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Investigating School Climate and School Leadership Factors that Impact Secondary STEM Teacher Retention

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Abstract

The present study used 2011–12 Schools and Staffing Survey (SASS) data to determine the impact of school organizational factors on secondary STEM teacher retention in the post-NCLB era. Researchers utilized teacher and principal instruments from the SASS to measure the retention of grades 9–12 STEM teachers ($n = 920$). Due to the nested nature of teachers within schools and based on previous retention research, multilevel logistic regression was used to examine the proportion of variance in STEM teacher retention across schools. The study focused on identifying the proportion of variance in STEM teacher retention that was attributable to school differences, as well as the effect of school climate on STEM teacher retention, controlling for teacher and principal characteristics. The study's most important finding was that having a principal who majored in a STEM subject had a positive and significant effect on the retention of secondary STEM teachers.

Keywords STEM teachers · Teacher retention · STEM principal · Leadership · Multilevel model

Chief among the recommendations put forth in a landmark report on improving United States (US) competitiveness in global markets over a decade ago (National Academies of Science 2007) was improving K-12 mathematics and science education in order to graduate more high school students capable of obtaining undergraduate degrees in science, technology, engineering, and mathematics (STEM) fields. Despite progress around the 2007 recommendations, including common mathematics and science standards across much of the US, a great deal of concern still surrounds the state of STEM

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education and STEM teacher preparation and retention (Carnegie Commission for Mathematics and Science Teaching 2009; Coble 2012; National Academy of Engineering,, and Institute of Medicine 2010; National Academy of Sciences, Presley and Coble 2012; Wilson 2013). For the last two decades, STEM teaching positions, particularly those at the secondary level, have persisted among the most difficult subject areas and grade levels to staff (American Association of Colleges for Teacher Education 2013; Cowan et al. 2015). At the beginning of the 2015–16 school year, 42 states and the District of Columbia reported teacher shortages in math, with 40 states reporting shortages in science (Sutcher et al. 2016).

Compounding the challenges related to filling STEM teaching positions initially, many novice STEM teachers are not retained in the teaching field their first few years in teaching. Between 19% and 30% of teachers leave the classroom within their first five years in the profession, with higher than average attrition rates among math and science teachers (Sutcher et al. 2016). Such high attrition rates levy both heavy financial burdens on schools (Schwartz et al. 2010) and create a constant experience deficit, as the brief tenure of many STEM teachers does not afford teachers the necessary time in practice needed to master the skills and gain the confidence needed to create successful learning experiences for students (Barnes et al. 2007). In many cases, these high attrition rates occur in schools where students are in greatest need (Simon and Moore 2015), resulting in insufficient STEM education for many K-12 students. STEM teacher shortages, combined with high attrition rates, necessitate the careful evaluation of factors impacting the career choices of secondary STEM teachers.

One explanation for the source of teacher shortages in STEM is linked to the current high stakes testing environment in education following implementation of the No Child Left Behind Act (2002) that increased standardized testing in mathematics and science, among other subjects. A heavy emphasis on testing has resulted in diminished feelings of classroom autonomy for many teachers. The increase in standardized testing has created what researchers have termed a "shrinking space" (Crocco and Costigan 2007, p. 520) in teaching due to the fact that high-stakes testing has taken priority in public schools and exerts great influence over teachers' pedagogical decisions. In addition, many teachers feel that high-stakes tests have narrowed their choice of instructional strategies and negatively influenced the curriculum because it has shifted focus more to test-taking strategies and memorization of content (Faulkner and Cook 2006). The shifts in autonomy are troubling, given that STEM teachers' feelings of autonomy have been found to positively and significantly predict STEM teachers' intentions to remain in the profession (McConnell 2017). It is imperative that we explore school and teacher factors that will contribute to STEM teacher retention while accounting for the between-school variability in US schools.

Literature Review

Gender and Race's Role in Teacher Retention

Gender and race/ethnicity seem to have an impact on teacher retention. As females control the teaching profession across most of the countries in the world, the struggle to recruit males continues. Drudy (2008) attributes some of the male recruitment challenges to the notion that teaching is a female-oriented occupation. Some studies that exist on the impact of sex on teacher attrition point to the feminization of the teaching profession, thus resulting in a lesser male teacher retention (Mills 2004; Mills et al. 2010). A study of Israeli teachers by Addi-Raccah (2005) found that male teachers left the profession at a faster pace than females, often leaving for better-paying jobs such as principalships. However, these studies are not examined in a US context. Within a US context, Grissom et al. (2012) found that the sex of the boss matters when considering retention and job satisfaction of teachers. Particularly, Grissom et al. (2012) found that female teachers are more likely to be retained and that of all teachers in their nationally-representative study, they prefer working for male principals. Our study uses teacher and principal sex as a control variable to determine if either has an impact on the retention of STEM teachers.

Similarly to gender differences, understanding the racial demographics of teachers could be predictors of teacher retention. A review of research on teachers of color by Achinstein et al. (2010) point to an urgency in the retention of teachers of color, as the turnover surpasses that of White teachers. That is, teachers of color are leaving the profession at a faster pace than their White counterparts. Achinstein et al. (2010) suggest that school organizational factors are not culturally-relevant enough to keep teachers of color. Moreover, Ingersoll and May's (2011) research concurred with past work that pointed to teachers of color shortage, even when there is an increase in the recruitment of minority teachers. However, at least for Black teachers, supportive school leadership could result in being retained in the profession (Campoli 2017), as well as community-focused programs that focus on "growing" their own teachers (Valenzuela 2016, 2017).

