is the first comprehensive examination of STEM teachers in Kansas and Missouri. We offer insights into the teacher workforce of the traditionally overlooked U.S. Midwest. Our results suggest important policy implications for sustaining a diverse and qualified STEM teacher workforce in the U.S. amid post-COVID-19 social changes, thereby informing decision making at state and national levels that aim to foster equitable access to high-quality STEM education among students in diverse contexts, while contributing to the U.S.'s long-term economic growth, sustainability, and the world's advancement of STEM education.

1 | Introduction

A diverse and strong labor force in the fields of science, technology, engineering, and mathematics (STEM) is pivotal to the United States' long-term economic growth, security, and global competitiveness (Xie, Fang, and Shauman 2015). However, recent statistics indicate women and people of color remain underrepresented in the U.S. STEM workforce. Women constitute only 34% of the STEM labor force, compared to 52% in non-STEM sectors, while Hispanic and Black workers make up 18% and 12% of the United States' overall workforce but only represent 14% and 9% of STEM workers (National Science Board and National Science Foundation 2021b).

Such demographic imbalances in the current U.S. STEM labor force likely originate, in part, from inequitable access to STEM education in K-12 schools and, thus, opportunity gaps in STEM job markets. In particular, women and students of color exhibit consistently lower participation rates in advanced STEM courses, lower achievement levels, and are less likely to apply for STEM majors in higher education institutions relative to their male and White peers (Bruno and Lewis 2021; Yoon and Strobel 2017).

A significant part of the issue is the lack of diverse backgrounds in the STEM teaching force, as U.S. STEM teachers have historically been more likely to identify as male and White (Ingersoll and May 2012). In contrast, having more female teachers and teachers of color is positively related to the likelihood of female and minoritized students enrolling in advanced STEM courses, and pursuing and completing STEM degrees at post-secondary levels (Bottia et al. 2015; Dee 2004; Egalite, Kisida, and Winters 2015; Grissom, Kabourek, and Kramer 2020; Lim and Meer 2020; Lindsay, Monarrez, and Luetmer 2021; Redding 2019). Having more diverse teachers can also benefit diverse students in non-academic aspects, such as lowering absenteeism, suspensions, and improving socio-emotional development (Cleveland and Scherer 2021; Holt and Gershenson 2019; Lindsay and Hart 2017; Rasheed et al. 2020; Redding 2019).

In addition to demographic characteristics, teacher qualifications are also crucial to student learning in STEM subjects (Harris and Sass 2011; Heck 2007; Henry, Fortner, and Bastian 2012; Hill and Dalton 2013; Mansell 2024; Stewart et al. 2019). However, school administrators consistently report challenges in filling qualified STEM teaching positions compared to other areas (Dee and Goldhaber 2017; Ingersoll and Perda 2010; Sutcher, Darling-Hammond, and Carver-Thomas 2019), especially after the COVID-19 pandemic outbreak (Goldhaber, Falken, and Theobald 2024; Nguyen, Lam, and Bruno 2024). In addition, racially minoritized and socio-economically disadvantaged students are consistently less likely to have access to high-quality STEM teachers (Gray, Taie, and Lewis 2022; Nguyen and Redding 2018; Rodriguez, Nguyen, and Springer 2023), leading to significant disparities in educational opportunities.

Furthermore, retaining diverse and high-quality STEM teachers in schools is essential for fostering the development of all students. High rates of teacher turnover disrupt student learning and impede schools' long-term progress (Allensworth, Ponisciak, and Mazzeo 2009; Carver-Thomas and Darling-Hammond 2017; Hanselman et al. 2016; Ronfeldt, Loeb, and Wyckoff 2013; Simon and Johnson 2015). As we entered the post-COVID-19 era, turnover rates across U.S. states reached historically high levels (Bacher-Hicks, Chi, and Orellana 2023; Bastian and Fuller 2023; Camp, Zamarro, and McGee 2023; Goldhaber and Theobald 2023; Hopkins, Strunk, and Rogers 2023). These higher turnover rates are consistently reported in areas characterized by low-income families and communities of color (Goldhaber and Theobald 2023; Malkus, Hoyer, and Sparks 2015; Marinell and Coca 2013; Williams, Swain, and Graham 2021).

As issues of teacher characteristics, qualifications, and retention become increasingly intertwined, the challenges of enhancing STEM learning opportunities for all students grow more complex. Furthermore, there is a lack of comprehensive analysis of the demographics, qualifications, and turnover of STEM teachers to inform educational policies and interventions that support the advancement of all students in STEM fields. Some studies (e.g., Ingersoll and May 2012; Nguyen and Redding 2018) have described the U.S. STEM teacher workforce using nationally representative survey data, particularly the Schools and Staffing Survey (SASS), which were administered every few years from 1988 to 2012. Such analysis, however, does not encompass the past decade, a period marked by increased policy attention and investment in STEM education (Johnson et al. 2020). These studies rely on cross-sectional data collected at the national level, which lack annual granularity and clarity on how the teacher workforce has responded to major social changes like the COVID-19 pandemic. Such data also fail to capture nuances at the district or school levels or describe certain characteristics that may be unique to individual states or geographical regions, including those in the Midwest.

To date, teacher workforce research has predominantly focused on states with established research resources and data systems, such as California, New York, Texas, or Washington (e.g., Darling-Hammond et al. 2016; Goldhaber and Theobald 2023; Holme et al. 2018; Ronfeldt, Loeb, and Wyckoff 2013), while there is limited knowledge about Midwestern states like Kansas and Missouri (Nguyen 2020b). These two states share similar socio-economic and demographic backgrounds: both states are in general rural and geographically isolated while some of their metropolitan areas disproportionately serve and employ students and teachers of color (Anglum, Manion, and Varkey 2024; Nguyen 2020a, 2020b). In addition, both states contain approximately four times as many students of color as teachers of color, a gap significantly wider than the national average (Swisher 2023). The unique contexts of Kansas and Missouri may make the characteristics of their teacher workforces and turnover patterns distinct from national and regional trends. Their specific geographical and socio-economic conditions can also add complexity to efforts to recruit and retain a strong and diverse STEM teaching force.

Using longitudinal administrative data from Kansas and Missouri spanning from 2010 to 2023, we examine the demographics, qualifications, and turnover of STEM teachers, whom we refer to as secondary teachers whose primary teaching disciplines include mathematics, computer science, and natural sciences, such as biology, chemistry, earth and space science, and physics. We conducted a comprehensive descriptive analysis of the demographic and professional characteristics of STEM teachers in these two Midwestern states, as well as their turnover patterns. Our study also examined how these factors vary among STEM teachers across different school settings and student body characteristics, as well as the extent to which they are associated with STEM teacher turnover. We addressed the following research questions:

RQ1. How have the demographic characteristics and qualifications of public school STEM teachers in Kansas and Missouri changed over the past decade? Do these changes vary across school's locale settings and student body characteristics, including racial/ethnic and socio-economic compositions?

RQ2. To what extent did public school STEM teachers in Kansas and Missouri turn over in the past decade? Do their turnover patterns differ among school locales and student body characteristics, including racial/ethnic and socio-economic compositions?

RQ3. To what extent do school characteristics as well as student racial/ethnic representations and socio-economic conditions predict STEM teacher turnover in Kansas and Missouri?

We addressed the first and second research questions using descriptive analysis and conducted regression analysis to tackle the third research question. Our results suggest the STEM teacher workforce in Kansas and Missouri share similarities with the U.S. national teacher workforce, but at the same time differ in several important ways, including trends in the teachers' demographics and working conditions, while providing evidence of differential turnover patterns between these two outwardly similar states and across school geographical conditions. We contribute significantly to the literature as the first study to provide a thorough examination of STEM teachers in two states of the U.S. Midwest, a region where teacher labor markets have traditionally been underexplored. Our findings have important implications for ongoing policy debates regarding the urgent need to cultivate a diverse and high-quality STEM teacher workforce in the U.S. Midwest. Furthermore, by enhancing the collective understanding of STEM teachers, this research lays the groundwork for future studies and policy initiatives aimed at promoting sustainable and equitable STEM education that is accessible to diverse students across the United States.

2 | Conceptual Framework

Decades of research have examined factors influencing teacher turnover. To address our investigation into how STEM teacher turnover varies by school and student characteristics, we draw on Nguyen and Springer's (2023) conceptual framework for teacher turnover. This framework identifies three domains of teacher attrition factors: personal factors, school factors, and external/policy factors. Teachers' personal factors include demographic characteristics (e.g., age, race, and gender), family backgrounds (e.g., marital status), and teacher qualifications (e.g., experience, certification, and degree). School factors encompass school organizational characteristics (e.g., school size, type, and locale), resources (e.g., class size and expenditure), and student body characteristics (e.g., achievement, discipline, and racial and socio-economic representations). External/policy factors include teacher salary, accountability policy, school improvement interventions, and broad workforce conditions (Nguyen and Springer 2023).

We are particularly interested in examining whether STEM teacher turnover differs by school and student characteristics, with a special focus on locale settings and student racial and socio-economic populations. Identifying such differences, if they exist, may suggest critical implications for addressing disparities in access to sustained and high-quality STEM teachers. Meanwhile, the emphasis on locale settings is especially important to the context of our study, given Kansas and Missouri's unique combinations of remotely rural regions alongside historically industrialized metropolitan areas. Geographical isolations and alternative employment opportunities from nearby industrial hubs may pose challenges to the recruitment and retention of STEM teachers in these states.

Based on the conceptual framework and our research context, we hypothesize turnover among STEM teachers in Kansas and Missouri would differ among school locales and between schools serving a majority of minoritized and impoverished students versus schools serving a majority of White and socio-economically advantaged students. As consistently suggested by the literature, teacher characteristics and working conditions in these varied school settings tend to differ substantially (Bettini et al. 2016; Nguyen 2021; Rodriguez, Nguyen, and Springer 2023) and, thus, could potentially differentiate their turnover patterns. Although our primary interest lies in the second domain—school factors—of Nguyen and Springer's (2023) conceptual framework, we include variables from the other two domains in our analysis as control variables. These include observed teachers' demographic and qualification characteristics (from the first domain), as well as other working environment factors, such as observed school characteristics, teacher salary, and unobservable time- and district-invariant elements (from the second and third domains).

