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Racially diverse educational pathways and STEM college outcomes: A quantitative analysis of students in North Carolina

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Abstract

This article investigates whether attending a sequence of racially diverse schools predicts science, technology, engineering, and mathematics (STEM) college outcomes. Such a relationship is important because of the increasingly diverse population of school-aged children who are likely to attend racially segregated K-12 schools and colleges, the benefits for individuals and society of STEM college graduates, and the projected shortage of people trained for future STEM workforce demands. We use a unique panel data set ($N = 14{,}980$) of the University of North Carolina graduates. Our main analytical approach is multilevel modeling to examine the relationship between attending a sequence of racially diverse educational institutions and the odds of declaring and/or graduating with a STEM major. We find that students who attended a diverse sequence of schools are more likely to declare and graduate with STEM majors than those who did not. Framing our results with theories of cumulative advantage and intergroup contact theories, we offer science education policy reform recommendations.

KEYWORDS

contact theory, cumulative advantage, diverse schools, multilevel modeling, race, STEM

1 | INTRODUCTION

Several noteworthy US societal trends and their intersection with educational institutions are the focus of this article. The first is shortages of youth from all demographic groups who are prepared in science, technology, engineering, and mathematics (STEM) fields; the second is that the population of school-aged children in the United States today is more ethnically and racially diverse than it was decades ago (National Center for Education Statistics, 2017); and third, all students are increasingly likely to attend schools that are racially segregated (Clotfelter et al., 2021; Fiel & Zhang, 2019). Even though a preponderance of research reports multiple benefits from attending racially diverse schools for students from all backgrounds (Mickelson & Nkomo, 2012; Mickelson et al., 2020; *Parents Involved in Community Schools V. Seattle School Dist. No. 1*, 2006), efforts to foster diverse educational institutions are controversial, contested, and largely stalled (Frankenberg et al., 2019). Finally, inequities in STEM achievement and attainment remain stubbornly stable, despite K-16 educational reforms (E. L. Green & Goldstein, 2019; Goldstein, 2019).

Regardless of how racial segregation is defined or measured, it is clear that it is increasing.[i] This is true for many reasons. Higher birth rates among American families of color, socioeconomic (SES) polarization, immigration by families from Latin America, Asia, and Africa, and the decline in the relative proportion of Whites attending K-12 schools have shifted the demographic characteristics of the nation's school population (Bottia, 2019). These demographic changes, combined with local, state, and federal policies that no longer advance residential and school desegregation, such as market-inspired reforms, contribute to greater racial segregation in schools (Fiel & Zhang, 2019).

Examining if there is a significant relationship between long-term STEM educational outcomes and attending a sequence of diverse schools and colleges is valuable for informing several educational policy debates, including strategies to meet STEM labor force demands. Prior studies suggest that students who attend diverse K-12 schools have, on average, higher average math and reading scores (Hanushek et al., 2009; Johnson & Nazaryan, 2019; Mickelson et al., 2013, 2020; Palardy, 2008), greater likelihood of enrolling in college (Bottia et al., 2021; Palardy, 2013; Teranishi & Parker, 2010), and a lower likelihood of dropping out of school (Saatcioglu, 2010) than students who learned in segregated contexts. This is particularly true for Black students. In addition, studies indicate that students who attend racially diverse educational institutions develop deeper ways of thinking, have higher aspirations—both educational and occupational— and report more positive interactions with students of other races and ethnicities compared with students who attend segregated schools (Gurin et al., 2002; Mickelson & Nkomo, 2012; Pettigrew & Tropp, 2006; Tropp & Prenovost, 2008).

With this study, we advance the literature by exploring an additional aspect of diverse schooling—the relationship between attending a sequence of racially diverse educational institutions and the successful pursuit of a college STEM major. We center attention on college STEM outcomes because worldwide, the importance of STEM degrees is increasing for individuals and their societies. The need to cultivate a cutting-edge STEM workforce in all sectors of the economy and society is also growing. For individuals, college attendance and choice of college major are strongly related to the occupational and mobility pathways that are available to them. We also focus on STEM degree attainment because of the pivotal role STEM has in current and projected labor force demands and the consequences for individuals' social mobility and life chances (Mickelson & Nkomo, 2012). Most STEM fields offer opportunities to obtain high-status and well-paying jobs with possibilities for upward mobility and meaningful, socially useful employment. However, recent data show that the demographics of the student population in STEM programs continue not to reflect the gender composition and racial diversity of the United States (Burke, 2022).

The specific context upon which we focus is the level of racial/ethnic diversity in the sequence of schools that pupils attended. Our analysis investigates racial diversity in K-12 and postsecondary educational contexts in relation to declaring a STEM major and/or graduating with a STEM degree (henceforth, college STEM outcomes). Prior research confirms that neither K-12 schools nor college contexts alone are predictive of students' college STEM outcomes. However, K-12 and postsecondary educational contexts are important for students' decisions to pursue STEM careers (Bottia, Stearns, Mickelson, Moller, & Parker, 2015; Bottia, Stearns, Mickelson, Moller & Valentino, 2015; Crisp et al., 2009; Espinosa, 2011; Phelps et al., 2018).

To our knowledge, no other study has focused on the relationship between the diversity of students' educational pathways and their college STEM outcomes. We investigate this relationship using a unique administrative data set from North Carolina that includes information about pupils' middle school, high school, 2-year, and 4-year college characteristics, and their STEM outcomes. Using multilevel binomial modeling and predicted probabilities, we examine the relationship between attending a sequence of racially diverse schools and students' odds of declaring and graduating with a STEM degree.

Many educators, social scientists, and civil-rights advocates argue that decreases in racial diversity in K-16 schools have become a source of inequality in educational opportunities and outcomes (*Parents Involved in Community Schools V. Seattle School Dist. No. 1*, 2006; Reardon & Owens, 2014). But to date, there has been no investigation of whether racial diversity in educational institutions relates to students' college STEM outcomes. We hypothesize that it does. In what follows, we review research that summarizes why diverse schools may influence STEM outcomes and lay out the theoretical framework that includes cumulative advantage and contact theory, which we use to develop our hypotheses. Next, we discuss the administrative data set and analytic strategies we employed and present our findings, then link the findings to the theoretical framework and offer policy recommendations.

2 | LITERATURE REVIEW

2.1 | Why attending a racially diverse schools matters for academic outcomes

Prior studies help us to understand the relationship that might exist between the racial composition of educational institutions attended, students' interest in STEM, and a decision to follow a STEM pathway. First, the context in which individuals receive their schooling strongly influences the quantity and quality of educational opportunities they receive (Berends & Peñaloza, 2010; Bohrnstedt et al., 2015; Bottia et al., 2018; Hanushek et al., 2009; Hogrebe & Tate, 2010; Lleras, 2008; Reardon, 2016). Educational opportunities and contexts develop students' academic skills and foster aspirations and goals that align with students' decisions to pursue STEM majors in college.

A school's racial/ethnic composition is associated with the mean SES of the school itself, parental involvement, the range of extra- and co-curricular activities, all of which correlate with the academic press, mean achievement in core subjects, teacher quality, scope and rigor of curricula, access to career guidance, and adult role models (Harris, 2010; Ready & Silander, 2011; as cited in Frankenberg & DeBray, 2011). For example, students attending schools with higher concentrations of underrepresented minoritized populations achieve fewer mathematics and reading gains than their otherwise comparable peers in diverse schools. This negative relationship becomes more pronounced as students transition through elementary to secondary school (Mickelson & Bottia, 2010; Mickelson et al., 2013; Mickelson et al., 2020). Several studies suggest that the ostensible race gap in achievement is due to stark SES differences in poverty levels among racially imbalanced schools and that much of the race gap reflects the effects of racially-correlated SES differences among students (Bohrnstedt et al., 2015; Reardon, 2016). Variations in resources among schools translate into different odds of students' college attendance and choice of major in college (Bottia et al., 2018; Teranishi & Parker, 2010).