Organizational Factors Affecting Teacher Attrition

In response to concerns about teacher attrition, researchers have focused holistically on the extent to which school organizational factors, such as school culture and teacher autonomy contribute to teachers leaving the profession, as well as the possible interactions between factors. Ingersoll's (2001) analysis of teacher turnover and teacher shortages was foundational in the manner in which the study addressed a gap in the research literature explaining both the sources and causes of teacher shortages. Using nationally representative sample of teachers from the *Schools and Staffing Survey* (SASS) Teacher Questionnaire and Teacher Follow-up Survey, Ingersoll (2001) was among the first to note that teacher staffing problems might not be due to shortages in recruitment, but instead due to a large number of current teachers leaving the profession due to dissatisfaction, mostly with school culture factors. A valuable contribution of the study was the manner in which the two SASS surveys were used with multi-level regression methods to study sources and causes of teacher retention, allowing for the investigation of differences in teacher and school factors between teachers who remained in their schools, moved to another school, or left the profession entirely. The study was the first to examine teacher retention using two nationally representative surveys that allowed for analysis of sources and causes of teacher retention over two subsequent years. The study's organizational analysis perspective highlighted factors of school culture, such as school trust and teacher autonomy, that contributed to teacher retention above and beyond school demographic factors that had been previously used to explain sources of teacher attrition.

More recent research on organizational factors contributing to teacher attrition and retention (Duyar et al. 2013; Ingersoll and May 2010; Shen et al. 2012; Wang et al. 2018) mirrored Ingersoll's early work, focusing on school organizational factors, such as teacher job satisfaction and teacher autonomy, with nationally-representative datasets. A 2010 study (Ingersoll & May) focused specifically on mathematics and science teacher retention, found that the majority of mathematics and science teachers who left the profession were leaving due to a lack of satisfaction with their jobs. In addition, researchers found that teachers' perceptions of autonomy and satisfaction with professional development and student behavior management were among the strongest predictors of mathematics and science teacher attrition. Another study (Shen et al. 2012) found that school process variables, such as levels of staff collegiality and time for collaboration positively predicted teachers' job satisfaction, which researchers posited contributes directly to teacher retention. Expanding on this work, Wang et al. (2018) used the 2011–2012 Schools and Staffing Survey to examine teacher retention of novice teachers. Specifically, Wang et al. (2018) looked at school support, student behavior, distributed leadership, teacher autonomy, collaboration, educational background, professional development, and self-efficacy as predictors of job satisfaction for novice teachers who intended to leave the profession and found that for novice STEM teachers with leaving intentions, student behavior, teaching autonomy, and professional development predicted job satisfaction. This present study expands on this work as it uses follow-up data of teachers who left the profession, which provide a rich insight for possible factors affecting STEM teacher attrition through the use of a multilevel model.

School Leadership

In addition to analyses of overall school culture, many researchers have focused specifically on school leadership, as principals are considered, in many cases, to be the driving force behind the culture of a school. In an international study of the influence of principal leadership on teachers' work lives (Duyar et al. 2013), researchers found that bureaucratic leadership styles significantly negatively predicted teachers' perceptions of satisfaction. In contrast, principals whose leadership style focused on helping teachers improve practice and understanding school goals significantly positively predicted teachers' self-efficacy. There is also evidence that instructional-focused leadership styles may contribute to improvement in student achievement. For example, two recent studies of the impact of principal leadership on school improvement and student achievement (Allensworth and Hart 2018; Grissom et al. 2013) found that principals who use their time to coach and develop school educational program goals, as well as encouraging teacher leadership, positively predicts school achievement gains for students. Though principal instructional leadership has been shown to have positive impacts on both teachers' work lives and student achievement, principal leadership for STEM teachers presents its own set of challenges, as many principals do not have high levels of STEM content knowledge or STEM teaching preparation themselves (Boston et al. 2017; Fuller and Schrott 2015), resulting in a lack of effective leadership and feedback for STEM teachers.

The present study uses the 2011–12 Schools and Staffing Survey Teacher Survey and Principal Survey, as well as the 2012–13 Teacher Follow-up Survey to determine the impact of school organizational factors on secondary STEM teacher retention in the post-NCLB education era (National Center for Educational Statistics 2011, 2012a, b, c, 2013). The use of the three surveys, the Teacher Survey, Principal Survey, and Teacher Follow-up Surveys for both current and former teachers, allows researchers to focus on the retention of grades 9–12 STEM teachers who did not retire in the 2012–13 school year. The study's main predictors, shown to be statistically significant predictors of teacher retention in previous research, include teacher perceptions of their influence on school-level decisions and curricula, interference of classroom duties with instruction, collegiality among staff members, general job interference, student truancy, socioemotional factors, and general job satisfaction. It is hypothesized that higher levels of feelings of influence, autonomy, collegiality, positive feelings toward students and parents, and job satisfaction result in greater retention among secondary STEM teachers. In addition, it is hypothesized that lower perceived levels of job interference with classroom instruction and lower levels of student truancy result in higher levels of retention. The study also examines the impact of teacher and school level demographic factors, such as years of teaching experience and principal ethnicity and preparation.