3 | Literature Review

3.1 | STEM Teacher Demographics

The demographic characteristics of STEM teachers are significant to student learning through various mechanisms, such as role-modeling effects and students' preferences for instructional styles (Dee 2004; Ehrenberg, Goldhaber, and Brewer 1995; Foster 1993). Having a teacher of the same gender or race/ethnicity is positively related to student academic achievement and behavior outcomes and can shape their choice of college major and career aspirations (Bottia et al. 2015; Egalite and Kisida 2018; Holt and Gershenson 2019; Lim and Meer 2020; Lindsay and Hart 2017; Rasheed et al. 2020; Redding 2019; Sass 2015). For example, Lim and Meer (2020) find having a female mathematics teacher in seventh grade increased the likelihood that female students take higher-level mathematics courses, aspire to a STEM degree, and attend a STEM-focused high school. A systematic review shows strong evidence that Black students scored higher on achievement tests in various subjects, especially mathematics, when assigned to a Black teacher (Redding 2019).

However, STEM teachers have historically been more likely to identify as male and White (Bruno and Lewis 2021; Ingersoll and May 2012). This disparity suggests that women and students of color are less likely to have STEM teachers who share their gender or race/ethnicity, reducing their likelihood of benefiting from the teacher-student gender or racial/ethnic congruence discussed above. Recent research has noted significant improvements: the share of female STEM teachers increased from 43% in 1988 to 64% in 2012, and the representation of Hispanic and Asian educators rose from 2% to 6% and from 1% to 3%, respectively (Nguyen and Redding 2018). Despite these improvements, mismatches between the racial distributions of teachers and students persist. For example, in the 2017–2018 school year, about 80% of U.S. mathematics and science teachers were White, compared to 48% of students (National Science Board and National Science Foundation 2021a).

3.2 | STEM Teacher Qualifications

In addition to their demographics, teacher qualifications, such as their years of teaching experience, certifications, and degree levels, are crucial to student STEM learning. Teacher productivity increases with experience (Harris and Sass 2011; Stewart et al. 2019), though significant variation exists in the returns by experience on effectiveness among different STEM disciplines, including algebra, geometry, biology, chemistry, and physics (Henry, Fortner, and Bastian 2012). Mansell (2024) highlights students taught by teachers prepared through a traditional certification pathway scored higher on their biology achievement tests than those taught by teachers who underwent an alternative pathway. Similarly, a higher percent of full-time state-licensed teachers correlates with increased achievement levels and greater student growth rates in mathematics (Heck 2007). In addition, having high school mathematics and physics teachers with a mathematics or physics degree, respectively, is associated with a higher likelihood of students taking STEM courses in their first year of higher education (Key and Sass 2019).

Despite the importance of teacher qualifications, persistent disparities exist in access to high-quality STEM teachers among different student populations across the United States. STEM teachers in high-poverty schools are less likely to hold a graduate degree and more often are novice teachers (Nguyen and Redding 2018). In the 2017–2018 school year, approximately 60% of U.S. high school mathematics and computer science teachers in schools where fewer than 75% of students were eligible for free or reduced-price lunch (FRPL) held both a degree and a certificate in their respective fields. Conversely, in schools with 75% or more students eligible for FRPL, only 50% of teachers had such qualifications. This gap was similarly observed in schools with predominantly racially minoritized student enrollments (Gray, Taie, and Lewis 2022). At the state level, racially minoritized and economically disadvantaged students in Tennessee were 5 to 15 percentage points less likely to have access to high-quality mathematics and reading teachers, with the most pronounced gaps in urban areas (Rodriguez, Nguyen, and Springer 2023). In addition, research from Florida and North Carolina indicates that the average effectiveness of teachers in high-poverty schools generally falls below that of teachers in other schools (Sass et al. 2012).

3.3 | STEM Teacher Turnover

Persistently high rates of teacher turnover negatively impact student learning (Carver-Thomas and Darling-Hammond 2017; Ronfeldt, Loeb, and Wyckoff 2013) and can lead to numerous organizational challenges within schools (Allensworth, Ponisciak, and Mazzeo 2009; Hanselman et al. 2016; Simon and Johnson 2015). Teacher turnover is particularly high in areas characterized by lower incomes and higher percent of students of color, both historically (Malkus, Hoyer, and Sparks 2015; Marinell and Coca 2013; Williams, Swain, and Graham 2021) and recently (Goldhaber and Theobald 2023). These challenges exacerbate efforts to enhance the diversity and qualifications of STEM teachers, thereby limiting educational opportunities for historically marginalized students.

The literature presents a nuanced picture of turnover among STEM teachers compared to their counterparts in non-STEM disciplines. A meta-analysis synthesizing findings from 40 years of research showed that STEM teachers exhibited marginally higher turnover rates relative to non-STEM teachers (Nguyen et al. 2020). Conversely, more recent empirical work suggests that STEM teachers either demonstrate comparable or lower turnover rates compared to teachers in other subject areas (Bardelli and Ronfeldt 2021; Nguyen and Redding 2018; Sullivan et al. 2017; Taie and Lewis 2023). For instance, in 2020–2021, public school mathematics and natural science teachers turned over at 14.3% and 12.8%, respectively, lower than the attrition rate of all teachers (15.9%) (Taie and Lewis 2023).

However, research focusing specifically on STEM teacher turnover trends over time, including those encompassing the period after the COVID-19 pandemic, remains limited. The scant evidence suggests turnover patterns among STEM teachers are not different from those observed among all teachers in the post-COVID-19 era (Hopkins, Strunk, and Rogers 2023). Meanwhile, recent studies suggest turnover in the overall teacher workforce was relatively stable prior to the pandemic, while some states even saw a decline in 2019–2020, the school year in which the outbreak was first declared in the United States; yet, many states observed increases in teacher turnover in 2020–2021, and some saw record high turnover rates 3 years after the pandemic outbreak (Bacher-Hicks, Chi, and Orellana 2023; Bastian and Fuller 2023; Camp, Zamarro, and McGee 2023; Goldhaber and Theobald 2023; Hopkins, Strunk, and Rogers 2023). For example, Massachusetts' teacher turnover rate was 14.8% in 2020–2021, slightly lower than the state's pre-pandemic levels, but then surged to 17.5% in 2021–2022 (Bacher-Hicks, Chi, and Orellana 2023). Data from Washington even show a dip in turnover in 2019–2020 to slightly over 15%, followed by a sharp increase reaching almost 20% in 2022–2023, marking a historic high for the state (Goldhaber and Theobald 2023).

3.4 | Factors of STEM Teacher Turnover

Teacher demographic and qualification characteristics, including gender, race/ethnicity, certifications, experience, and degrees, have been examined with respect to teacher turnover in the extensive literature (Borman and Dowling 2008; Macdonald 1999; Nguyen et al. 2020; Nguyen and Springer 2023). The findings regarding gender and race/ethnicity are inconclusive; more recent studies and those utilizing longitudinal data show no significant differences in turnover rates between female and male teachers, or between teachers of color and their White colleagues (Nguyen et al. 2020; Nguyen and Springer 2023). As for qualification factors, early-career teachers are consistently found more likely to turn over than more experienced teachers (Fuller and Pendola 2019; Papay et al. 2017; Redding and Henry 2018). Some studies note teachers with graduate degrees turned over at marginally higher rates than those with bachelor's degrees (Marinell and Coca 2013; Rockoff et al. 2011), yet such findings remain inconclusive within the current turnover literature landscape (Nguyen et al. 2020).

Teacher working conditions, including school organizational characteristics, student body characteristics, urbanicity, and salary and compensation, have been linked to teacher turnover. Research consistently shows STEM teachers turn over at higher rates in schools serving more students of disadvantaged backgrounds (Carver-Thomas and Darling-Hammond 2017; Ingersoll and May 2012; McConnell, 2017; Nguyen and Redding 2018). For instance, national representative data from 2012 to 2013 showed that mathematics and science teachers in Title I schools had a 17.8% turnover rate compared to 10.5% in non-Title I schools (Carver-Thomas and Darling-Hammond 2017).

While many studies identify challenges in recruiting and retaining teachers in rural areas that may stem from the remoteness of their surroundings, such as low salaries, professional isolation, and restricted access to professional development (Boyd et al. 2005; Lazarev et al. 2017; Rhinesmith et al. 2023), there is no consistent conclusion regarding whether rural school teachers are more or less likely to turn over compared to their colleagues in urban areas (Han and Hur 2022; Hodges, Tippins, and Oliver 2013; Imazeki 2005; Ingersoll and Tran 2023; Lochmiller, Sugimoto, and Muller 2016; Palermo, Kelly, and Krakehl 2021, 2022). This is likely because the existing literature often concentrates on large urban areas, utilizing limited samples of rural teachers, while rural school contexts—such as the social and economic environments they operate within and the student populations they serve—can vary significantly across regions (Nelson and Nguyen 2023; Nguyen 2020a, 2020b).

It is also notable that STEM teachers, in particular, have been found to be responsive to salary differences (Bueno and Sass 2018; Clotfelter et al. 2008; Feng and Sass 2018; Ingersoll and May 2012; Nguyen and Redding 2018). In North Carolina school districts, a modest bonus of $1800 given to certified mathematics and science teachers was sufficient to reduce the mean turnover rates of the targeted teachers by 17% (Clotfelter et al. 2008). Similarly, a study in Georgia found a statewide program that provided bonuses to mathematics and science teachers reduced the probability of teacher turning over by 18%–28% (Bueno and Sass 2018). This responsiveness may be partly due to the significant salary gap between STEM professionals and STEM educators (Hansen, Breazeale, and Blankenship 2019). In fact, STEM teachers typically have more opportunities outside of education and can command slightly higher salaries than non-STEM teachers when they leave public schools (Brummet et al. 2024).

In addition, supportive work environments, such as greater classroom autonomy, improved administrative support, and targeted professional development, are important factors impacting STEM teacher turnover (Han and Hur 2022; Ingersoll and May 2012; Nguyen and Redding 2018; Suárez and Wright 2019).