Overall, diverse educational contexts better prepare students for a global economy by providing them with skill sets for working with varied groups of people through exposure to different cultures (Tichnor-Wagner et al., 2016). These contexts allow students to become comfortable with cultural differences across groups, promote empathy for others, and reduce discriminatory stereotypes by making students capable of connecting their own lives with the lives of peers from different racial/ethnic groups (Martin & Fisher-Ari, 2021; Wells et al., 2016) and, in general, helping students build self-confidence, so they have lower levels of social vulnerability (Kogachi & Graham, 2020).

Studies find that diverse educational institutions have a role in enhancing critical thinking capacities and improving students' problem-solving and communication capacities (Legal Defense and Educational Fund, 2008). Importantly, together with basic skills in writing, math, and commitment to persevere in a difficult course of study, critical thinking is considered one of the most important factors that helps prepare a student for a STEM academic career (Bertram, 2017; Ramsey & Baethe, 2013). Furthermore, the capacity for higher levels of critical thinking is associated with better mathematics performance (Mickelson & Bottia, 2010), a precondition for students' STEM success. Therefore, diverse educational contexts where students can increase their critical thinking and problem-solving likely lead to a greater likelihood of majoring in STEM and following a career in a related occupation.

Research also shows that a diverse college context can influence students' persistence to graduation in STEM. For example, the culture of undergraduate STEM courses, the type of curriculum the institution offers, shared cultural understandings, peer influences, and the presence of supportive classroom climates can foster a sense of belonging in STEM that helps students persist in STEM (Mullen, 2013; Rainey et al., 2018; Shapiro & Sax, 2011; Soria & Stebleton, 2013). Frequent interaction with diverse peers during college is also positively associated with students' intellectual engagement, leadership skills and psychological well-being, and self-reported gains in generic collegiate skills such as critical thinking and problem-solving (Bowman, 2013; Bowman et al., 2011; Gurin et al., 2002). Furthermore, minoritized students at diverse institutions are more likely to encounter professors who provide them with the feeling of acceptance, support, and encouragement that contribute to the student's feeling of belonging, a sentiment that is important for completing their STEM majors (Benitez et al., 2017; Rainey et al., 2018). Importantly, the magnitude of the benefits of learning in racially diverse contexts might vary depending on the students' race/ethnicity.

3 | THEORETICAL FRAMEWORK

3.1 | Intergroup contact theory

Intergroup contact theory is the first of two theories that help account for the processes that foster greater STEM success in a diverse sequence of schools. Proposed by Allport (1954), intergroup contact theory emphasizes the importance of contact between marginalized populations and majority group actors. Contact leads to mutual positive affect and reduces prejudice and negative stereotypes (Pettigrew & Tropp, 2006), especially if contact is cooperative, officially sanctioned interaction, such as activities in schools, increases the quantity and quality of knowledge that all students have about others' lifestyle, promotes the sharing of cultural and social capital, and fosters important affective ties through enhanced empathy and reduced anxiety (Aberson & Haag, 2007; Vezzali et al., 2018; Yosso, 2005). The more contact students from different race/ethnic backgrounds have, the greater the creativity and the innovations that can emerge as these groups interact (Montuori & Stephenson, 2010; Page, 2008). Ethnically diverse schools can contribute to more inclusive attitudes about others, enhanced capacity to work effectively with those who are different, and problem-solving in new ways that draw upon the knowledge and lived experiences of diverse peers in ways that promote creativity and innovation.

Studies using an intergroup contact lens have also shown the importance of exposure to racially diverse educational contexts for reducing stereotypes. By reducing individuals' essentialist beliefs, the likelihood of gendered and racialized microaggressions and social dominance orientations decrease, and egalitarian attitudes increase (Pauker et al., 2016; Pettigrew & Tropp, 2006; Sue et al., 2008). Such outcomes have the potential to increase previously underrepresented students' participation in STEM majors because they reduce students'—and perhaps teachers' and guidance counselors'—stereotypical beliefs that STEM majors are only for certain types of students. Just as gender essentialism helps account for female students' less frequent choice of STEM majors

(Beutel et al., 2019; Hägglund & Leuze, 2020; Thébaud & Charles, 2018), racial essentialism likely also shape choices of majors that students of color make.

3.1.1 | Cumulative advantages

Cumulative advantage is the second theory that accounts for the processes in diverse schools that foster STEM success. Cumulative advantage is recognized as a mechanism for generating inequality across any temporal process in which a favorable relative position contributes to further production of relative advantage. Research on cumulative advantage as an inequality-generating process exists in sociological literature about neighborhood effects, work and careers, health, and education (DiPrete & Eirich, 2006). It results from not just an individual or a groups' position at the point of origin but from the interaction of complex forces over time (Dannefer, 2003; DeLuca et al., 2016). The theory highlights the power of structural realities within which human agency operates, including secondary course enrollment decisions, academic effort, and choice of college major.

Inspiration and preparation for college STEM ideally begins in early middle school, if not before. Initial small differences in middle school experiences grow larger over the years because progression from one step to the next depends on satisfactory acquisition of skills and knowledge in a normative environment that encouraged the pursuit of STEM in the previous step. Prior empirical research has used cumulative advantage theory to understand the association between teacher quality, curricular rigor, special education/gifted placement, and tracking and students' outcomes over time (Bottia, Stearns, Mickelson, Moller, & Parker, 2015; Bottia, Stearns, Mickelson, Moller & Valentino, 2015; Gamoran & Mare, 1989; Kerckhoff & Glennie, 1999; Lee & Mamerow, 2019; Lucas, 2001; Sanders & Rivers, 1996).[ii]

Attending diverse schools that contribute to cognitive and noncognitive skills and knowledge acquisition creates advantages that accumulate over time relative to attending segregated schools, especially racially imbalanced minority schools with high concentrations of students in poverty. Racially segregated schools are, with few exceptions, less effective educational institutions than racially diverse ones. This statement is especially true for schools with concentrated low-income racial minoritized youth.

To sum up, previous research suggests several ways in which attending a sequence of diverse educational institutions might relate to students' better odds of declaring and graduating with a STEM degree. First, for minoritized students, the accumulation of educational experiences in diverse contexts provides students the opportunity to share certain levels of social and cultural capital with college-oriented peers, exposure to more high-quality teachers, and other experiences that directly and indirectly relate to students' choice of major. Second, for minoritized and White students, the exposure to diverse educational contexts appears to foster creativity and encourage problem-solving, critical thinking and creativity (Bargh, 2006; Gurin et al., 2002; Loes & Pascarella, 2017; Page, 2008), all of which are connected to students' future success in STEM. Third, racially diverse educational institutions have a very important role in limiting essentialist racial and gender stereotypes that can undermine students' decisions to pursue STEM college majors—especially true for minoritized populations. Fourth, these advantages cumulate each year a student attends a diverse school.

Although prior research has addressed how diverse educational institutions at the primary, secondary, and tertiary levels influence various short- and long-term outcomes, to our knowledge, no other study has explicitly examined if the accumulation of exposure to diverse school contexts associated with attending a *sequence* of racially diverse educational institutions is related to students' odds of majoring in STEM and graduating with a STEM degree. We investigate whether a diverse sequence of educational contexts predicts undergraduates' choice to major in a STEM field and their likelihood of earning a STEM degree. In addition, we also explore how the relationship between learning in a sequence of diverse educational contexts relates differently for students of various races/ethnicities given that the related mechanisms are probably different for different groups of students given their racialized identities and their resultant structural positions.