Many of the recent teacher retention and attrition studies utilized large datasets that allowed researchers to use multilevel modeling to explore the impact of school culture on retention across both schools and teachers. However, though there are several studies examining school organizational factors using multi-level modeling across all types of teachers or studies utilizing older datasets with multi-level modeling to examine STEM teacher retention specifically, there are no current studies of secondary STEM teacher retention that use nationally representative data collected post-NCLB. This is a critical factor, given teacher shortages in secondary STEM subjects, as well as the impact that NCLB and related accountability measures policy have had on the education landscape. Due to the nested nature of teachers within schools in the dataset and based on previous work with similar independent and dependent measures, the present study utilizes multilevel logistic regression to examine the proportion of variance in STEM teacher retention across schools. Multilevel logistic regression, rather than hierarchical linear modeling, is used due to the dichotomous nature of the dependent variable of retention, which was operationalized as whether a teacher stayed in the same school between the 2011–12 and 2012–13 school year or not. Similar to prior teacher retention research examining organizational factors (Ingersoll 2001; Ingersoll and May 2010), teachers who moved schools or left the profession were considered as not retained because the resulting cost for a school to hire a new teacher is the same regardless of whether a teacher moved to another school or left teaching entirely.

Research Questions

The present study focused on the following questions:

1. What proportion of the variance in secondary STEM teacher retention is due to school differences? Is there a significant variation among schools in STEM teacher retention?

2. What is the effect of school climate on secondary STEM teacher retention, controlling for teacher and principal characteristics?
3. What is the predictive ability of the final model, compared to the null model?

The present study is different from others that have been published as its main focus is secondary STEM teachers who have either stayed or left the profession. Other current literature on teacher attrition has focused on all teachers as a whole. While that is important, it could be that STEM teachers have different needs compared to their non-STEM counterparts. Additionally, the literature on STEM teachers tends to focus on recruitment, and not always on retaining the teachers that are currently in-service (Hutchison 2012) or on the effect of pre-service teacher preparation on STEM teacher retention (Kirchoff and Lawrenz 2011; Schuster et al. 2012). Therefore, this study will contribute to teacher retention literature, as well as studies on STEM educators.

Conceptual Model

Chapman (1983) was among one of the first researchers to conceptualize a model that could predict teacher retention after studying teachers' job satisfaction (Chapman and Lowther 1982). Chapman (1983) posited that teacher attrition was influenced by seven different factors: personal factors, the preparation of the teacher (pre-service education), commitment to teaching, experiences at their first place of employment upon certification, environmental factors (school climate), skills attained after preparation or social/professional integration, and job satisfaction. Chapman (1983) added that some of the factors, such as those that were personal, consist demographics such as age, gender, socioeconomic status, and race/ethnicity, and that professional and social integration into teaching may include variables such as salary and marital status.

Since then, support for Chapman's (1983) initial model has been tested with various teacher populations, accounting for years of experience (Chapman 1984; Chapman and Green 1986). Different studies have confirmed some of the seven individual factors in different contexts, such as high-poverty urban areas (Whipp and Geronime 2015), US secondary science teachers (Wong and Luft 2015), teacher education programs (Rots et al. 2014) and in different countries (Fresko et al. 1997; Rots et al. 2014; Sammons et al. 2007). The present study examines several of Chapman's (1983) factors that influence teacher retention in a STEM context.

Methods

The present study utilized the 2011–2012 restricted-use Schools and Staffing Survey (SASS) from the National Center for Education Statistics for teachers and principals. As restricted data was utilized for this study, the researchers gained consent from their institution's Institutional Review Board. The SASS was initially administered in the 1987–1988 school year as a way to view a snapshot of what was occurring in US public and private schools. The SASS Teacher and Principal questionnaires are administered every four years after the 1999–2000 cycle to a nationally representative sample of teachers and includes public charter schools. Surveys are targeted at measuring factors including teacher education and training, work environment factors, and perceptions about teaching and other school factors. The sample is taken from all elementary and secondary schools in the US (Goldring et al. 2013). The Teacher Follow-up survey is administered in the year following the SASS Teacher and Principal surveys to a representative sample of teachers and principals who completed the SASS the year prior (Goldring et al. 2014). Both current and former teachers participate in the Teacher Follow-up Survey. For the present study, three SASS surveys were merged using the school control number (*cntlnums*): the Teacher Survey, Principal Survey, and the Teacher Follow-up Survey (TFS). SASS comprises a stratified, proportionate to size sample from the population of all public schools in the US and its territories. In efforts to obtain estimates for certain subgroups, beginning and early-career teachers were oversampled (Goldring et al. 2013).

In order to identify scales for the school organizational independent measures, an exploratory factor analysis with varimax rotation was conducted on 35 SASS items from the Teacher Survey addressing teachers' perceptions of school organizational culture. The results of this exploratory factor analysis revealed seven factors with eigenvalues greater than 1, accounting for 58.13% of the total variance. The seven extracted factors which were used as independent variables in this study are shown in Table 1. A composite mean for the items in each scale was created for further analysis. Reliability for each scale ranged from .43 to .87, and each individual factor's reliability is also shown in Table 1 (Cronbach 1951). Factors with low reliability were removed from the analysis.