3.5 | Kansas and Missouri Contexts

Kansas and Missouri, two contiguous states in the U.S. Midwest, share similar socio-economic landscapes, with fewer than 20% of schools classified as urban, with much of its geography some of the most geographically isolated in the country (Nguyen 2020a). Despite their rural predominance, both states also have major metropolitan areas where students and teachers of color are disproportionately served and employed (Anglum, Manion, and Varkey 2024; Nguyen 2020b). For example, more than 70% of Missouri's traditional public school districts are in rural areas, yet these districts serve fewer than a quarter of the state's total student and teacher populations (Anglum, Manion, and Varkey 2024).

In addition, the demographic distributions of the teacher workforce in both Kansas and Missouri are predominantly White, prompting discussions on the need for greater diversity to better reflect their student populations. In Kansas and Missouri, only 10% and 7% of public school teachers are people of color, compared to 37% and 31% of public K-12 students, respectively. Consequently, both states have approximately four times as many students of color as they have teachers of color, a gap significantly wider than the national averages, where 20% of public school teachers and 50% of public K-12 students are people of color (Swisher 2023).

The salaries for teachers in both states are well below the national average. For the 2022–2023 school year, the average salary for K-12 teachers in Missouri was $53,999, placing the state 46th nationally, while Kansas had a slightly higher average salary of $56,481, ranking 39th (National Education Association 2024b). Starting salaries are even lower, with Missouri ranked 50th at $36,829 and Kansas 35th at $41,200 (National Education Association 2024a). Although many school districts nationwide claim to offer additional pay for teachers in high-need subjects such as STEM (Putman and Nittler 2019), neither state has implemented differential pay policies to support higher salaries for STEM teachers (National Council on Teacher Quality 2021).

Teachers in Kansas and Missouri generally exhibit turnover rates that fall within the middle to higher ranges compared to other states (Carver-Thomas and Darling-Hammond 2017). The distinct contexts of these two states suggest that their teacher turnover patterns may not align with national trends. For instance, while teachers with graduate degrees in the Great Plains area are generally more likely to leave their positions, those in Kansas with similar qualifications are substantially less likely to experience turnover (Nguyen 2020b).

Mathematics and science are subject areas experiencing significant teacher shortages in both states (Educate Kansas 2024; Katnik 2023). To address this issue, both states have implemented policies and programs aimed at recruiting more teachers in hard-to-fill areas. A range of these policies supports potential teachers in acquiring degrees or endorsements in STEM fields through loan cancellation, scholarships, and financial aid (The Kansas Board of Regents 2024b; Missouri Department of Higher Education and Workforce Development 2024a, 2024b). For instance, the Kansas Teacher Service Scholarship offers financial assistance of up to $6504 per academic year for the 2024–2025 cohort to students in bachelor's degree programs and licensed teachers pursuing endorsements or master's degrees in high-need disciplines, as well as those planning to teach in underserved areas (The Kansas Board of Regents 2024a). In addition, both states have implemented general teacher recruitment and retention policies, such as "Grow-your-own" programs aimed at recruiting and diversifying the workforce (Kansas State Department of Education 2024; The Hunt Institute 2024).

3.6 | Contributions

Our study highlights notable demographic trends among Kansas and Missouri STEM teachers throughout the past decade, noting changes in annual shares of early-career teachers, STEM certification, along with rising turnover rates overall and especially in urban schools, schools serving more racially diverse students, and schools serving higher percent of socio-economically disadvantaged students.

Our research contributes to the field in three important ways. First, it is the first study to use longitudinal data spanning over a decade to analyze changes in the characteristics and working conditions of all STEM teachers. In 2011, President Barack Obama emphasized the importance of advancing the national STEM agenda in his State of the Union address, a focus that continues under President Joe Biden's promotion of STEM education initiatives (The White House 2022; U.S. Department of Education 2022). As policymakers prioritize the development of the STEM teaching workforce, our study provides detailed evidence on how the characteristics and working conditions of STEM teachers have evolved over the past decade amid these policy and economic changes. Second, our research deepens the understanding of the STEM teacher workforce by focusing on Kansas and Missouri, two Midwestern states whose teacher labor markets have traditionally been underexplored. By examining variations within these states across different school contexts, we offer holistic insights into their STEM teacher workforce. Third, we investigate factors that may influence STEM teacher turnover, laying the groundwork for policy discussions and future research aimed at retaining teachers and supporting equitable student development in STEM fields.

4 | Data and Methods

This study employed data from the Kansas Educator Data Collection and the Missouri Core Data System from 2010–2011 to 2022–2023, including demographic characteristics, qualifications, and employment information (e.g., district and school information, employment hours, and course assignments) on all public school teachers in Kansas and Missouri.

We curated data for the teachers' primary teaching assignment, by highest full-time or equivalent status (FTE), in elementary and secondary schools, excluding central offices and/or specialized programs to attain consistency between the two states and across years. We then matched the state data with the National Center for Education Statistics (NCES)'s school-level Common Core Data (CCD) to obtain information on the teachers' working conditions, such as school locale and student body characteristics, since these school factors are crucial for research on teacher workforces and understanding teacher mobility (e.g., Nguyen and Springer 2023). We provide the details of all data points and curation processes in Appendices S1 and S2.

4.1 | Identifying STEM Teachers and STEM Certification

We identified STEM teachers as *non-elementary teachers whose primary/highest-FTE teaching assignment is in the areas of mathematics, computer science, and natural sciences that include biology, chemistry, earth and space science, and physics*. We included only computer science subject matters that directly stemmed from mathematics, such as algorithm development or programming methodology, while excluding those that generally covered computer applications. We did not include technology and engineering, as they could not be consistently identified from our data. We also excluded elementary-school teachers, as general and subject-matter specific teachers in elementary school were not clearly distinguished in our data, especially in the early half of the panel. Besides, from the certification perspectives of Kansas and Missouri, there are no STEM teachers in elementary grades. Kansas, for example, offers STEM certification pathways only for middle- and secondary-level teachers (grades 5–8 and grades 7–12), while the elementary certification (grades K-6) allows teachers to teach both general and STEM subjects. The STEM subject areas are identified using a computer algorithm that we developed, and the school levels are based on the 2016–2017 school level logic by the NCES (2023) (see Appendix S2 for more details).

In addition to identifying STEM teachers based on what they taught, we also identified teachers who were certified in STEM areas, specifically in mathematics, computer science, and natural sciences, as defined above. The certification areas were also systematically classified by our algorithm. Due to the lack of effective and expiration dates in our data, we identified STEM-certified teachers as those who were *ever* certified in a STEM subject area over any year of our panel. This approach has limitations, as it may include a small subset of STEM teachers who obtained certification in a later year instead of the current year, or those whose certification were earned in a prior year but have since expired.

4.2 | Identifying Teacher Mobility

We identified five different forms of teacher mobility, including *stayer*, *school switcher*, *district switcher*, *leaver*, and *closure mover*. Given a school year and conditioning on its continuing operation status, a *stayer*, or returning teacher, is one who would remain employed in the same position through the immediate next school year. In this vein, a *school switcher* is identified if the teacher switched to another school but remained in the same district. A *district switcher* is identified if they switched to a different district in the same state. A *leaver* is identified if the teacher was no longer observed in the state's public elementary and secondary schools. Finally, if the school was closed and the teacher was forced to move (either to another school or out of the system), they were classified as a *closure mover*. Our research does not focus on the mobility of closure movers, but they must be identified to be separated from the analysis of other turnovers. The (non-closure) switchers and leavers comprised the group of turned over teachers, henceforth the measure "overall turnover," which is the focus of our study.

It is important to note that teacher mobility could only be observed within each state separately. Our data did not allow us to observe teachers who moved between Kansas and Missouri, or those who left the states' public school systems.

4.3 | Analytic Approaches

For this study, we employed both descriptive and regression analyses. The descriptive analysis addresses the first and second research questions, while the regression analysis focuses on the third research question. We describe the details of our methodology below.

First, we used descriptive statistics to examine the characteristics of the STEM teachers who served in Kansas and Missouri public elementary and secondary schools in the past 13 years. We analyzed annual changes in the teachers' demographics, including age, race, and gender, as well as qualifications, including teaching experience, STEM certification, and graduate degree. As there has been substantial interest in the literature regarding differences among teachers across school and student contexts (e.g., Goldhaber, Quince, and Theobald 2019), we disaggregated and examined the teachers' data by school locale (urban, suburban, and rural/town) and student body characteristics, including annual quartiles by the school's percent of students of color and annual quartiles based on the school's percent of FRPL-eligible students.

We note that while some prior work relied on fixed percentage-point benchmarks (e.g., 25%, 50%, or 75%) to categorize schools (e.g., Ingersoll and May 2012; Nguyen, Anglum, and Crouch 2023; Nguyen and Redding 2018; Simon and Johnson 2015), we used annual school quartiles to account for the heavily skewed and changing distributions of student characteristics in Kansas and Missouri, especially race/ethnicity and to obtain comparable numbers of schools per category across years (Appendix S3: Table C1). We report these annual quartiles in Appendix S3: Table C1 of the Supporting Information. In addition, the school quartiles are based on the whole sample of Kansas and Missouri teachers, as opposed to STEM teachers only, thus the findings could be contextualized in terms of the overall Kansas and Missouri teacher workforce.

Regarding the second question, we began by examining the annual rates of overall turnover among STEM teachers in Kansas and Missouri. We also compared turnover rates among school locales and quartiles based on student racial/ethnic and socio-economic backgrounds because some prior work suggested mobility differences among teachers serving in these school settings (e.g., Ingersoll and May 2012), as well as examined whether the patterns had changed over time by observing the year-to-year statistics. In the same vein, we examined the teachers' turnover rates in specific forms (school switchers, district switchers, and leavers) among schools across locale settings and student racial and socio-economic quartiles. Examining these form-specific turnovers is important as they may suggest different policy implications at the school, district, and state levels, and earlier research has found differentiated associations between these specific career movements and school and student contexts (Clotfelter, Ladd, and Vigdor 2011; Elfers, Plecki, and Knapp 2006; Kukla-Acevedo 2009; Larkin et al. 2022).