4 | HYPOTHESES

We expect that, consistent with cumulative advantage and intergroup contact theories, the academic and interpersonal benefits from learning in diverse contexts will amass from middle school through college. By accumulating STEM-supportive learning experiences due to superior teaching resources, academically oriented peers, and rich and rigorous curricula in science and math, individuals likely will enhance their abilities in critical thinking capacities, problem-solving, and communication capacities, all of which are necessary for college STEM success. Similarly, students who attend a sequence of diverse schools will have had sustained contact with individuals who are different from themselves and are less likely to hold stereotyped beliefs that STEM careers are more or less appropriate for certain individuals. This more inclusive academic climate can motivate under-represented minoritized and/or female students to pursue STEM. Diverse, inclusive school climates foster a greater sense of belonging in math and science for all youth. Minoritized and White youth who interact with students from different race/ethnic backgrounds are likely to exhibit increased levels of creativity and innovation that also can prepare them for success in STEM fields.

Therefore, based on the advantages associated with diverse schooling that cumulate over time, we hypothesize that, net of individual, family, and other school characteristics, all students who attend a sequence of racially diverse educational institutions will be:

H1: *More likely to declare a STEM major than those students who did not attend a sequence of racially diverse educational institutions.*

H2: *More likely to graduate with a STEM major than those students who did not attend a sequence of racially diverse educational institutions.*

and

H3: *The magnitude of the effects will be greater for Black*[iii] *students than for White students, but that White students who attended a diverse sequence of schools will also benefit from them.*

5 | DATA AND METHODS

5.1 | Data

We use the North Carolina (NC) Roots of STEM Success data set (henceforth, the Roots data set), which contains longitudinal administrative data on the academic performance and scholastic experiences of all 2004 North Carolina public school graduates who later attended 1 of the 16 campuses of the University of North Carolina (UNC) system and declared a major before 2010. The Roots data set contains highly detailed information about North Carolina students' educational trajectories and experiences from middle school through college. The data take the format of a panel study, following the entire population of students from one particular cohort from middle school through college graduation.

The cohort in this study includes students who were in the seventh grade in 1999, graduated high school in 2004, and matriculated into college that fall. Most of the cohort entered 1 of the 16 campuses of the UNC system in the fall of 2004. The remainder initially attended an NC community college and then transferred into a UNC 4-year university. The Roots data include student, family, school, community, and achievement indicators from seventh grade through college graduation, as well as information about the characteristics of the schools and colleges that students attended. The data used in this study come from administrative records collected by the North Carolina Department of Public Instruction (grades 7–12) and the UNC System Office (college experiences).

We focus on this racially and socioeconomically diverse sample of 15,920 college-bound students who attended approximately 520 middle schools and 310 high schools in North Carolina before entering public colleges. The sample we employ is demographically representative of the segment of the state's student population that has ever attended a 4-year college and who declared a major within 6 years of high school graduation.[iv] A large majority of college-attending students in North Carolina remain in-state in part because NC's colleges are relatively affordable. The institutions in the UNC system vary widely in levels of prestige and rigor (including very competitive public universities such as UNC Chapel Hill and North Carolina State University), types of institution (including minority-serving and historically Black colleges and universities [HBCUs]), and areas of specialty (comprehensive liberal arts, science and engineering, and the arts).

5.2 | Outcome variables

The focal outcome variables for the present analyses are the major students declared and the major in which their bachelor's degree was awarded.[v] These variables are binary, where 0 indicates declaration or graduation with a non-STEM major, and 1 represents declaration or graduation with a major in STEM. To define a STEM major, we use the categorization utilized by the National Science Foundation (2001) where majors such as engineering, physical sciences, earth, atmospheric or ocean sciences, mathematical and computer sciences, and biological and agricultural sciences are considered to fall within the STEM category.

5.3 | Key independent variables

The key independent variable in these analyses is whether a student experienced exposure to certain levels of racial diversity in their educational pathways. We capture the degree of diversity when students are in middle school, high school, and postsecondary context (community college if attended and 4-year college) instead of just K-12 schools because of the relevance all educational contexts have to students' college decisions about majors. We start in middle schools because middle school years are a pivotal time in shaping youths' sense of selves in relation to STEM (Kang et al., 2019). The high school years are also recognized as critical for developing interest and success in STEM fields (Koomen et al., 2021; Wang, 2013). In general, before students enter high school and long before they enter college, disparities in STEM aspirations are clearly apparent (Riegle-Crumb et al., 2011). We expect the accumulation of learning in diverse educational contexts to be related to the strengthening of different learning processes, the minimization of certain racial prejudices, and the solidification of self-beliefs that might promote a broader group of students' likelihoods of declaring and graduating with a STEM major.

To operationalize racially diverse educational institutions, we use their overall racial makeup. We consider educational institutions to be diverse when neither White students, nor the sum of Black/Latinx students constitutes more than 75% of the school system's student body overall following Rabinowitz et al. (2019). This 75% threshold ensures substantial exposure to different racial/ethnic groups.[vi] According to the North Carolina Department of Public Instruction, 64% of the 2004 graduating high school class members were White, 28% were Black, 4% were Latinx (32% is the Black/Latinx threshold in regression models), 2% were Asian, and 1% were American Indian.[vii]

Using the more than 75% threshold, we identified 268 of the state's 504 middle schools as diverse and out of the 310 high schools, 162 were diverse. Our analysis included 59 community colleges, of which 38 were classified as diverse. Notably, five of the state's sixteen 4-year institutions of higher education are HBCUs. Lastly, out of the UNC system's sixteen 4-year college campuses, five were categorized as diverse.

The effects of the *sequence* of diverse schools are the dynamic of interest in this paper. Our independent variables capture continuous exposure to diverse educational contexts that we hypothesize offers *cumulative advantages* to their students. To test our hypothesis, we utilize two different measures of accumulation of diverse educational experiences. The first measure is a dummy variable that measures if all schools a student attended were diverse (1) or not (0). The second measure is a categorical variable that tracked the pathway of students from middle school through 4-year college. The measurement of those who attended all diverse institutions is the same as the first measure, but it disaggregates the "0" category of nondiverse pathways into three different pathways: (1) segregated Black/Latinx educational pathway if students attended only segregated Black/Latinx institutions; (2) segregated White educational pathway if students attended exclusively segregated White institutions; and, (3) any other type of educational pathway (combinations of segregated Black/Latinx, segregated White and/or diverse schools), categorized as "Other." Consistent with our theoretical framework, attending segregated institutions, either segregated White and/or segregated Black/Latinx, should not offer the type of benefits a diverse educational institution might offer to students. Given that segregated White schools in suburban communities likely have student bodies with higher SES, we anticipate that segregated White sequences will boost the odds of choosing a STEM major and graduating with a STEM compared with the influence of the sequence of segregated minority schools. But the advantages associated with the higher SES of segregated White sequences will not be as strong as those associated with the sequence of diverse schools.

Table 1 shows that 19% of our overall sample of students followed a diverse educational pathway, while 1% followed a segregated Black/Latinx educational pathway, 22% followed a segregated White educational pathway, and 58% attended a combination between diverse and/or segregated White and/or segregated Black/Latinx. Depending on students' race, there are important racial differences in the percentage of students who attended a sequence of racially diverse educational institutions. While 40% of the Asian American, 35% of the Latinx, and 20% of the Black students in our sample attended a sequence of racially diverse educational institutions, only 17% of the White students followed this sequence. In addition, a greater proportion of Black students followed a segregated Black/Latinx educational pathway (6%) compared with almost none of the White or Asian American students. Table 1 also shows that a substantial segment of White students in NC (29%) attended only segregated White educational institutions from middle schools through 4-year college.

TABLE 1 Proportion of students by race and the type of racial educational pathway followed (middle school through college).