Participants

For reporting purposes, all unweighted sample sizes were rounded to the nearest 10 per Institute for Education Sciences (IES) restricted-use guidelines. The sample for the present study includes only full-time public school secondary STEM teachers who completed both the 2011–2012 SASS Survey and the TFS and their principals. A STEM teacher is identified as any teacher who self-reported teaching a STEM-related subject, while a secondary teacher is operationalized as those that reported teaching any grade from 6 to 12 . A complete list of the STEM subjects is included in Appendix. Additionally, the non-retained teachers in the final sample consist of only STEM teachers who indicated that they decided to leave the profession on the 2012–13 TFS Questionnaire for reasons not due to retirement. A total of 690 teachers (43.5% of the secondary STEM teacher sample) who selected retirement as their reason as leaving the profession on the TFS former teacher survey were eliminated from the sample due to the concern that their perceptions of school organizational factors and job satisfaction might skew the results. Therefore, the final sample size for this study consists of 920 STEM teachers and their principals that completed the TFS. The total number of principals (schools) in the sample is 860. Since our data consisted of a very select group of teachers that met all the criteria, there was no need to treat any missing data, as there was none in the sample we had.

Variables

Independent Variables Level 1 teacher variables included consist of personal characteristics measured by *teachersex* (0 = Female, 1 = Male), whether the teacher was a teacher of color, or *pocteach* (0 = White, 1 = Teacher of color/non-White), age (numeric variable);

Table 1 Exploratory factor analysis results for school organizational factors

SASS Item	Factors and Factor Loadings						
	Collegiality	Truancy	School Influence	Socio-emotional	Classroom Duties	Curriculum Influence	Job Interference
T0435	.661						
T0441	.697						
T0442	.651						
T0443	.653						
T0444	.765						
T0445	.729						
T0446	.719						
T0451	.571						
T0450		.708					
T0455		.784					
T0456		.738					
T0457		.808					
T0458		.438					
T0459		.625					
T0420			.546				
T0422			.626				
T0423			.715				
T0424			.696				
T0425			.690				
T0426			.703				
T0460				.525			
T0461				.756			
T0462				.836			
T0463				.753			
T0464				.716			
T0429					.706		
T0430					.768		
T0431					.678		
T0432					.760		
T0421						.594	
T0427						.692	
T0428						.718	
T0437							.416
T0440							.546
T0447							.540
α	.872	.841	.790	.860	.766	.732	.433
Variance	12.16	10.69	9.27	9.05	7.38	5.36	4.33

pre-service teacher education as measured through *mastersdegree* (0 = No masters, 1 = Master's degree), *majorstem*, whether the teacher majored in a STEM field (0 = Non-

STEM major, 1 = STEM major), whether the teacher took graduate or undergraduate courses focusing on teaching *methods* (0 = No, 1 = Yes), *numcourses,* or number of courses taken focusing on teaching methods (1 = 1 or 2 courses, 2 = 3 or 4 courses, 3 = 5 to 9 courses, 4 = 10 or more courses), whether the teacher student taught, or *practice* (0 = No, 1 = Yes), the *length* of their student teaching experience (1 = 4 weeks or less, 2 = 5 to 7 weeks, 3 = 8 to 11 weeks, 4 = 12 weeks or more); commitment to teaching measured by their intent to continue teaching, or *retention* (1 = As long as possible, 2 = Others, 3 = Unsure); experiences at their first place of employment upon certification measured by *fulltimeteach*, whether they were employed full-time (0 = Not full-time, 1 = Full-time), *lepstudents*, whether the teacher had limited English proficient (LEP) students in their classroom (0 = Less than 50% LEP students, 1 = Over 50% LEP students), if teachers were supported their first year of teaching in attending seminars or classes for beginning teachers, or *seminars* (0 = No, 1 = Yes), if the teacher had regular supportive communication with an administrator in their school, or *suppcomm* (0 = No, 1 = Yes); environmental factors (school climate) measured by the school organizational variables that were the result of the exploratory factors mentioned in Table 1 (school influence/*schinfluence*, curriculum influence/*currinfluence*, classroom duties/*clsrmduties*, *collegiality*, *truancy*, and *socioemotional*); skills attained after preparation and social/professional integration measured by the teacher's *salary* (numeric variable) as suggested in Chapman (1983) and utilized in Chapman (1984), *maritalstatus* (0 = Not married, 1 = Married or in a committed/domestic partnership), participation in professional development focused on their content, or *pdcontent* (0 = No, 1 = Yes), participation in professional development focused on classroom management, or *pdclassmanage* (0 = No, 1 = Yes); and job satisfaction, a composite mean score of seven items related to teachers' degree of agreement with statements about their job satisfaction. The Cronbach's alpha (Cronbach 1951) for the job satisfaction scale was 0.83. Five of the job satisfaction items were negatively worded, and those items were reverse-scored such that a high level of agreement with an item was equivalent to a high level of job satisfaction. Each of the school organizational items were scored on a four-point Likert scale, with 1 = strongly agree, 2 = somewhat agree, 3 = somewhat disagree, and 4 = strongly disagree. All positively-worded items were reverse-coded such that a high score on an item equaled a positive feeling regarding items on a scale. Job interference was removed from the analysis due to low reliability.

Level 2 principal/school variables include *principalsex* (0 = Female, 1 = Male), *pocprincipal*, whether the principal was a principal of color (0 = White, 1 = Principal of color/non-White,), *prinmajorstem*, whether the principal majored in a STEM field (0 = Non-STEM major, 1 = STEM major), and *prinmasters*, whether the principal had a master's degree (0 = No master's degree, 1 = Master's degree).

Dependent Variable The main outcome, *retained*, is derived from the TFS final teacher status variable (STTUS_TF). The original variable was categorical with three outcomes, comparing a teacher's employment status in 2012–13 with their status in 2011–12: (1) teachers who left the profession altogether, (2) teachers who stayed in their school, and (3) teachers who moved to another school. Following prior work in teacher retention using SASS data (Ingersoll 2001; Ingersoll and May 2010), the final teacher status was collapsed into a dichotomous variable, with teachers who either left or moved coded as non-retained (0) and teachers who stayed at their 2011–12 school as retained (1).