As for the third research question, we conducted regression analysis to further examine the extents to which turnover among STEM teachers in Kansas and Missouri related to their characteristics and the conditions in which they worked. We conducted the main analysis by estimating the following linear probability model (LPM) on the turnover outcomes[1]:

$$Y_{ist} = \beta_0 + \text{Tcher}'_{ist}\beta_1 + \text{WorkCond}'_{ist}\beta_2 + \text{Controls}'_{ist}\beta_3 + \text{Year}_t + \text{District}_s + \epsilon_{ist},$$

where Y_{ist} is the turnover outcome of teacher i from school s in year t, which equals one if the teacher turned over and zero if they stayed. On the right-hand side, Tcher_{ist} is a vector of teacher factors of interest, including demographic characteristics (female, teacher of color), and qualifications (novice/ having up to 3 years of teaching experience, STEM-certified, and having obtained a graduate degree). WorkCond_{ist} is a vector of working conditions of interest, including inflation-adjusted base salary, school-level locale setting (urban, suburban), and school-level student racial quartiles, and school-level FRPL-based quartiles. Controls_{ist} is a vector of control variables, including whether the teacher was certified and/or taught in the areas of career and technical education (CTE), and/or in special education or English for speakers of second languages (SPED/ESOL), as it would be natural for a teacher to have additional CTE assignment(s) due to their specialty in STEM, and such assignments might relate to their turnover; by the same token, SPED/ESOL assignments should also be controlled for as teachers in general might be assigned SPED/ESOL-related tasks depending on the school's needs, especially when facing challenges finding SPED/ESOL teachers (Nguyen, Lam, and Bruno 2024), and SPED/ESOL teaching would likely correspond to teacher turnover (Billingsley and Bettini 2019). Moreover, Controls_{ist} consists of working condition factors that the literature suggested associated with teacher turnover (Nguyen et al. 2020), including employment status (less than full-time), school level (high school, other level), school type (charter, magnet), school size (student enrollment), and percentages of female students, also controlling for student body demographic characteristics. Furthermore, Controls_{ist} includes flags of outliers and/or abnormally recorded data in terms of FTE and salary (details in Appendix S1). In addition, we included year and district fixed effects to control for the time- and district-invariant factors that were unobservable from our data. Finally, ϵ_{ist} represents the error term. The models were estimated with heteroskedasticity-robust standard errors clustered at the district level.

In addition, we examined the factors of STEM teacher turnover specific to each locale setting. This was because we observed significantly skewed and vastly different distributions of student characteristics among school locales, particularly in terms of racial/ethnic and socio-economic compositions (Appendix S3: Tables C2–C4). For instance, urban schools tended to enroll student populations that were heavily skewed with FRPL eligibility, while student bodies in rural/town schools were predominantly populated by White students.

Meanwhile, suburban schools enrolled skewed student distributions in both terms, by having much fewer FRPL-eligible students than urban schools, while serving higher shares of students of color than rural/town schools. Different student contexts among school locales could relate to disparities among teacher characteristics and their working conditions, thus might differentiate turnover outcomes (Rodriguez, Nguyen, and Springer 2023). We therefore estimated the turnover regressions separately for subsamples of STEM teachers in each locale. The school quartiles in this secondary analysis were locale-specific, while all other specifications remained the same.

5 | Results

5.1 | RQ1—The Kansas and Missouri STEM Teaching Force

Table 1 highlights results from the descriptive analysis of STEM teachers. The full set of descriptive statistics is provided in Appendices S4 and S5. Overall, about 66% of STEM teachers in Kansas and Missouri were women, 16% were under 30 years old, and only 6% were teachers of color, per the pooled statistics. Noticeably, the rate of teachers under 30 years old rose from 16% in 2012–2013 to 17% between 2014 and 2019, then dropped to 15% in 2022–2023. Taking a closer look, while Kansas had a lower share of under-30 STEM teachers compared to Missouri (14% vs. 17% overall), the downtrend in Missouri was more salient than in Kansas, from 18% in 2012–2013 to 16% in 2022–2023 (Appendix S5 Tables E1 and E2), suggesting differences exist between these two states despites their many similarities.

As for qualifications, the share of novices among Kansas and Missouri STEM teachers has been on a decline from 20% in 2010–2011 to 17% in 2022–2023. The STEM certification rate also decreased, from 72% in 2010–2011 to around 65% in 2022–2023. As this measure did not account for certification dates, such a downtrend could be more dramatic if counting exclusively active STEM certification. Relatedly, the share of graduate degree holders in the states' STEM teacher workforce has slightly increased, from 54% in 2010–2011 to 55% in 2022–2023. Notably, Missouri employed a substantially larger share of STEM teachers with graduate degrees compared to Kansas (62% vs. 39%, per the pooled statistics).

Regarding working conditions, we first notice contrasting patterns between the unadjusted and inflation-adjusted salary figures. The teachers' unadjusted salary, on average, increased from $44,000 in 2010–2011 to about $54,000 in 2022–2023. However, the inflation-adjusted salary (in 2023 dollars) was almost $60,000 in 2010–2011, gradually dropped to about $58,000 in 2020–2021, and dramatically fell to around $55,000 beginning in 2021–2022. In terms of school locales and student characteristics, about 18% STEM teachers in Kansas and Missouri were employed in urban schools, 24% in suburban schools, and 57% in rural or town schools. Across the panel, about 47% of students were eligible for FRPL, while the average rate of students of color has substantially increased, from 25% in 2010–2011 to 31% in 2022–2023.

Examining teacher characteristics by school locale and student body quartile, we find substantial and persisting racial and qualification gaps among STEM teachers across these settings. To better contextualize the findings, we note schools in the first quartiles of students of color enrolled less than 5% to less than 9% students of color a year, while schools in the fourth quartiles enrolled over 32% to over 41% minoritized students (Appendix S3: Table C1). Meanwhile, schools in the first FRPL eligibility quartiles enrolled from under 30% to under 39% FRPL-eligible students, and the fourth quartiles had from over 63% to over 70% FRPL eligibility.

Kansas and Missouri seemed to employ similar portions of teachers of color for their STEM instruction, yet a close look indicated some upward trending among Kansas STEM teachers but not in Missouri (Figure 1). Across school locales, we find high concentrations of STEM teachers of color in urban schools, where the annual shares of teachers of color were nearly twice as much as those in suburban and six to nine times higher than in rural/town schools. Meanwhile, huge teacher racial gaps exist across student body quartiles. The annual shares of teachers of color among STEM teachers in fourth-quartile schools, either by percent of minoritized or FRPL-eligible students, are from 10 to 20 times higher than in other quartiles.

In terms of qualifications, urban schools and schools serving the fourth quartiles of students of color and FRPL eligibility consistently employed the least experienced STEM teaching force, by annual shares of novice STEM teachers, compared to schools in other locale settings and schools serving lower shares of minoritized and FRPL-eligible students (Figure 2). Meanwhile, STEM certification rates were the highest among STEM teachers in suburban schools and schools serving the lowest quartiles of FRPL-eligible students. The shares of graduate degree holders were also the highest among suburban STEM teachers, with about 20 percentage points higher compared to the shares among their urban and rural/town counterparts, as well as the highest among STEM teachers serving the lowest quartiles of FRPL-eligible students, with 10 to 15 percentage points higher than among STEM teachers serving a higher percent of socio-economically disadvantaged students.

In summary, our analysis for RQ1 shows STEM teachers in Kansas and Missouri are majority women and predominantly White. In contrast, the rate of students of color they serve has substantially increased, underscoring stagnated teacher diversity relative to the growing diversity among students. We also observe declines in the rates of young and early-career STEM teachers, STEM certification, and stagnated STEM teacher salary, especially after the pandemic outbreak. Most importantly, we observe huge and persistent gaps in racial representation and qualifications of STEM teachers across school locales and quartiles of minoritized and impoverished students. Urban schools and those serving the highest quartiles of marginalized students employed the least experienced and credentialed STEM teacher workforces, while students in rural school settings had the least access to diverse STEM teachers.

TABLE 1 | Descriptive statistics of the STEM teacher workforce in Kansas and Missouri.

	10–11	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21	21–22	22–23	Pooled KS	Pooled MO	Pooled STEM
Under 30			0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.15	0.14	0.17	0.16
Above 65			0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.04	0.01	0.02
Female	0.65	0.65	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.67	0.66	0.67	0.67	0.62	0.68	0.66
Teacher of col.	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06
Novice	0.20	0.18	0.17	0.18	0.19	0.19	0.19	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.18	0.18
STEM cert.	0.72	0.72	0.68	0.68	0.68	0.68	0.67	0.68	0.68	0.67	0.67	0.66	0.65	0.67	0.69	0.68
CTE cert.	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.03	0.08	0.07
SPED/ESOL cert.	0.20	0.20	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.21	0.21	0.21	0.17	0.23	0.21
Grad degree	0.54	0.55	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.56	0.55	0.55	0.39	0.62	0.55
CTE teacher	0.14	0.14	0.15	0.16	0.16	0.17	0.18	0.18	0.18	0.18	0.19	0.18	0.17	0.08	0.20	0.17
SPED/ESOL teacher	0.18	0.19	0.19	0.19	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.19	0.19	0.03	0.26	0.19
Middle school	0.38	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.39	0.40	0.40
High school	0.57	0.57	0.56	0.56	0.56	0.56	0.56	0.56	0.56	0.55	0.55	0.54	0.54	0.55	0.56	0.56
Other level	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.04	0.04
Part-time	0.06	0.07	0.08	0.08	0.07	0.08	0.08	0.08	0.10	0.08	0.09	0.09	0.07	0.08	0.08	0.08
Base Sal./$1 K	4.39	4.43	4.49	4.55	4.62	4.68	4.74	4.80	4.90	5.01	5.12	5.20	5.39	4.85	4.79	4.80
Adj B. Sal./$1 K	5.95	5.84	5.82	5.80	5.84	5.89	5.85	5.80	5.80	5.84	5.83	5.53	5.39	5.84	5.76	5.78
Urban	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.24	0.16	0.18
Suburban	0.22	0.21	0.25	0.25	0.25	0.25	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.14	0.29	0.24
Rural/town	0.60	0.61	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.56	0.56	0.56	0.56	0.63	0.55	0.57
Charter/magnet	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04		0.02	0.04	0.04
Student enroll.	78.08	76.71	76.82	76.50	76.93	77.26	76.81	77.61	77.99	78.69	78.48	78.27	78.00	75.03	78.64	77.56
Pct female	48.75	48.75	48.66	48.75	48.73	48.72	48.72	48.74	48.80	48.76	48.83	48.77	48.71	48.62	48.80	48.75
Pct St. of color	24.83	24.58	25.07	25.77	26.26	26.72	27.42	28.00	28.56	29.02	30.12	30.14	30.94	32.77	25.35	27.57
Pct FRPL elig.	43.14	44.70	45.21	47.71	48.63	47.48	48.03	48.25	47.91	47.80	47.39	43.30	46.45	46.56	46.71	46.67
Observations	15,685	15,747	16,991	17,609	17,736	17,785	17,987	17,782	17,756	17,904	18,162	18,146	18,090	68,062	159,318	227,380

Note: Selected descriptive statistics for STEM teachers are presented. The full set of descriptive statistics is available in Appendix S4. Appendix S4: Tables D1 and D2 provide the pooled and year-to-year summary statistics for all teachers. Appendix S4: Tables D3 and D4 provide the pooled and year-to-year summary statistics for STEM teachers.