	Segregated White	Other/mix	Diverse	Segregated Black/Latinx
Black	0.03	0.71	0.20	0.06
Latinx	0.10	0.54	0.35	0.00
Asian	0.11	0.49	0.40	0.00
American Indian	0.04	0.68	0.26	0.01
Other	0.21	0.54	0.25	0.01
White	0.29	0.54	0.17	0.00
Total	0.22	0.58	0.19	0.01

5.4 | Control variables

Although the focus of this manuscript is various sequences of racially diverse or segregated educational institutions—a school organizational feature that we hypothesize fosters or undermines the successful completion of a college STEM degree—there are important individual, family, and other school characteristics that interact with this focal variable of interest and also contribute to STEM outcomes. Therefore, we include a variety of control variables identified in prior research as important either for understanding students' choice of STEM majors or factors possibly related to students' likelihood of following a diverse educational pathway.

Individual student characteristics and family financial, cultural, and social capital resources are correlated with STEM outcomes (Bottia et al., 2018, 2021; Bottia, Stearns, Mickelson, Moller, & Parker, 2015; Bottia, Stearns, Mickelson, Moller & Valentino, 2015). The demographic factors include students' gender, race/ethnicity, and socioeconomic status measured by parental education and whether a student was from a low-income family during middle school. Parental education is included to check if their family SES and not their diverse educational pathways predict entry into STEM. We include different variables to control for students' prior academic achievement, such as students' math SAT scores, high school class rank, whether the individual took a course in physics during high school, and whether the student was identified as academically gifted. In addition, we control for secondary school characteristics including the percent of low-income students in a middle school, the average SAT total score at the high school, and the percent of non-STEM courses offered at the high school (an indicator of students' potential exposure to non-STEM subjects that could influence students' breadth of information about different career options). We also include measures of whether the high school was a magnet school and if the school had a math- and science-focused program. These measures were included to control for possible exposure to special programs and resources that promote STEM education. Additionally, we control for a host of teacher characteristics including percent of high school faculty with advanced degrees, licensure, and experience (over 10 years of experience in teaching); the school's rate of teacher turnover, gender composition of faculty, student/teacher ratio, and its urbanicity (rural or not).

Lastly, we included a measure indicating whether a student attended a community college before entering their 4-year college. In some models, we also include a measure of students' overall GPA from their 1st year of college. The extensive range of student, family, and secondary school characteristics is included to isolate the relationship of racial/ethnic composition of the institutions to college STEM outcomes from other important factors known to contribute to these outcomes.

5.5 | Analytic strategy

The main analytical approach we use to examine the relationship between attending a sequence of racially diverse educational institutions and odds of declaring and/or graduating with a STEM major is multilevel modeling. This strategy takes into consideration the fact that certain groups of students attended the same middle schools, high schools, and the same colleges. Individual error terms in nested data like the Roots of STEM data set typically have correlated errors among individuals at the same middle school, or the same high school, or the same college (Raudenbush & Bryk, 2001). Our multilevel binomial logistic models (Grilli & Rampichini, 2006) estimate the probability students choose STEM majors, correcting for random effects.

We ran multilevel models using the *xtmelogit* command in STATA with random effects by middle school and high school attended and fixed effects for the type of college attended to control for students' demographic and academic characteristics, as well as other high school and college characteristics. *Xtmelogit* is a command used to model binary outcome variables, in which the log odds of the outcomes are modeled as a linear combination of the predictor variables when data are clustered or there are both fixed and random effects. In this case, the mixed models contain both fixed effects and random effects.

We included college-type fixed effects as controls for the variability in academic culture on a college campus. Therefore, we included dummy variables for the main STEM degree-granting campus in NC (North Carolina State University), the flagship campus in the UNC system (UNC Chapel Hill), and for all historically Black colleges (North Carolina Agricultural & Technical State University, North Carolina Central University, Elizabeth City State University, Fayetteville State University, and Winston-Salem State University). The omitted category is the remaining nine institutions that are neither the main STEM campus, the flagship, nor the HBCUs.

We test our hypotheses by examining potential differences in two college outcomes—undergraduates' likelihood of declaring a STEM major during the years 2005–2011 and students' probability of graduating with a STEM degree in those same years. We examine the probabilities for students who followed diverse educational pathways or not, and for students who followed different types of racial educational pathways (racially diverse, segregated, or a combination of educational institutions along their middle school to college educational careers). Every regression analysis we report estimates the probability of selection and graduation in non-STEM or STEM majors. Because the majority of students are non-STEM majors, we use non-STEM as the baseline category. We ran separate analyses for each outcome. Such an approach permits us to look both at major selection and major completion effects for college students who attended various sequences of racially diverse or segregated educational institutions.

Since the previously described analyses were conducted with the full sample, we were concerned that the multilevel regression models could mask unique effects for White and Black, students. Therefore, we conducted separate analyses by racial/ethnic subgroups to see if declaring and graduating with a STEM major still were significantly influenced by the type of sequence of educational institutions students attended, and if so, whether various student race/ethnic subpopulations were affected differently by the diverse sequence. The sample size of specific subpopulations was too small to run multilevel models with students nested by high school and middle school in categories of the various sequence (diverse, mixed/other, segregated White, or segregated Black/Latinx) of schools attended. Instead, we ran logit models and then calculated predicted probabilities of declaring and graduating with a STEM major for the different racial/ethnic subgroups of students.

6 | FINDINGS AND INTERPRETATION

6.1 | Descriptive analysis

Table 2 presents the means for all variables included in our study by the four different racial/ethnic diversity educational pathways (diverse, mixed/other, segregated White, or segregated Black/Latinx). We included this table to test for possible differences in the individual and school-level characteristics among students who follow a sequence of diverse educational institutions versus other sequences. Data show that students in our sample who followed a diverse educational pathway had the highest high school class rank, were most likely to have taken high school physics, and were most likely to be identified as academically gifted. Additionally, students who followed a sequence of diverse educational institutions were the least likely to have attended high schools in rural areas.

Descriptive analyses of data also show that students who followed segregated White pathways appear to have the highest math SAT scores and experienced the most favorable high school opportunities to learn (lowest percentage of low-income classmates, highest percentage of teachers with advanced degrees, highest percentage of licensed teachers, highest school-level average SAT, lower rates of teacher turnover). Table 2 also presents evidence that students who followed segregated Black/Latinx educational pathways to college had less advantageous school conditions than students in diverse or majority White contexts. Students who attended a sequence of segregated Black/Latinx schools had the lowest levels of academic preparation. These descriptive statistics underscore the importance of including controls in our multilevel binomial models.

TABLE 2 Summary statistics (mean percent of sample) for the roots of STEM success data set, by type of racial educational pathway followed from middle school through college.

	Full sample of students (n = 15,920)	Students who attended a sequence of segregated White educational institutions (n = 3610)	Students who attended a sequence of Other (mixed) educational institutions (n = 9020)	Students who attended a sequence of diverse educational institutions (n = 2890)	Students who attended a sequence of segregated Black/Latinx educational institutions (n = 220)
	Mean	Mean	Mean	Mean	Mean
Declared a STEM major	0.223	0.246	0.223	0.195	0.136
Graduated with a STEM major	0.194	0.216	0.195	0.158	0.128
Dummy attended a sequence of racially diverse educational institutions	0.200	0.000	0.000	1.000	0.000
Reference sequence of segregated White educational institutions	0.226	1.000	0.000	0.000	0.000
Sequence of Other educational institutions	0.572	0.000	1.000	0.000	0.000
Sequence of diverse educational institutions	0.190	0.000	0.000	1.000	0.000
Sequence of segregated Black/ Latinx educational institutions	0.012	0.000	0.000	0.000	1.000
Demographic characteristics					
Student is male	0.436	0.465	0.440	0.388	0.344
Student is Black	0.204	0.025	0.247	0.238	0.977
Student is Latinx	0.015	0.007	0.013	0.024	0.005
Student is Asian	0.033	0.015	0.027	0.066	
Student is American Indian	0.009	0.001	0.011	0.009	0.009
Student is Other race/ethnicity	0.007	0.005	0.004	0.007	0.005

TABLE 2 (Continued)