Analysis

A two-level logistic model with a likelihood estimation method was utilized for this study, due to the dichotomous nature of the dependent variable (Hox 2010). Multilevel analysis is preferred to analyze data that is nested in structure. For this study, the teachers were nested within the schools (principals). All data analyses were conducted using Stata® 15 Statistics/ Data Analysis Software. Below are the four models used in the study's analysis: the unconditional model (Model 1), a random intercept model with only level one teacher predictors (Model 2), a random intercept model with only level two principal/school predictors (Model 3), and a final model containing only significant level one and level two predictors (Model 4). Due to the failure of the random slope model (Model 3) to converge for both the level one and level two, the study findings focus only on random intercept model (Model 4) for both levels of predictors.

The baseline, or unconditional model (Model 1) is shown as:

$$retained_{\mathrm{ij}} = \gamma_{00} + \mathrm{U}_{0\mathrm{j}} + \mathrm{eij} \tag{1}$$

where $retained_{\mathrm{ij}}$ represents retention for individual i in school j, γ_{00} represents the grand mean score on retention for all clusters, $\mathrm{U}_{0\mathrm{j}}$ represents the variation across clusters, and e_{ij} represents the variation within school j.

Model 2, the random intercept model with teacher-level (level 1) predictors is shown as

$$\begin{aligned} retained_{\mathrm{ij}} &= \beta_{0\mathrm{j}} + \beta_{1\mathrm{j}} teachersex_{\mathrm{ij}} + \beta_{2\mathrm{j}} pocteach_{\mathrm{ij}} + \beta_{3\mathrm{j}} age_{\mathrm{ij}} + \beta_{4\mathrm{j}} mastersdegree_{\mathrm{ij}} \\ &+ \beta_{5\mathrm{j}} majorstem_{\mathrm{ij}} + \beta_{6\mathrm{j}} methods_{\mathrm{ij}} + \beta_{7\mathrm{j}} numcourses_{\mathrm{ij}} + \beta_{8\mathrm{j}} practice_{\mathrm{ij}} + \beta_{9\mathrm{j}} length_{\mathrm{ij}} \\ &+ \beta_{10\mathrm{j}} retention_{\mathrm{ij}} + \beta_{11\mathrm{j}} fulltimeteach_{\mathrm{ij}} + \beta_{12\mathrm{j}} lepstudents_{\mathrm{ij}} + \beta_{13\mathrm{j}} seminars_{\mathrm{ij}} \\ &+ \beta_{14\mathrm{j}} suppcomm_{\mathrm{ij}} + \beta_{15\mathrm{j}} schinfluence_{\mathrm{ij}} + \beta_{16\mathrm{j}} currinfluence_{\mathrm{ij}} + \beta_{17\mathrm{j}} clsrmduties_{\mathrm{ij}} \\ &+ \beta_{18\mathrm{j}} collegiality_{\mathrm{ij}} + \beta_{19\mathrm{j}} truancy_{\mathrm{ij}} + \beta_{20\mathrm{j}} socioemo_{\mathrm{ij}} + \beta_{21\mathrm{j}} salary_{\mathrm{ij}} + \beta_{22\mathrm{j}} marital_{\mathrm{ij}} \\ &+ \beta_{23\mathrm{j}} pdcontent_{\mathrm{ij}} + \beta_{24\mathrm{j}} pdclassmanage_{\mathrm{ij}} + \beta_{25\mathrm{j}} jobsatis_{\mathrm{ij}} + \mathrm{U}_{0\mathrm{j}} + e_{\mathrm{ij}} \end{aligned} \tag{2}$$

where $retained_{\mathrm{ij}}$ represents retention for individual i in school j, $\beta_{0\mathrm{j}}$-$\beta_{25\mathrm{j}}$ represents the coefficients associated with each of the level 1 covariates, $\mathrm{U}_{0\mathrm{j}}$ represents the variation across clusters, and e_{ij} represents variation within school j.

Model 3, the random intercept model with teacher-level (level 1) predictors is shown as

$$\begin{aligned} retained_{\mathrm{ij}} &= \beta_{0j} + \beta_{1\mathrm{j}} teachersex_{\mathrm{ij}} + \beta_{2\mathrm{j}} pocteach_{\mathrm{ij}} + \beta_{3\mathrm{j}} age_{\mathrm{ij}} + \beta_{4\mathrm{j}} mastersdegree_{\mathrm{ij}} \\ &+ \beta_{5\mathrm{j}} majorstem_{\mathrm{ij}} + \beta_{11\mathrm{j}} fulltimeteach_{\mathrm{ij}} + \beta_{12\mathrm{j}} lepstudents_{\mathrm{ij}} + \beta_{15\mathrm{j}} schinfluence_{\mathrm{ij}} \\ &+ \beta_{16\mathrm{j}} currinfluence_{\mathrm{ij}} + \beta_{17\mathrm{j}} clsrmduties_{\mathrm{ij}} + \beta_{18\mathrm{j}} collegiality_{\mathrm{ij}} + \beta_{19\mathrm{j}} truancy_{\mathrm{ij}} \\ &+ \beta_{20\mathrm{j}} socioemo_{\mathrm{ij}} + \beta_{25\mathrm{j}} jobsatis_{\mathrm{ij}} + \mathrm{U}_{0\mathrm{j}} + e_{\mathrm{ij}} \end{aligned} \tag{3}$$

where $retained_{\mathrm{ij}}$ represents retention for individual i in school j, $\beta_{0\mathrm{j}}$-$\beta_{25\mathrm{j}}$ represents the coefficients associated with each of the level 1 covariates, $\mathrm{U}_{0\mathrm{j}}$ represents the variation across clusters, and e_{ij} represents variation within school j.