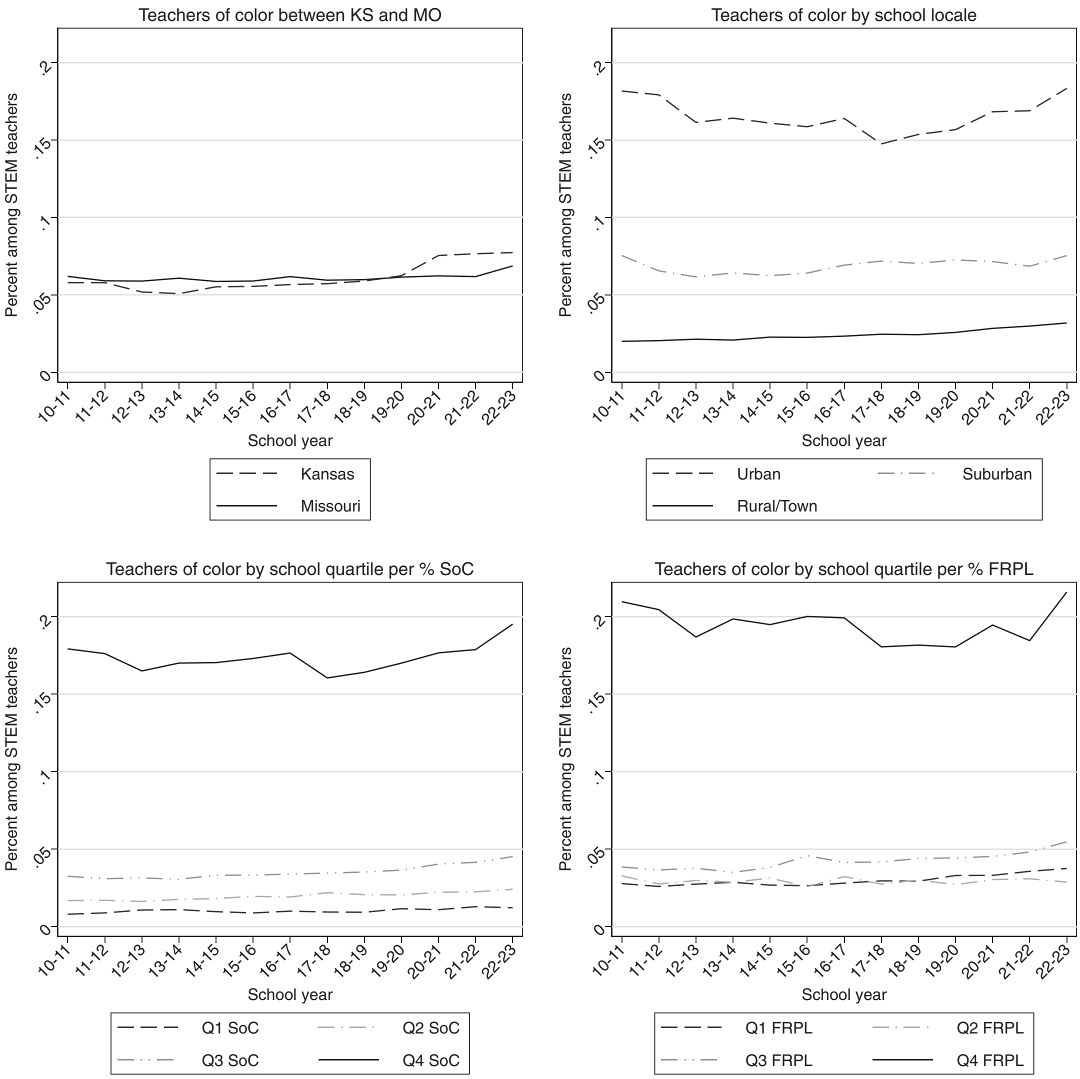

FIGURE 1 | STEM teachers of color by state, school locale, and student body quartiles.

5.2 | RQ2—STEM Teacher Turnover in Kansas and Missouri

Overall, turnover among Kansas and Missouri STEM teachers has increased over the past 13 years. About 13%–15% of STEM teachers turned over a year from 2010 through 2021 (Figure 3). In 2021–2022, the overall turnover rate surged to almost 20%, reflecting turnover trends elsewhere in the post-COVID-19 era (e.g., Goldhaber and Theobald 2023).

There were some differences in STEM teacher turnover between Kansas and Missouri. In 2016–2017, Kansas' STEM teacher turnover peaked at a rate of 19%, while Missouri's was 14%. Both states experienced post-COVID-19 turnover surges, but the increase in Missouri was substantially higher, rising to over 20% compared to Kansas' 17%. Noticeably, immediately after the pandemic outbreak (2019–2020), while STEM teacher turnover in Kansas dropped from 15% to 14%, Missouri experienced an increase from under 14% to over 15%.

We also observe turnover differences among school locales and student body quartiles. Throughout the panel, urban schools exhibited the highest annual rates of STEM teacher turnover: 2 to 7 percentage points higher than rural/town schools, and 5 to 9 percentage points higher than suburban schools. Among school quartiles by percent of students of color, STEM teachers of the fourth quartiles turned over at the highest rates, from 3 to 7 percentage points higher than those of the first three quartiles. The differences were even more pronounced among schools by FRPL eligibility quartiles, where STEM teachers in the fourth quartiles turned over at rates that were 4 to 8 percentage points higher than in the third and second quartiles, and 7 to 10 percentage points higher than in the first quartiles.

In terms of turnover in specific forms, STEM teachers in Kansas and Missouri left their states' public secondary schools more often than switching, with 8% teacher-year observations recorded as leavers, compared to only 6.7% switchers, including 2.5% and 4.2% at the school and district levels, respectively (Table 2).

Diving deeper, Kansas STEM teachers left school systems more frequently, with 9.8% recorded as leavers compared to Missouri's 7.2%, while Missouri STEM teachers switched schools more often, 7.2% compared to 5.5% in Kansas. Urban STEM teachers

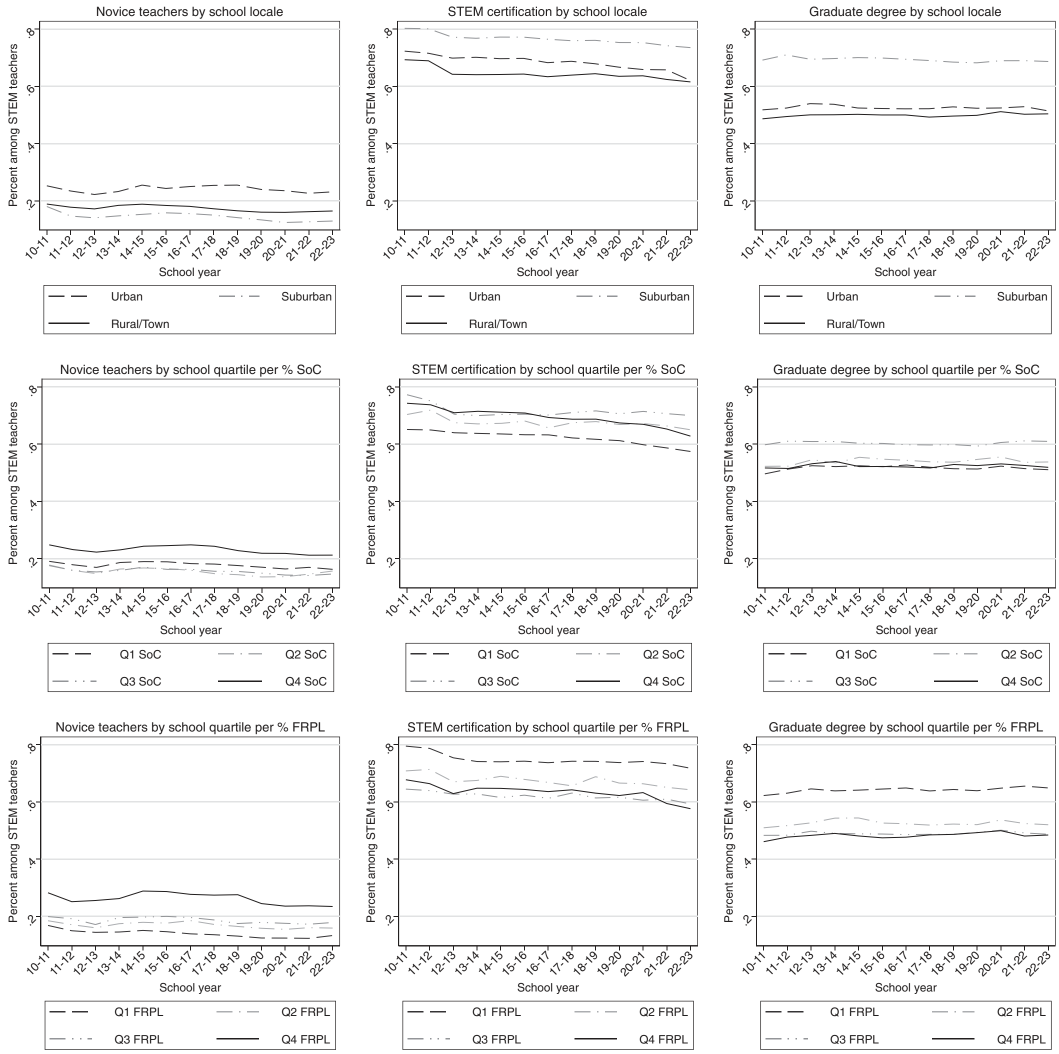

FIGURE 2 | STEM teacher qualifications by school locale and student body quartiles.