	Full sample of students (n = 15,920)	Students who attended a sequence of segregated White educational institutions (n = 3610)	Students who attended a sequence of Other (mixed) educational institutions (n = 9020)	Students who attended a sequence of diverse educational institutions (n = 2890)	Students who attended a sequence of segregated Black/Latinx educational institutions (n = 220)
	Mean	Mean	Mean	Mean	Mean
Student is White	0.732	0.947	0.699	0.656	0.005
Parent did not finish high school	0.013	0.008	0.014	0.014	0.014
Parent is a high school graduate	0.109	0.104	0.111	0.113	0.176
Parent did some additional education	0.100	0.105	0.099	0.091	0.122
Parent is a trade or business school graduate	0.025	0.029	0.024	0.024	0.023
Parent is a community, technical or junior college graduate	0.149	0.169	0.148	0.134	0.244
Parent is a 4-year college graduate	0.390	0.391	0.394	0.376	0.321
Parent has a graduate school degree	0.214	0.193	0.211	0.247	0.100
Student is economically disadvantaged	0.126	0.051	0.137	0.161	0.461
Academic achievement measures					
Math SAT	508.834	523.828	506.229	504.866	411.973
High school class rank	72.602	73.821	71.913	76.738	69.233
Took physics when in high school	0.288	0.280	0.263	0.325	0.186
Identified as academically gifted	0.266	0.263	0.263	0.294	0.036
High school level characteristics					
High school SES	0.208	0.144	0.219	0.231	0.525

(Continues)

TABLE 2 (Continued)

	Full sample of students (n = 15,920) Mean	Students who attended a sequence of segregated White educational institutions (n = 3610) Mean	Students who attended a sequence of Other (mixed) educational institutions (n = 9020) Mean	Students who attended a sequence of diverse educational institutions (n = 2890) Mean	Students who attended a sequence of segregated Black/Latinx educational institutions (n = 220) Mean
Percent teachers with advanced degrees	0.271	0.287	0.265	0.274	0.194
High school in rural area	0.362	0.582	0.326	0.204	0.385
Percent of licensed teachers	0.821	0.855	0.815	0.807	0.692
Average SAT at HS	998.512	1020.745	994.506	995.430	816.683
Teacher turnover	0.203	0.176	0.205	0.221	0.299
Percent of experienced teachers	0.546	0.577	0.541	0.526	0.552
Percent of female students	0.495	0.491	0.496	0.498	0.510
Student–teacher ratio	16.034	15.661	16.219	16.132	13.064
Proportion of non-STEM courses taught at HS	0.758	0.763	0.756	0.761	0.730
Attended magnet school	0.062	0.000	0.069	0.104	0.195
Attended a school with a math and science focus	0.066	0.050	0.069	0.073	0.174
Type of college					
Attended UNC Chapel Hill	0.123	0.000	0.092	0.373	0.000
Attended North Carolina State University	0.154	0.251	0.174	0.000	0.000
Attended historically Black college	0.131	0.000	0.181	0.071	1.000

6.2 | Pooled models predicting STEM major declaration and graduation

We began our analyses by exploring if students' STEM participation in college significantly differed depending on the racial composition of the educational institutions they attended from middle school to college. We have two alternate specifications of the racial composition of the sequence of educational institutions, which we model separately: (a) a dummy variable for a sequence of diverse educational institutions or not, and (b) categorical variables that flagged if a student attended a sequence of segregated White educational institutions (reference category), a sequence of diverse educational institutions, a sequence of segregated Black/Latinx educational institutions, or a sequence of Other combinations of diverse or not diverse schools. We chose sequence of segregated White educational institutions as a reference because these contexts already appear to offer substantial academic benefits to many students and we want to test if attendance to diverse contexts provides benefits that go even further. All models include random effects for middle schools and high schools attended and fixed effects for types of college institutions attended.

Table 3 shows the results of 12 different models utilized to test Hypotheses 1 and 2. Each group of models includes first, the three models predicting students' odds of declaring a STEM major, and second, the three models predicting students' odds of graduating with a STEM major. The modeling begins with basic demographic controls, then adds academic achievement controls, and finally, the complete models include high school-level control variables. We offer this set of models to see how the relationship between attending diverse educational pathways and students' odds of declaring and graduating with a STEM major varies as we add additional variables that have theoretical or empirical importance for this core relationship of interest.

Models 1–6 in Table 3 show the odds ratios from multilevel binomial models that estimate the probability of declaring and graduating with a major in a STEM field when we utilize a *dichotomous measure* of attending a sequence of diverse educational institutions. Models 7–12 in Table 3 show the odds ratios that estimate the probability of declaring and graduating with a major in a STEM field when we utilize a *categorical measure* of attendance in a sequence of diverse educational institutions (the reference category is the students who attended a sequence of racially segregated White educational institutions).

Results show that in all models the odds that a student who attended a diverse sequence of schools declared a STEM major and graduated with a STEM degree is roughly 1.2–1.3 times higher than those students who did not attend a diverse sequence. These results support Hypotheses 1 and 2, which stated that students who attended diverse educational institutions would be more likely to declare and graduate with STEM majors. Models 1–6 in Table 3 also show that the significant and positive relationship between following a racially diverse educational pathway (measured as a dummy variable) and the two STEM outcomes remains almost unchanged for all models, regardless of which control variables are included. These results, therefore, suggest that the positive relationship between attending a diverse sequence of schools and higher odds of college STEM outcomes is reliable.

Similarly, Models 7–12 in Table 3 present results from models that utilize a categorical measure of attending a sequence of diverse educational institutions. This operationalization of diverse school pathways also shows that students who followed a diverse sequence have odds of declaring and graduating with a STEM major 1.3–1.5 times higher than those students who attended a sequence of segregated White schools. Once again, the odds ratios remain fairly unchanged—although in this case, they are slightly larger—when more controls are added to the models. These findings suggest that the results are reliable and are not due to the influence of confounding variables.

We also ran models without 1st-year college GPA as a control variable to ensure that the relationship between exposure to racially diverse schools and declaring/graduating with a STEM major does not operate solely through enhancing students' achievement as measured by their college GPA. The results in all models are almost identical to the ones from the previous analyses. These findings indicate that the relationship between greater exposure to racially diverse schools and declaring/graduating with a STEM major does not operate through enhancing students' college GPA (see Appendix A).

TABLE 3 Multilevel binomial models predicting odds of declaring and graduating with a STEM major by different measures of exposure to racially diverse educational institutions (odds ratios).

	Dichotomous dependent variable						Categorical dependent variable					
	Declare a STEM major			Graduate with a STEM major			Declare a STEM major			Graduate with a STEM major		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Dummy attended a sequence of racially diverse educational institutions	1.226 (0.080)***	1.236 (0.092)***	1.285 (0.100)***	1.191 (0.094)**	1.167 (0.106)*	1.235 (0.116)**						
Reference (sequence of segregated White educational institutions)												
Sequence of racially Other/mix educational institutions							1.056 (0.064)	1.097 (0.075)	1.144 (0.082)*	1.073 (0.273)	1.202 (0.093)**	1.231 (0.101)**
Sequence of racially diverse educational institutions							1.282 (0.111)***	1.335 (0.130)***	1.453 (0.152)***	1.250 (0.019)**	1.374 (0.159)***	1.51 (0.188)***
Sequence of segregated Black/Latinx educational institutions							0.936 (0.222)	0.774 (0.204)	0.831 (0.227)	1.290 (0.375)	1.055 (0.351)	1.022 (0.356)
Demographic characteristics												
Race/ethnicity	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Gender	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
SES	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included

TABLE 3 (Continued)