Model 4, the random intercept model with principal/school-level (level 2) predictors added is shown as

$$\begin{aligned} retained_{ij} = {} & \beta_{0j} + \beta_{1j} teachersex_{ij} + \beta_{2j} pocteach_{ij} + \beta_{3j} age_{ij} + \beta_{4j} mastersdegree_{ij} \\ & + \beta_{5j} majorstem_{ij} + \beta_{11j} fulltimeteach_{ij} + \beta_{12j} lepstudents_{ij} + \beta_{15j} schinfluence_{ij} \\ & + \beta_{16j} currinfluence_{ij} + \beta_{17j} clsrmduties_{ij} + \beta_{18j} collegiality_{ij} + \beta_{19j} truancy_{ij} \\ & + \beta_{20j} socioemo_{ij} + \beta_{24j} jobsatis_{ij} + \gamma_{01} principalsex + \gamma_{02} pocprincipal \\ & + \gamma_{03} prinmajorstem + \gamma_{04} prinmasters + U_{0j} + e_{ij} \end{aligned} \quad (4)$$

where *retained*$_{ij}$ represents retention for individual i in school j, β_{0j}-β_{25j} represents the coefficients associated with each of the level 1 covariates, γ_{01}- γ_{04} represent the coefficients associated with each of the level 2 covariates, U_{0j} represents the variation across clusters, and e_{ij} represents variation within school j.

Model 5, the final random intercept model with teacher-level (level 1) and principal/school-level (level 2) predictors is shown as

$$retained_{ij} = \beta_{0j} + \beta_{3j} age_{ij} + \beta_{24j} jobsatis_{ij} + \gamma_{03} prinmajorstem + e_{ij} \quad (5)$$

where *retained*$_{ij}$ represents retention for individual i in school j, β_{0j}, β_{3j}, and β_{24j} represents the coefficients associated with each of the level one covariates, γ_{03} represents the coefficient associated with the level two covariates, and e_{ij} represents variation within school j.

Results

Descriptive statistics of the variables of interest are shown in Table 2. As mentioned previously, the level 1 variables were all teacher variables taken from the original 2011–2012 SASS Teacher Survey administration. Level 2 variables were taken from the 2011–2012 SASS Principal Survey administration.

Research Question One

The study's first research question was focused on determining what proportion of the variance in STEM teacher retention was due to school differences and whether there was a significant variation among schools in STEM teacher retention. The intraclass correlation for the null model (1) was .292 (SE = .192, CI = [.063, .718]). This indicates that about 29.2% of the variance in STEM teacher retention was accounted for by differences across the schools.

Primary Based on the unconditional model (1), the average odds for secondary STEM teachers to be retained is 3.037, which was statistically significant ($z = 5.47$, $p < .001$), as seen on Table 3. However, the null model does not appear to be significantly different from a logistic model ($\chi^2 = 2.45$, $p = .059$). Null model odds ratio estimates can be seen in Table 3. Additionally, the odds of a STEM teacher being retained is 1.359, with no additional predictors in the model. That is, secondary STEM teachers

Table 2 Descriptive statistics

Variables	n	M	SD	Min	Max	%
Age	920	41.730	11.578	20	77	
Salary	920	49,823	15,807.83	1500	139,000	
School influence	920	2.043	.619	1	4	
Curriculum influence	920	2.703	.864	1	4	
Classroom duties	920	3.551	.503	1	4	
Collegiality	920	1.950	.637	1	4	
Job interference	920	2.491	.684	1	4	
Truancy	920	2.832	.695	1	4	
Socioemotional	920	2.283	.719	1	4	
Job satisfaction	920	2.136	.714	1	4	
Female	920					57.57
Teacher of color	920					10.39
Master's degree	920					56.09
Full-time teacher	920					95.29
Married	920					75.05

are about 3.037 times as likely to be retained when all the other predictors are at 0. Since the dataset only contains secondary STEM teachers, our subject of interest, it does not compare them to non-STEM teachers.

Research Question Two

Models 2, 3, 4, and 5 are displayed on Table 3. Model 2 with all of Chapman's (1983) predictors did not converge. The final model (5), displayed in Table 3, shows that secondary STEM teachers age is a significant predictor of retention. Each additional unit increase in age is associated with a higher likelihood of being retained ($OR = 1.020$, $z = 2.48$, $p = .013$). Additionally, secondary STEM teachers who are highly satisfied are less likely to be retained ($OR = .377$, $z = -3.50$, $p < .001$) than non-satisfied secondary STEM teachers. Morever, having a principal who majored in STEM increases the odds of being retained ($OR = 2.137$, $z = 2.27$, $p = .023$), compared to having a principal who did not major in a STEM major. Conversely, the odds of a STEM teacher being retained with low job satisfaction and a principal who did not major in STEM are 17.351 ($z = 3.46$, $p = .001$). That is, those secondary STEM teachers are 17.351 times as likely to be retained in the classroom, holding all else equal.