switched schools at the highest rates, compared to those in suburban and rural/town schools, while rural/town STEM teachers exhibited the highest frequencies of moving across districts, highlighting the geographical distinction between these locales. Concerningly, STEM teachers in urban schools and schools with the fourth quartiles of students of color and FRPL-eligible students exhibited the highest leaver-year frequencies relative to their colleagues in other locales and quartiles, respectively. Even more concerning is such gaps in leaver rates among these school and student contexts are substantial and have persisted throughout the entire 13 years, per the year-to-year specific turnover statistics (Figure 4). In particular, leaver rates were 2 to 4 percentage points higher in urban schools than in rural/town and suburban schools, as well as 3 to 8 percentage points higher in fourth-quartile schools by percent of students of color and FRPL eligibility than schools in the first three quartiles.

In brief, our analysis for RQ2 shows STEM teacher turnover in Kansas and Missouri has been increasing, especially in the most recent school year (2021–2022). Despites the overall trend, we observe large and persistent gaps in turnover rates across school locales and varied student racial and socio-economic populations, with urban schools and schools serving the highest quartiles of marginalized students experiencing the least-frequently retained STEM teaching force. This consistently reflects the findings of RQ1. Relatedly, we notice STEM teacher turnover differs between Kansas and Missouri, especially in turnover forms.

5.3 | RQ3—Factors of STEM Teacher Turnover in Kansas and Missouri

Table 3 below highlights the results of the primary regression analysis. The full set of results and robustness checks are given in Appendices S6 and S7.

First, we notice women STEM teachers in Kansas and Missouri were slightly less likely to turn over compared to men, while STEM teachers of color were not more or less likely to turn over relative to White STEM teachers (Table 3). Novice STEM teachers were significantly more likely to turn over compared to their more experienced counterparts, particularly as district switchers and leavers, while graduate degree

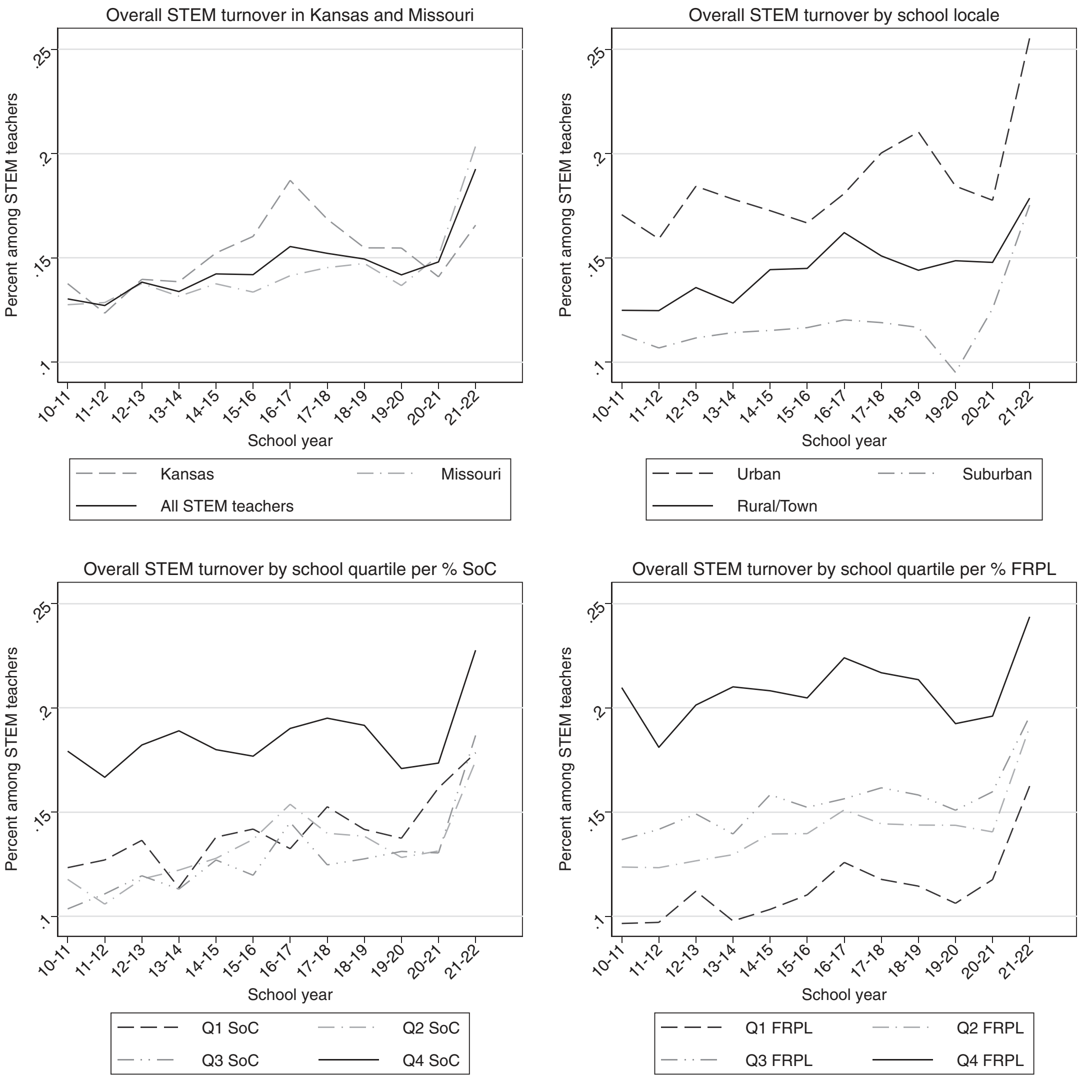

FIGURE 3 | STEM teachers' annual turnover rates by state, school locale, and student body quartiles.

holders were significantly more likely to turn over in all forms relative to their colleagues without a graduate degree. STEM teachers with STEM certification were not more or less likely to turn over overall compared to non-STEM-certified teachers. This estimate, however, obscured the nuances in turnover among STEM-certified STEM teachers, as the form-specific turnover regression showed they were more likely to switch districts but less likely to depart as leavers. We also replicated the estimates separately for each state as robustness checks (Appendix S7: Table G3). While most estimates were similar between the states, in Kansas, STEM-certified teachers were significantly less likely to turn over compared to their non-STEM-certified colleagues, whereas in Missouri, STEM-certified teachers were significantly more likely to turn over compared to non-STEM-certified teachers.

As for working conditions, teacher salary was significantly related to turnover among STEM teachers in Kansas and Missouri: a $10,000 increase in the inflation-adjusted base salary was associated with a 1.3 percentage point decrease in probability of overall turnover. Notably, the association between salary and district switching is substantially larger in magnitude compared to that between salary and leaving among STEM teachers (1.0 vs. 0.3 percentage points). Meanwhile, school locales and school quartiles by percent of students of color were not significantly associated with turnover among STEM teachers, which appeared inconsistent with the descriptive analysis results. This seems to relate to the regression controls, however. Relaxing the district fixed effects (Appendix S6: Table F1), locale settings and students of color quartiles were significantly associated with STEM teacher turnover. Controlling for district-invariant factors could have absorbed variation in turnover outcomes that were related to school locales and/or student of color quartiles. Nevertheless, STEM teachers serving in schools in the third and fourth FRPL eligibility quartiles were 1.2 and 2.0 percentage points significantly more likely to turn over compared to STEM teachers employed in first-quartile schools, even with the district fixed effects included. More importantly, these high FRPL-eligibility quartile STEM teachers were particularly more likely to depart as leavers, especially the fourth-quartile STEM teachers, as shown by the descriptive analysis, who were 1.2 percentage points more likely to resign from school systems relative to their colleagues in the first FRPL-eligibility quartiles.

TABLE 2 | Pooled statistics of STEM teacher turnover across school and student contexts.

	School switcher	District switcher	Leaver	Total (overall turnover)	Teacher-year observations
Kansas	0.020	0.035	0.098	0.153	68,062
Missouri	0.027	0.045	0.072	0.144	159,318
Urban	0.042	0.037	0.109	0.188	41,922
Suburban	0.025	0.029	0.066	0.120	55,327
Rural/town	0.019	0.049	0.077	0.145	130,131
Q1 students of color	0.018	0.055	0.068	0.140	47,970
Q2 students of color	0.019	0.043	0.071	0.134	52,033
Q3 students of color	0.026	0.030	0.072	0.129	70,371
Q4 students of color	0.034	0.044	0.107	0.186	57,006
Q1 FRPL eligibility	0.021	0.027	0.065	0.114	78,828
Q2 FRPL eligibility	0.019	0.046	0.076	0.142	59,441
Q3 FRPL eligibility	0.025	0.051	0.080	0.156	49,539
Q4 FRPL eligibility	0.039	0.054	0.116	0.209	39,572
All STEM teachers	0.025	0.042	0.080	0.147	227,380

Note: Q1 through Q4 indicators represent school-level quartiles based on percent student of color and FRPL eligibility. Q1 represents the first quartile (below the 25th percentile), including schools with the lowest percentages of student of color or FRPL-eligible students. Q4 represents the fourth quartile (above the 75th percentile), indicating schools with the highest shares of students of color or FRPL-eligible students. The specific benchmarks for these quartiles are detailed in Appendix S3: Table C1.