	Dichotomous dependent variable						Categorical dependent variable					
	Declare a STEM major			Graduate with a STEM major			Declare a STEM major			Graduate with a STEM major		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Academic achievement measures												
Math SAT		Included	Included		Included	Included		Included	Included		Included	Included
College GPA		Included	Included		Included	Included		Included	Included		Included	Included
High school class rank		Included	Included		Included	Included		Included	Included		Included	Included
Took physics when in high school		Included	Included		Included	Included		Included	Included		Included	Included
Identified as academically gifted		Included	Included		Included	Included		Included	Included		Included	Included
High school level characteristics			Included			Included			Included			Included
Teacher related characteristics			Included			Included			Included			Included
High school SES			Included			Included			Included			Included
High school in rural area			Included			Included			Included			Included
Average SAT at HS			Included			Included			Included			Included
Percent of female students			Included			Included			Included			Included
Attended magnet school			Included			Included			Included			Included
Attended a school with a math and science focus			Included			Included			Included			Included

(Continues)

TABLE 3 (Continued)

	Dichotomous dependent variable						Categorical dependent variable					
	Declare a STEM major			Graduate with a STEM major			Declare a STEM major			Graduate with a STEM major		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Attended community college before joining 4-year college			Included			Included			Included			Included
Type of college fixed effects												
Attended UNC Chapel Hill	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Attended North Carolina State University	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Attended historically Black college	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included	Included
Random-effects parameters- high school	0.2084 (0.0483)	0.184 (0.066)	0.097 (0.116)	0.203 (0.067)	0.180 (0.093)	0.000 (0.325)	0.201 (0.049)	0.180 (0.067)	0.106 (0.107)	0.194 (0.053)	0.165 (0.099)	0.000 (0.321)
Random-effects parameters- middle school	0.187 (0.064)	0.198 (0.081)	0.237 (0.070)	0.274 (0.065)	0.308 (0.077)	0.325 (0.052)	0.203 (0.059)	0.218 (0.074)	0.236 (0.070)	0.268 (0.056)	0.322 (0.074)	0.326 (0.052)
Log likelihoods	−6979.8	−5418.8	−5170.9	−5335.5	−4159.9	−3964.8	−7346.6	−5581.9	−5168.2			
LR test versus logistic model: χ^2	33.76	17.54	11.98	38.03	26.08	16.57	36.25	20.31	12.38	43.26	27.52	16.83
N	14,980	12,080	11,580	12,630	10,350	9,880	15,740	12,410	11,580	15,320	10,640	9,880

Note: Numbers in parentheses are standard errors.

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$ (two-tailed tess).

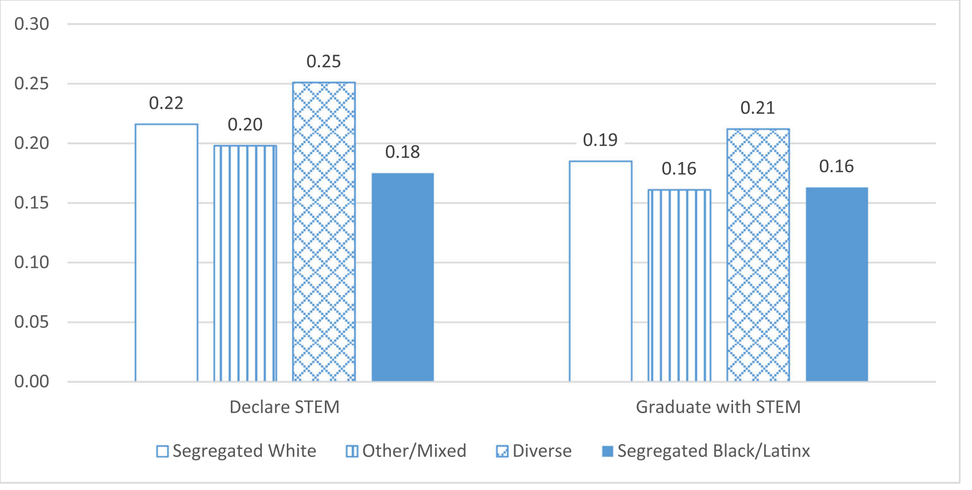

FIGURE 1 Predicted probabilities of declaring/graduating with a STEM major, by the type of racial educational pathway followed (middle school to college).

Using results of Models 9 and 12 that utilize categorical measures of racial/ethnic sequence of educational institutions, we calculated predicted probabilities for our outcome variables. Figure 1 presents the predicted probability of declaring and graduating with a STEM degree when all other variables are kept at their means. Students who attended a sequence of racially diverse schools and colleges have the highest predicted probabilities of declaring and graduating with STEM majors, 25% and 21%, respectively, compared with rates of STEM college declaration and graduation of 18% and 16% for students who followed segregated Black/Latinx educational pathways; and rates of 22% and 19% for those students who had a segregated White sequence of schools. These results suggest a 3%–8% greater likelihood of declaring and graduating with a STEM degree for those students who attended a sequence of racially diverse educational institutions.

6.3 | Models predicting STEM major declaration and graduation with race-specific interactions

Next, we explored if the relationship between the racial composition of the sequence of schools and students' odds of either STEM outcome varied by students' own race/ethnicity. We included only Black and White students in this analysis due to the small sample sizes of Other racial/ethnic groups. The addition of race-specific interactions appears in Models 13 and 14 in Table 4. They show that overall, irrespective of a student's own racial background, the positive link remains between a sequence of diverse educational pathways and students' likelihood of choosing a STEM major and graduating with a STEM degree, although the magnitude of the relationship is somewhat smaller for White students. These results confirm that following a sequence of racially diverse educational pathways is related to increases in all students' chances of going into STEM. The relatively stronger positive relationship between Black students and diverse educational institutions indeed suggests that diverse educational contexts are particularly beneficial for Black students' futures in STEM, results that support Hypothesis 3. Importantly, the STEM benefits of attending a sequence of diverse pathways do not accrue exclusively to students from underrepresented minoritized groups.

We ran separate analyses by racial/ethnic subsamples to see if the predicted probabilities of students' declaring and graduating with a STEM major depend on the type of racial sequence of educational institutions

TABLE 4 Multilevel binomial models predicting odds of declaring and graduating with a STEM degree if attended racially diverse educational institutions with interactions by race (odds ratios).

	Dichotomous key independent variable	
	Declare a STEM major	Graduate with a STEM major
	Model 13	Model 14
Dummy attended a sequence of racially diverse educational institutions	1.217 (0.115)**	1.79 (0.329)***
Dummy attended a sequence of racially diverse educational institutions* White	0.808 (0.132)	0.615 (0.127)**
Demographic characteristics		
Black	1.273 (0.187)	0.769 (0.103)*
Gender	Included	Included
SES	Included	Included
Academic achievement measures		
Math SAT	Included	Included
College GPA	Included	Included
High school class rank	Included	Included
Took physics when in high school	Included	Included
Identified as academically gifted	Included	Included
High school level characteristics		
Teacher related characteristics	Included	Included
High school SES	Included	Included
High school in rural area	Included	Included
Average SAT at HS	Included	Included
Percent of female students	Included	Included
Attended Magnet School	Included	Included
Attended a school with a math and science focus	Included	Included
Attended community college before joining 4-year college	Included	Included
Type of college fixed effects		
Attended UNC Chapel Hill	Included	Included
Attended North Carolina State University	Included	Included
Attended historically Black college	Included	Included
Random-effects parameters—high school	0.115 (0.107)	0.082 (0.199)
Random-effects parameters—middle school	0.252 (0.072)	0.313 (0.078)
Log likelihoods	−4812	−3687.2

TABLE 4 (Continued)

	Dichotomous key independent variable	
	Declare a STEM major	Graduate with a STEM major
	Model 13	Model 14
LR test versus logistic model: χ^2	13.67	13.84
N	10,940	9350

Note: Numbers in parentheses are standard errors. Sample includes only students who are Black or White.
**p* < 0.10; ***p* < 0.05; ****p* < 0.01 (two-tailed tests).

TABLE 5 Predicted odds of declaring a STEM major, by racial composition of sequence of educational institutions attended.