Research Question Three

In order to determine the proportion of variance in secondary STEM teacher retention explained by the final model, the Raudenbush and Bryk (2002) R^2 was calculated. The result was 0.138, indicating that the final model explained about 13.8% of the variation in secondary STEM teacher retention.

Table 3 Models odds ratio estimates predicting STEM teacher retention

Parameters	Model 1 OR (SE)	Model 2 OR (SE)	Model 3 OR (SE)	Model 4 OR (SE)	Model 5 OR (SE)
Constant (γ_{00})	3.037***	–	82.579**	56.515*	17.351**
	(.617)		(136.840)	(101.671)	(14.311)
Fixed Effects					
Level 1					
β_{1j}*teachersex*$_{ij}$			1.052	1.077	
			(.217)	(.233)	
β_{2j}*pocteach*$_{ij}$			.725	.629	
			(.213)	(.207)	
β_{3j}*age*$_{ij}$			1.022*	1.023*	1.020*
			(.009)	(.010)	(.008)
β_{4j}*mastersdegree*$_{ij}$			.820	.765	
			(.175)	(.173)	
β_{5j}*majorstem*$_{ij}$			.826	.862	
			(.172)	(.189)	
β_{6j}*methods*$_{ij}$					
β_{7j}*numcourses*$_{ij}$					
β_{8j}*practice*$_{ij}$					
β_{9j}*length*$_{ij}$					
β_{10j}*retention*$_{ij}$					
β_{11j}*fulltimeteach*$_{ij}$			.524	.546	
			(.215)	(.224)	
β_{12j}*lepstudents*$_{ij}$			.952	.915	
			(.197)	(.199)	
β_{13j}*seminars*$_{ij}$					
β_{14j}*suppcomm*$_{ij}$					
β_{16j}*currinfluence*$_{ij}$			.961	.972	
			(.137)	(.145)	
β_{17j}*clsrmduties*$_{ij}$			.775	.695	
			(.191)	(.185)	
β_{18j}*collegiality*$_{ij}$			1.286	1.327	
			(.279)	(.307)	
β_{19j}*truancy*$_{ij}$			1.049	1.103	
			(.209)	(.234)	
β_{20j}*socioemo*$_{ij}$			.710	.732	
			(.141)	(.151)	
β_{21j}*salary*$_{ij}$					
β_{22j}*marital*$_{ij}$					
β_{23j}*pdcontent*$_{ij}$					
β_{24j}*pdclassmanage*$_{ij}$					
β_{25j}*jobsatis*$_{ij}$			.432**	.396**	.377***
			(.131)	(.128)	(.105)

Table 3 (continued)

Parameters	Model 1 OR (SE)	Model 2 OR (SE)	Model 3 OR (SE)	Model 4 OR (SE)	Model 5 OR (SE)
Level 2					
γ_{01}*principalsex*				.916	
				(.205)	
γ_{02}*pocprincipal*				1.434	
				(.436)	
γ_{03}*prinmajorstem*				2.176*	2.137*
				(.795)	(.715)
γ_{04}*prinmasters*				1.698	
				(1.185)	
Random					
σ_e^2	1.359		1.867	1.899	1.577
	(1.260)		(1.918)	(1.869)	(1.474)
	CI = [.221, 8.371]		CI = [.249, 13.981]	CI = [.276, 13.077]	CI = [.252, 9.855]

*$p < .05$, **$p < .01$, ***$p < .001$. OR represents the odds ratio. SE represents the standard errors

Discussion

The researchers explored various variables that not only related to the teacher but also organizational variables related to school leadership and school climate. Of all the teacher-level variables examined, job satisfaction was the only significant variable with a positive effect on STEM teacher retention. The relationship between the positive effect of teacher job satisfaction on teacher retention teachers has been documented in over a decade of research that supports the notion that teachers who are satisfied will be more likely to stay in the field teaching (Duyar et al. 2013; Ingersoll 2001; Ingersoll and May 2010; Shen et al. 2012). The sex of the teacher, whether they were a teacher of color, whether they majored in a STEM-related field, whether they had a master's degree, whether they taught a STEM-related subject, whether they were full-time or taught LEP students, and the rest of the organization variables did not significantly predict STEM teacher retention, as we had originally thought from past research (Campoli 2017; Grissom et al. 2012; Mills 2004; Mills et al. 2010). Additionally, none of the principal variables explored (sex of the principal, whether they were a principal of color, and whether they had a master's degree) significantly predicted STEM teacher retention, except for whether the principal majored in a STEM-related field. Moreover, the finding that age significantly predicts retention is similar to results by Tai et al. (2007). Tai et al. (2007) found that older teachers are more likely to be retained. We found that older STEM teachers are more likely to be retained.

Few studies have examined teacher retention, particularly among secondary STEM teachers, following the implementation of NCLB. The present study's most important finding was the positive and significant effect that having a principal who majored in STEM major has on the retention of secondary STEM teachers. The results of the study show that the odds that secondary STEM teachers with principals who have a better understanding of STEM content significantly and positively predict retention, with the odds of teachers who have a principal who majored in STEM 2.137 times that of teachers who have a principal who did not major in a STEM field.