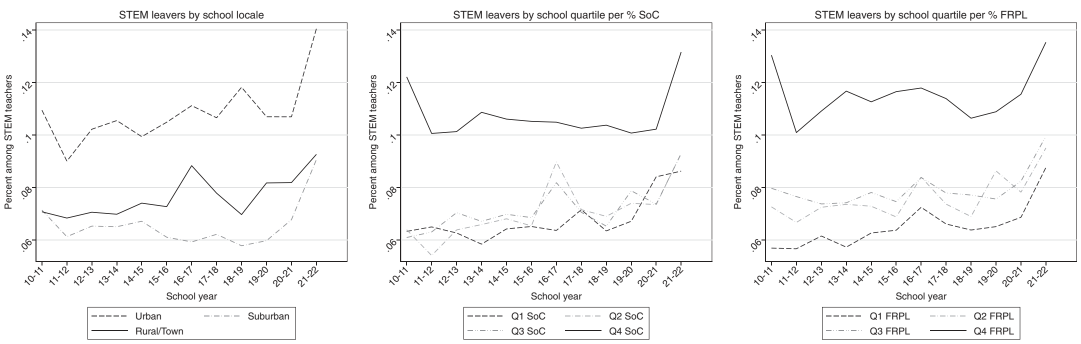

FIGURE 4 | STEM teachers' annual leaver rates by school locale and student body quartiles.

5.3.1 | Factors of STEM Teacher Turnover Across Locale Settings

Estimating the regression separately for each locale (Table 4), we not only find nuances in the relationship between student body characteristics and STEM teacher turnover that were obscured in the main analysis but also distinctive patterns with respect to other factors.

In particular, female STEM teachers were significantly less likely to turn over relative to men in rural/town areas but not in urban and suburban regions. Novice STEM teachers were significantly more likely to turn over relative to veteran teachers across locales, with a particularly higher risk of turning over in rural/town areas than in urban or suburban contexts. Notably, a $10,000 increase in the inflation-adjusted base salary was significantly associated with a 2.1 percentage point decrease in the probability of urban STEM teacher turnover, but only 1.4 and 0.7 percentage point decreases in the likelihood of turnover among rural/town and suburban STEM teachers, respectively.

As for student characteristics, student of color quartiles were significantly related to STEM teacher turnover in urban areas, FRPL eligibility quartiles were significantly related to turnover among rural/town STEM teachers, and no significance was found as to STEM teachers in suburban schools. Remarkably, STEM teachers serving the third and fourth quartiles of students of color in urban areas were more likely to turn over with staggering 7.1 and 12.8 percentage point higher likelihoods than their colleagues serving the first quartile. Diving deeper, STEM teachers serving high quartiles of students of color in urban areas were particularly more likely to depart as leavers: third- and fourth-quartile teachers were 4.6 and 8.2 percentage points more likely to leave school systems compared to first-quartile teachers (Appendix S6: Table F6).

TABLE 3 | The associations of teacher and school characteristics with various forms of STEM teacher turnover.

	Overall turnover	School switcher	District switcher	Leaver
Female	−0.007**	−0.001	−0.009**	0.001
	(0.002)	(0.001)	(0.001)	(0.002)
Teacher of color	0.006	0.011*	−0.006+	0.002
	(0.005)	(0.005)	(0.003)	(0.003)
Novice	0.055**	0.004+	0.037**	0.027**
	(0.004)	(0.002)	(0.003)	(0.003)
STEM certified	−0.003	−0.005**	0.014**	−0.011**
	(0.003)	(0.002)	(0.002)	(0.002)
Grad degree	0.021**	0.004**	0.009**	0.013**
	(0.003)	(0.001)	(0.001)	(0.002)
Adj base salary/$10 K	−0.013**	−0.004**	−0.010**	−0.003+
	(0.002)	(0.001)	(0.001)	(0.002)
Urban area	0.004	0.008	0.001	−0.002
	(0.006)	(0.006)	(0.003)	(0.003)
Suburban area	0.005	−0.001	0.003	0.005
	(0.005)	(0.003)	(0.002)	(0.003)
Q2 students of color	0.000	−0.000	−0.001	0.001
	(0.004)	(0.002)	(0.003)	(0.003)
Q3 students of color	0.003	0.004	0.001	−0.003
	(0.006)	(0.003)	(0.003)	(0.005)
Q4 students of color	0.006	0.007+	0.004	−0.003
	(0.007)	(0.004)	(0.004)	(0.006)
Q2 FRPL eligibility	0.006	0.000	0.001	0.006*
	(0.004)	(0.003)	(0.002)	(0.003)
Q3 FRPL eligibility	0.012**	0.004	0.004	0.007*
	(0.005)	(0.003)	(0.003)	(0.003)
Q4 FRPL eligibility	0.020**	0.008	0.005	0.012*
	(0.008)	(0.005)	(0.004)	(0.005)
Observations	208,817	183,314	186,877	194,867

Note: District and year fixed effects are employed. Standard errors clustered at the district level are in parentheses. The reference group includes STEM teachers who are male, white, have over 3 years of teaching experience, possess a graduate degree, and work in schools that are in rural/town area, first quartile based on percentages of students of color, and first quartile based on percentages of FRPL-eligible students. The full set of results, including controls, are provided in Appendix S6: Table F2.
+$p < 0.10$.
*$p < 0.05$.
**$p < 0.01$.

To summarize, our analysis for RQ3 suggests turnover among STEM teachers in Kansas and Missouri reflects, to some extent, patterns observed in the general teacher workforce (Nguyen et al. 2020), with predictive factors including being in an early career stage, holding a graduate degree, and teacher salary. However, we uncovered additional nuances in the turnover of these teachers, such as certified STEM teachers being more likely to switch districts but less likely to leave, salary explaining greater variation in district switching than in leaving, and, most importantly, teachers serving the most impoverished students being significantly more likely to depart compared to those working in more advantageous conditions, as hypothesized in the *Conceptual framework* section. Equally important are the differential associations of salary and turnover in urban versus rural/town school settings, and that urban STEM teachers were significantly more likely to turn over from working in schools

TABLE 4 | The associations of teacher and school characteristics and STEM teacher turnover by school locale.

	Urban turnover	Suburban turnover	Rural/town turnover
Female	−0.004	−0.003	−0.011**
	(0.005)	(0.003)	(0.003)
Teacher of color	0.002	0.001	0.008
	(0.007)	(0.008)	(0.008)
Novice	0.031**	0.047**	0.065**
	(0.010)	(0.008)	(0.004)
STEM certified	−0.016+	−0.005	−0.000
	(0.008)	(0.005)	(0.003)
Grad degree	0.025**	0.011*	0.024**
	(0.007)	(0.005)	(0.003)
Adj base salary/$10 K	−0.021**	−0.007*	−0.014**
	(0.004)	(0.003)	(0.002)
Locale-specific Q2 students of color	0.015*	−0.002	−0.000
	(0.007)	(0.006)	(0.005)
Locale-specific Q3 students of color	0.071**	0.012	0.017*
	(0.010)	(0.008)	(0.006)
Locale-specific Q4 students of color	0.128**	0.016	0.013
	(0.021)	(0.016)	(0.009)
Locale-specific Q2 FRPL eligibility	−0.002	−0.001	0.004
	(0.011)	(0.006)	(0.004)
Locale-specific Q3 FRPL eligibility	0.002	−0.007	0.012*
	(0.011)	(0.012)	(0.006)
Locale-specific Q4 FRPL eligibility	−0.011	0.011	0.020**
	(0.016)	(0.021)	(0.007)
Observations	38,210	50,792	119,815

Note: District and year fixed effects are employed. Standard errors clustered at the district level are in parentheses. The reference group includes STEM teachers who are male, white, have over 3 years of teaching experience, possess a graduate degree, and work in schools that are in the first locale-specific quartile based on percentages of students of color, and the first locale-specific quartile based on percentages of FRPL-eligible students. The full set of results, including controls, are provided in Appendix S6: Table F3.
+$p < 0.10$.
*$p < 0.05$.
**$p < 0.01$.

with the highest quartiles of students of color, while rural/town STEM teachers were significantly more likely to depart from serving in schools with the highest quartiles of FRPL-eligible students.

6 | Discussion and Conclusion

In this paper, we examine changes in STEM teacher characteristics and mobility patterns in Kansas and Missouri over the most recent 13 years. Our results indicate that the STEM teacher workforce in Kansas and Missouri reflects the national teacher workforce in many ways but also differs substantially in various aspects. We also find evidence of differential turnover patterns between two outwardly similar states, as well as school geographical contexts, thereby emphasizing the necessity of considering local conditions in fostering a diverse and qualified STEM teacher workforce across the United States' diverse contexts.

First, unlike evidence at the national level (e.g., Redding and Nguyen 2021), STEM teachers in Kansas and Missouri are not "greening" in the same way. In particular, since the pandemic, we observe the shares of teachers under 30 years old as well as the shares of teachers in their first 3 years of teaching have been declining. This is especially true in Missouri. Such declines in young and new STEM teachers dovetail with increases in teacher vacancy and underqualification in these two states (e.g., Nguyen, Lam, and Bruno 2024). Relatedly, we also observe that the inflation-adjusted salary for STEM teachers in Kansas and Missouri has stagnated over the last several years. These findings suggest teacher staffing difficulties in some states, specifically in STEM fields, may be related to the decline of young and new teachers coming into the profession, perhaps in part due to salary compensation (Baker, Farrie, and Sciarra 2016; Sutcher, Darling-Hammond, and Carver-Thomas 2019).

Along this line, there is also evidence that STEM teacher certification is declining in these two states. Specifically, we observe the shares of STEM-certified teachers have decreased across a number of contexts. This is disconcerting because prior research has shown STEM-related qualification is positively associated with student learning (Heck 2007; Key and Sass 2019; Mansell 2024). Moreover, this decline is more pronounced in traditionally disadvantaged schools and settings, specifically highly urban and rural areas, as well as high poverty schools and racially minoritized schools. Relatedly, our results show only 6% of STEM teachers in Kansas and Missouri are teachers of color while nearly 30% of students in their school are racially minoritized students. In fact, the exposure to STEM teachers of color is well below 5% for the first three quartiles by percent of students of color and FRPL eligibility. As exposure to high-quality STEM education is associated with future aspiration and exposure to same-race teachers is associated with improved student outcomes (Bruno and Lewis 2021; Ingersoll and May 2012; Redding 2019), there is a strong need for schools and districts to provide more high-quality STEM teachers, and to diversify their STEM teacher workforces, especially for their most marginalized students.