	All	White	Black	Black and Latinx
Segregated White	0.202	0.211	0.115	0.136
Other/mixed	0.218	0.223	0.167	0.169
Diverse	0.250	0.248	0.201	0.198
Segregated Black/Latinx	0.175	Not estimable	0.136	0.143

they attended. The purpose was to investigate whether findings we obtained with the subsamples were consistent with the results using the full sample of students who attended a diverse sequence of schools. Because the subsample size in specific racial/ethnic subpopulations was so small, we were not able to run models where we nest students by high school and middle school in categories of the racial sequence of educational institutions they attended (segregated White, segregated Black/Latinx, Other, diverse). Instead, we ran logit models and then calculated predicted probabilities of declaring and graduating with a STEM major for the different groups of students.

Table 5 and Figure 2 below present the results of the calculations of predicted probabilities by subgroup for declaring a STEM major. Table 6 and Figure 3 show the results for the predicted probabilities of graduating with a STEM degree for different subgroups.

Our new analyses yielded results that were consistent with the original analyses which show that having attended a sequence of diverse educational institutions provides the highest predicted probability of declaring and graduating with a STEM major for White, Black, and the combined subsample of Black/Latinx students.[viii] This confirms that both, the samples of White students and the sample of Black students, in diverse schools have better STEM outcomes than if they attend predominantly White schools (which have even more academic resources), than if they attend predominantly Black schools and, than if they attend "Other" pathways.

6.4 | Reliability analyses

While these results offer evidence that is consistent with our hypotheses, given the high correlation between schools' racial and socioeconomic compositions across NC, it is possible that the sequence of racially diverse educational pathways is a proxy for the students' sequence of socioeconomically diverse or segregated educational pathways. Therefore, we ran an additional analysis to confirm that our measure of the sequence of educational

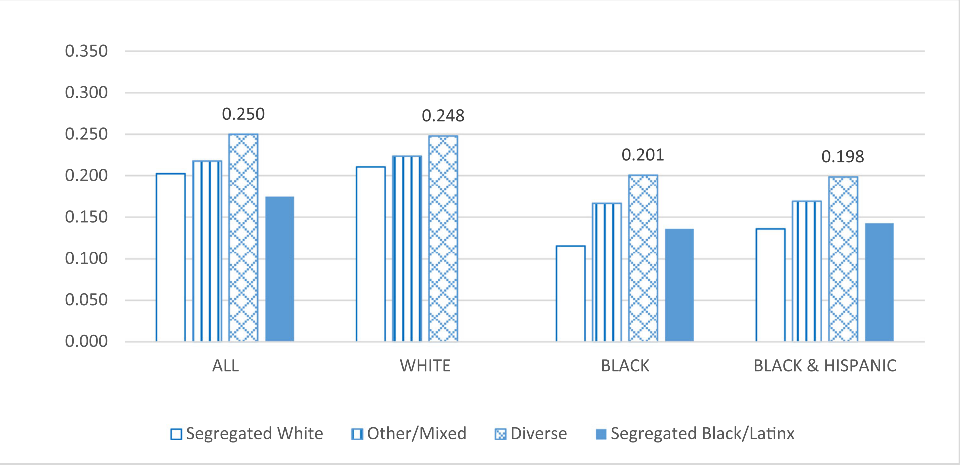

FIGURE 2 Predicted odds of declaring a STEM major, by racial composition of sequence of educational institutions attended.

TABLE 6 Predicted odds of graduating with a STEM major, by racial composition of sequence of educational institutions attended.

	All	White	Black	Black and Latinx
Segregated White	0.166	0.174	0.094	0.092
Other/mixed	0.189	0.199	0.119	0.122
Diverse	0.211	0.209	0.168	0.165
Segregated Black/Latinx	0.169	Not estimable	0.098	0.106

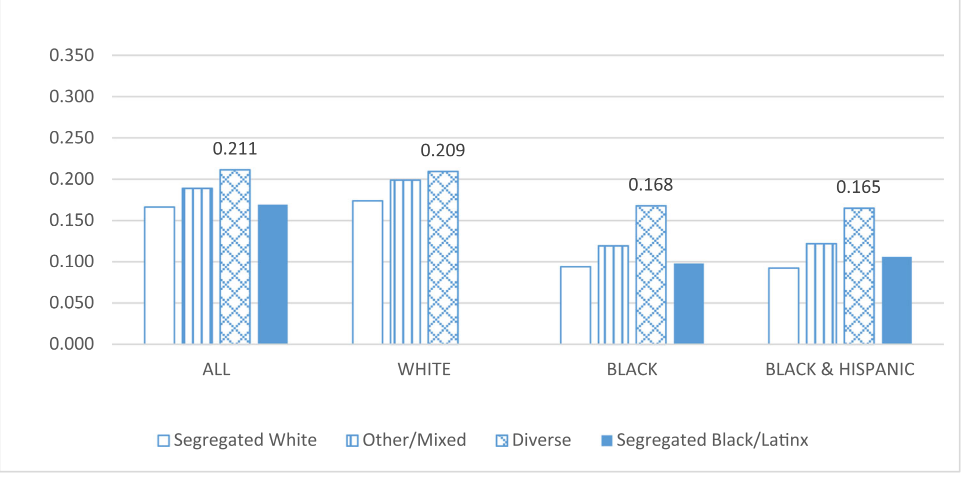

FIGURE 3 Predicted odds of graduating with a STEM major, by racial composition of sequence of educational institutions attended.

institutions' racial composition is not capturing the effects of the sequence of educational institutions' socioeconomic composition.

We duplicated our analyses with a sequenced SES diversity pathway variable constructed in a fashion similar to how we constructed our sequenced racial diversity variable. We considered educational institutions to be socioeconomically diverse when their percentage of low-SES populations did not exceed 75% and was not below 25%. Two-hundred and two out of the 506 middle schools, 101 out of the 321 high schools, and 6 out of the 16 college institutions were categorized as SES diverse educational institutions. Given these numbers, 40% of our students attended a sequence of only low SES educational institutions, 50% of students attended a sequence of high SES educational institutions, and 10% of students attended a sequence of diverse SES educational institutions. The correlation between attending a sequence of racially diverse schools with attending a sequence of socioeconomic diverse schools is only 4%.

Results indicate attending a sequence of socioeconomically diverse educational institutions has no significant effect on the odds of declaring a STEM major or graduating with STEM degree (see Table 7). Although most of the student- and other school-level characteristics have relationships similar in significance and magnitude to the model of school racial composition sequence, SES pathway diversity operates differently than racial/ethnic pathway diversity with respect to college STEM outcomes. These results indicate that the racial composition sequence of the educational institutions' students attended influences their odds of majoring in and graduating with a STEM degree, but the SES composition sequence does not. Additional analyses were also conducted to further test reliability of the results.[ix]

7 | DISCUSSION AND CONCLUSIONS

Our study finds that there is a 3-8% greater likelihood of declaring and graduating with a STEM degree for those students who attended a sequence of racially diverse educational institutions from middle school through postsecondary education compared with otherwise comparable individuals who attended either a mixed or racially segregated sequence of educational institutions. Our theoretical framework suggests the mechanisms by which these striking results developed. It is likely that the sequence of diverse environments that some North Carolina college students experienced since the beginning of middle school offered them greater opportunities to learn through complex cultural, social, and educational resources than offered their otherwise comparable peers who attended segregated schools. A sequence of diverse learning contexts appears to challenge prevailing stereotypes about who does or does not belong in STEM. The schools they attended most likely were characterized by a college-oriented academic environment, and a cultural climate that embraced ethnic, gender, racial, and SES diversity, so their cognitive strategies broaden. Year after year, the accumulation of these benefits appears to have fostered student success in STEM fields irrespective of individuals' demographic background, but Black youth likely benefitted slightly more than White youth did.