This finding extends the results of two recent studies (Fuller and Schrott 2015; Shen et al. 2012) that investigated the impact of principal characteristics on teacher retention. The Shen et al. (2012) study looked at several principal characteristics, including prior leadership positions, such as being a department head, coach, or curriculum specialist. However, though that study also examined principal education, the non-subject specific nature of the sample did not allow for consideration of whether a principal's college major significantly predicted satisfaction or retention in a particular group of teachers. The Fuller and Schrott (2015), using data from Texas secondary teachers, determined that having sustained access (3 or more years) to a principal with a STEM major did increase the likelihood that teachers would be retained on a campus. However, the studies findings, though meaningful, were not statistically significant at the $p < .05$ level and only included only mathematics and science teachers. Though it is widely believed that principals are instructional leaders playing critical roles in STEM education (Community for Advancing Discovery Research in Education 2011; Nelson and Sassi 2005), efforts to improve STEM education fall mainly on the shoulders of classroom teachers, with little specific information as to how principals might be selected and trained for greater student STEM success. In order to recruit and retain more STEM teachers, national efforts to recruit and retain more principals who majored in STEM may be another avenue for STEM teacher retention policy efforts. Another major contribution of this study is the generalizability of the study findings to secondary STEM teachers in the US due to the fact that SASS data is drawn from a nationally-representative sample of teachers.

Limitations and Directions for Future Research

This study's findings that higher job satisfaction results in greater odds of secondary STEM teachers remaining in teaching combined with the findings that secondary principals with STEM majors positively and significantly predict secondary STEM teacher retention has several important implications for education research and policy. First of all, due to the present study's relatively small sample size for multilevel modeling, compared to the overall SASS sample size, it is critical for organizations, such as the IES to consider conducting surveys of STEM teachers on a larger scale. Based on these results, oversampling STEM teachers at the elementary and secondary levels, similar to the oversampling of beginning teachers for SASS, would provide a greater sample of STEM teachers in the SASS data. Though surveys such as the National Survey and Science and Mathematics Education (NSSME; Banilower et al. 2013) and the Trends in International Mathematics and Science Study (TIMSS, National Center for Education Statistics 2015) focus on nationally-representative surveys of secondary STEM teachers, these surveys do not currently conduct follow-up studies similar to SASS that allow for examination of the actual retention of teachers in the field. In addition, in order to determine if there are post-NCLB differences in secondary STEM teacher autonomy, a longitudinal comparison of pre- and post-NCLB SASS survey data would provide a clearer link of how, or if, high stakes testing environments impact autonomy for STEM teachers specifically. Moreover, it appears that improving the quality of work lives of STEM teachers could prove to be an area of interest for future study, as job satisfaction significantly improved the odds of being retained. This finding is consistent with recent research of novice STEM teachers (Wang et al. 2018). The results of the unconditional model show that STEM teachers, without looking at other predictors in the model, are about 3 times as likely to be retained, indicating that some aspect or aspects of teachers' work makes them more satisfied. More research is needed with regard to potential ways in which job satisfaction play a role for STEM teachers. Rich qualitative data could help in this area, perhaps with focus groups, one-on-one interviews, or observational studies.

In addition to surveys with a stronger focus on STEM teachers, the present study's findings indicate that secondary STEM teacher retention could be aided by state and local education policies that focus on a concerted effort to recruit and retain more principals with expertise in STEM fields. A possible explanation could be that STEM-degreed principals simply have an understanding of the content and therefore might understand the needs of STEM teachers to a greater degree than their non-STEM counterparts. While decades of federal reports and studies on how to improve US STEM education have focus mainly on STEM teacher education and teacher quality (Hattie 2008; National Commission on Excellence in Education 1983; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine 2007, 2010; Rivkin et al. 2005), the field could also benefit from further quantitative and qualitative research looking at characteristic of STEM-degreed secondary principals and their leadership style to determine differential impacts on STEM teachers. As school districts consider ways in which they can keep STEM teachers, they should consider incentivizing STEM-degreed principals as a way to increase their recruitment, by providing resources such as moving expenses and signing bonuses, possible bonuses for retention of STEM teachers, among others. It is evident that further research is needed on interventions that have resulted in the recruitment and retention of STEM-degreed principals, and ways in which they contribute to STEM teachers' job satisfaction.

Conclusion

This study set out to examine characteristics of teachers and principals that contributed to the retention of secondary STEM teachers in the United States. We used a multilevel analysis of the NCES SASS dataset to account for the nested structure of the data. STEM teachers' job satisfaction showed to play a significant positive effect on their retention. However, the present study's most important contribution to the literature on teacher retention was that having a principal who majored in a STEM subject had a positive and significant effect on the retention of secondary STEM teachers. STEM teachers that had a principal who majored in a STEM field were 2.137 times as likely to be retained than STEM teachers who had a principal that did not major in a STEM field. If schools are to retain STEM teachers, we need to start thinking of creative ways of hiring and retaining more STEM principals.

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Appendix

List of STEM subjects using variable *t0090*

Code	Teaching Assignment	Code	Teaching Assignment
191	Algebra I	210	Science, general
192	Algebra II	211	Biology or life sciences
193	Algebra III	212	Chemistry
194	Basic and general mathematics	213	Earth sciences
195	Business and applied math	214	Engineering
196	Calculus and pre-calculus	215	Integrated science
197	Computer science	216	Physical sciences
198	Geometry	217	Physics
199	Pre-algebra	246	Construction trades, engineering, or science technologies (including CADD and drafting)
200	Statistics and probability	255	Industrial arts or technology education
201	Trigonometry	256	Other career or technical education

Source. National Center for Education Statistics (2011). *SASS, Schools and Staffing Survey*. Washington, DC: U.S. Dept. of Education, Office of Educational Research and Improvement, National Center for Education Statistics

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