Beyond STEM teacher demographics and qualifications, we also explore changes to their turnover over the 13-year time span. First, to contextualize our findings, the national teacher turnover rate over the last few decades has been around 15%, with about half of the mobile teachers switching schools and half leaving the profession (Nguyen 2021). In contrast, after the onset of the pandemic, STEM teacher turnover rates surged, reaching over 20% in Missouri and 17% in Kansas. While turnover was elevated in all contexts in the 2021–2022 school year, the STEM teacher turnover rate was most pronounced in urban schools and schools with the highest quartiles of students of color and poverty. These findings suggest variations in STEM teacher turnover contribute to how teacher staffing difficulty has increased recently and how staffing challenges can vary substantially by context (Goldhaber, Falken, and Theobald 2024; Nguyen, Lam, and Bruno 2024).

Beyond describing these changes over time and their implications for a stable STEM teacher workforce as well as aspiring future generation of STEM students, we also examine the factors associated with the various forms of turnover. We consistently find, reflecting the descriptive statistics, that STEM teachers in traditionally disadvantaged schools tend to turn over substantially more often than their counterparts even after accounting for a host of teacher and school characteristics. This reflects prior works, which have strongly suggested that teacher working conditions, including resources and supports for teachers, for these disadvantaged schools serving marginalized students are worse than working conditions at more advantageous schools, and that they matter greatly for teacher retention (Bettini et al. 2016; Nguyen 2021). Furthermore, we find evidence consistent with the existing literature (Nguyen and Springer 2023) that teacher compensation, specifically salary, matters greatly for STEM teachers, which is now critically important given the stagnated teacher salary amid post-COVID-19 inflation surges.

6.1 | Implications for Policy and Practice

Across the country, the post-pandemic education policy landscape features active teacher-focused policy debates and legislation as teacher turnover has spiked amid changing teacher working conditions. As states and local school districts initiate reforms to combat teacher staffing challenges, new evidence should guide them to be more sensitive to local conditions. To be most applicable, this evidence cannot be populated through research examining a traditionally narrow set of states and regions. Inquiries into understudied states, like our study of Kansas and Missouri, can help provide a fuller picture of the continually evolving teacher policy landscape and its efficacy in addressing contemporary challenges, especially for the most marginalized populations of students. Even between these two outwardly similar states, and within this group of teachers of the same subject area category, STEM, we observe substantially different patterns in demographic representation, qualifications, and especially, turnover across school and student contexts. Our findings provide critical insights for on-going policy considerations aimed at recruiting and retaining diverse and qualified STEM teachers in these understudied settings.

In recent years, both Kansas and Missouri have implemented a range of policies to address teacher recruitment and retention challenges. These include the Kansas Registered Teacher Apprenticeship program, aiming to provide an alternative pathway for school districts to recruit teachers (Kansas State Department of Education 2024), the Kansas Teacher Service Scholarship, targeting hard-to-staff subject areas (elementary education, English Language Arts, mathematics, science, and special education) and school districts (e.g., USD #259, USD #501, USD #500, etc.) (The Kansas Board of Regents 2024a). Similarly, Missouri has introduced the Urban Flight and Rural Needs Scholarship, also aiming to recruit teacher candidates to staff similarly high-need schools and disciplines (Missouri Department of Higher Education and Workforce Development 2024a, 2024b). In fact, Missouri has planned to triple the scope of this scholarship program: by 2030, up to 600 candidates can receive a total of $3.4 million in tuition scholarships, though the program's grants are forgiven over an 8-year teaching period, and 25% of which must be furnished by the local school district. Relatedly, such targeted teacher incentive policies have gained increasing support in the public, per a recent national survey (Anglum, Manion, and Varkey 2023). The aims of these policy considerations and initiatives are largely reinforced by on our study's findings, especially concerning the high levels of turnover among early-career STEM teachers, as well as the substantial differences among STEM teachers working across these high-need settings relative to more advantageous conditions.

The most active recent teacher policy debates in these contexts center Missouri's teacher compensation reform efforts. Missouri pursued a series of bills and budgetary appropriations over the pandemic to increase teacher pay, culminating in S.B. 727, which takes effect in the 2024–2025 school year. S.B. 727 will raise statutory minimum teacher salaries from $25,000 to $40,000, and create district pathways for differentiated teacher pay for hard-to-staff subjects (S.B. 727, 3329S.03I 2024). As of yet, the bulk of attention to within-district differentiated teacher pay has focused on pay-for-performance (e.g., Pham, Nguyen, and Springer 2021; Podgursky and Springer 2007), while fewer policies and related studies pertain to reform with differentiated teacher pay for hard-to-staff subjects and schools, including Missouri's S.B. 727. To date, scant evidence indicates such policies improve teacher retention. Clotfelter, Ladd, and Vigdor (2011) found lower-quality teachers more sensitive to differentiated salary incentives to serve in schools with high-minority student populations than their higher-quality peers, while Strunk and Zeehandelaar (2011) found the policy much less effective in attracting math and science teachers than SPED/ESOL teachers. As these studies took place in the oft-studied North Carolina and California contexts, as well as in pre-pandemic working conditions, they may not offer universal guidance across geography and time (e.g., the unique pandemic circumstances). Future evaluations of the Missouri teacher pay reform could certainly build upon our study's findings to explore how local circumstances and workforce dynamics contribute to the effectiveness of their policy intervention.

Furthermore, it remains to be seen if these policy shifts may be effective tools to mitigate post-pandemic teacher turnover in the most challenged school settings, in part due to cross-state disparities. At the state level, many of Missouri and Kansas' most populous regions are located within commuting distance of state borders, rendering adjacent state teacher policies highly relevant to local education labor markets. To this point, Missouri's salary reforms have occurred concurrently to other regional policy shifts, perhaps most notably the Arkansas LEARNS Act (Zamarro et al. 2024). Arkansas now boasts a $50,000 minimum teacher salary and a flattened salary scale, which has created a more equitable distribution of teacher pay across district types but has not (at least yet) proven effective in reducing teacher turnover. In this vein, our study offers important implications for Kansas, as they may consider similar reform approaches to Missouri's, given their teacher starting salaries often are not competitive (National Education Association 2024b), and teacher vacancies have continued to increase in the state (Nguyen, Lam, and Bruno 2024). We have to keep in mind that our results show the Kansas and Missouri contexts differ in several important ways, especially pertaining to the forms of their teacher turnover, necessitating careful consideration if extrapolating Missouri's policy reforms to Kansas.

It is also important to note that legislating the possibility of differentiated pay across subject matters, or broadly instituting financial incentives to attract and retain teachers, does not automatically create new state funding streams to fund local school district efforts to staff and retain teachers in hard-to-staff subject areas, including STEM. Thus far, Missouri's increasing minimum salary requirements and related state grants overwhelmingly served to increase the salaries of rural, White teachers. This has occurred largely due to large regional compensation differences between the state's rural areas, comprised largely of White teachers (98%), and its urban metropolitan areas, which contain the vast majority of the state's teachers of color. In fact, less than 3% of the state's teachers of color received a salary boost through the program in 2022–2023, the first year the state began to increase minimum salaries (Anglum, Manion, and Varkey 2024). Many of these teachers work in the state's hardest to staff schools, serving the largest shares of low-income and minoritized students. As we emphasized, these tend to be schools with the most acute teacher turnover. This underscores the need to further tailor reform efforts to account for regional differences, ensuring that resources are allocated where they are most needed, and that the existing access and opportunity gaps among diverse students are not perpetuated.

Finally, teachers in Missouri and Kansas' urbanized regions, like the St. Louis, Kansas City, or Wichita metropolitan areas, often encounter wider ranges of alternative employment opportunities in local STEM industries, including life sciences, geospatial technology, healthcare, agricultural technology, and aviation. School districts, therefore, must significantly exceed state minimum salaries to attract and retain a high-quality workforce amid this employment competition. This is evident from our findings, as salary accounted for a great extent of the variation in district switching but relatively little of the variation among STEM teachers who exited the states' public schools. Our analysis also indicated sharp imbalances in the representation of teachers of color and students of color across school settings, gaps that may reinforce disruptions to the pipeline of students in STEM. In summary, salary and other teacher workforce-oriented reforms at the state and national levels are unlikely to encourage the recruitment and retention of diverse and qualified STEM teachers if they fail to compete with the working conditions offered by nearby industrial workplaces and/or address the aforementioned geographically and societally diverse school and student contexts.

6.2 | Limitations and Future Research

Our research provides evidence that specific working conditions are related to STEM teacher turnover. However, we are unable to draw causal conclusions about how these factors impact teacher turnover. Given STEM teachers appear particularly responsive to salary changes and may be more affected by broader economic shifts, further studies using causal designs are needed to examine how economic and societal events, such as the Great Recession in the U.S. or social changes following the COVID-19 pandemic, influence STEM teacher turnover. Moreover, although we observe different turnover patterns across schools in urban, suburban, and rural areas, this simple categorization of school locales may have obscured the nuances of varying developmental conditions within the states (Nelson and Nguyen 2023). Future research should explore these variations with more granular measures of rurality.

From a broader perspective, while promoting diversifying the STEM teacher workforce and urging careful consideration of local contexts for the advancement of STEM education that is accessible to diverse students in Kansas and Missouri, our study provides a solid foundation for future research and policy considerations aimed at promoting equitable student development in STEM fields on regional and national stages.

Data Availability Statement

The datasets analyzed during the current study are not publicly available. We have data-use agreements with the Kansas Department of Education (KSDE) and the Missouri Department of Elementary and Secondary Education (MDSE). We are not able to share the data publicly. Researchers can make requests to obtain these same sets of data from KSDE and MSDE.

Endnotes

[1] We conducted logistic regression as robustness checks and provide the results in Appendix S7: Tables G1-G3.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.