Our findings also further explored if the role of racial segregation is really due to socioeconomic segregation. Results show that with respect to North Carolina college STEM outcomes, school racial composition is far more consequential than SES composition. These findings are distinct from prior research on the topic. Previous analysis of US school district data finds that the negative effects of racial segregation on achievement in grades 3–8 can mostly be attributed to differences in SES. Reardon (2016) argues that the biggest portion of the variance in grade 3–8 achievement is due to SES composition of schools and not due to racial segregation. While we do not question his findings about test scores, our findings suggest that with respect to college STEM outcomes, racial segregation has an identifiable effect that is not due to SES segregation.

TABLE 7 Multilevel binomial models predicting odds of declaring and graduating with a STEM degree if attended socioeconomic diverse educational institutions (odds ratios).

	Dichotomous key independent variable	
	Declare a STEM major	Graduate with a STEM major
	Model A	Model B
Dummy attended a sequence of economically diverse educational institutions	1.02 (0.143)	1.208 (0.219)
Demographic characteristics		
Race	Included	Included
Gender	Included	Included
SES	Included	Included
Academic achievement measures		
Math SAT	Included	Included
College GPA	Included	Included
High school class rank	Included	Included
Took physics when in high school	Included	Included
Identified as academically gifted	Included	Included
High school level characteristics		
Teacher related characteristics	Included	Included
High school SES	Included	Included
High school in rural area	Included	Included
Average SAT at HS	Included	Included
Percent of female students	Included	Included
Attended magnet school	Included	Included
Attended a school with a math and science focus	Included	Included
Attended community college before joining 4-year college	Included	Included
Type of college fixed effects		
Attended UNC Chapel Hill	Included	Included
Attended North Carolina State University	Included	Included
Attended historically Black college	Included	Included
Random-effects parameters—high school	0.114 (0.097)	0.000 (0.413)
Random-effects parameters—middle school	0.227 (0.072)	0.323 (0.053)
Log likelihoods	−5175.9	−3970.1
LR test versus logistic model: χ^2	11.86	16.05
N	11,580	9880

Note: Numbers in parentheses are standard errors.

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$ (two-tailed tests).

7.1 | Limitations

A fundamental limitation arises from our research design and the Roots data set. While the data identify demonstrably positive academic benefits accruing to the college students who attended a diverse sequence of schools, they do not permit us to demonstrate the various externalities that historically accompanied the desegregation of schools in North Carolina, and elsewhere, and continue to some extent today. The historical record indicates that when the *de jure* segregated schools were dismantled in the 1970s, the process of desegregation was also costly to many Southern Black and Brown educators, students, and communities that suffered losses. The shuttering of Black and Brown schools left many neighborhoods without their community's cultural and social anchor (K. Green, 2015). Scores of Southern Black and Brown teachers and administrators were reassigned or lost their jobs. Paradoxically, mandated desegregation created conditions that resulted in small increases in the Black teaching force outside the South. Some research suggests that mandatory desegregation may have fostered institutional conditions that result in Black and other minoritized educators remaining underrepresented in the profession (Oakley et al., 2009). Initially, desegregation left many minoritized students facing lowered teacher expectations, racial/ethnic hostility from White peers and educators, and disproportionate disciplinary referrals in newly desegregated schools (Milner & Howard, 2004) and continue to the present (Wiley, 2021).

This study has a number of other important limitations. The possibility of sample selection bias exists. A shared characteristic among individuals who attended diverse schools might be the underlying dynamic responsible for the significant relationship between attending a sequence of diverse educational institutions and better college STEM outcomes. Exploring factors possibly related to students choosing to enroll in diverse middle schools, high schools, community colleges, and 4-year colleges is not feasible with our data. These decisions involve different time periods, institutional options, school policy, community characteristics, and a host of actors making a series of choices over many years. Nevertheless, we controlled for as much self-selection as possible by including variables for school, student, and family characteristics. Appendix C presents a correlation table with many individual-level variables. We inspected it to examine whether following a diverse educational pathway is correlated with other variables. None of the variables correlate with our key independent variable more than 0.10, suggesting that following a diverse educational pathway is relatively weakly correlated with family or student attributes available in our data set.

Another limitation arises because our sample is restricted to students who graduated from NC public high schools in 2004 and entered 1 of the 16 public 4-year institutions of the UNC system. This means that our findings do not apply to students who did not attend public colleges in North Carolina and those students who graduated from a high school in North Carolina but then attended private universities in or out-of-state. Private colleges are not part of our data set. Unfortunately, we do not have access to the data outside of the public NC system. This limits the generalizability of our findings. Future studies should aim to include students who attended K-12 and higher education at private schools.

Furthermore, given the age of our data, collected roughly from 1996 to 2010, our findings do not capture the effects of many programs in secondary and tertiary educational institutions designed to boost the success of women and minoritized students in STEM fields. We also acknowledge that classifying all STEM majors into a single category limits our study because of the constraints associated with aggregating highly gendered fields such as engineering, computer science, and physics with those with a more even gender balance, such as biology and chemistry. Lastly, our study could not capture the negative effects of widespread racialized tracking at diverse secondary schools.

7.2 | Importance and implications

These limitations notwithstanding, this manuscript makes important contributions in several areas. It adds to the growing documentation of school diversity's positive outcomes. No prior research has demonstrated that students who attended a diverse sequence of schools, irrespective of their race/ethnicity, have greater odds of declaring and graduating with STEM college degrees than their otherwise comparable peers who did not attend a similar sequence of schools. It also demonstrates that the benefits of the diverse sequence vary by students' ethnicity, with Black youth gaining the most from this educational pathway and White youth gaining somewhat less from it. The findings also suggest that the advantages of diversity cumulate over the course of students' educational trajectories. Finally, our analyses reveal that the racially diverse sequence is not a proxy for attending educational institutions with socioeconomically diverse student bodies.

Our findings identify a potential strategy for growing and diversifying the future STEM workforce. There are structural benefits from a more demographically heterogeneous STEM labor force, including a broadened pool of candidates for projected labor force demands and employees with greater capacity to avoid racism and sexism in STEM work products (e.g., medical technology, facial recognition software, other AI technologies that encode the biases of a more demographically homogeneous workforce). Some of these structural benefits will cumulate and compound over time as minoritized youth and females gain footholds in STEM fields.

7.3 | Policy implications

These results are especially important given that recent national and international standardized tests in mathematics, science, and language arts suggest that reforms during the last two decades—including No Child Left Behind, Race-to-the Top, the growth of charters, privatization, school choice, standards and accountability, and other market-inspired reforms—appear to have largely failed to systematically improve US student performance (E. L. Green & Goldstein, 2019; Goldstein, 2019). At the same time, there is a growing body of evidence that an equity-inspired reform—diverse school composition—has a positive relationship with academic outcomes more broadly (Johnson & Nazaryan, 2019; Mickelson & Nkomo, 2012; *Parents Involved in Community Schools V. Seattle School Dist. No. 1*, 2006). With this article, we can now include college STEM outcomes in this category.

Although our study is primarily descriptive and correlational, our findings suggest that ensuring the opportunity to attend a sequence of racially diverse educational institutions may be an effective strategy to help increase the number of students who follow a STEM pathway.

Policies that create diverse educational contexts have the potential to benefit the future STEM outcomes of all students irrespective of their race/ethnicity. The results undercut claims that fostering diversity in educational institutions augments minoritized students' achievement at the expense of educational interests of Whites. Beyond anecdotes, this claim is unsupported by systematic empirical research. Our results are consistent with the historical record that shows between roughly 1970 and 1990—the heyday of desegregation—the Black–White gap in educational outcomes shrank not because White pupils did worse but because Black and Brown youth did better. While some scholars argue that policies aiming to remedy socioeconomic disparities in educational contexts may be more effective strategies for addressing problems associated with lack of racial diversity in educational contexts (Kahlenberg, 2019; Reardon et al., 2018), our findings suggest the need for policies that foster racially diverse educational contexts, as well.

8 | CONCLUSION

Since desegregation policy has stalled across much of this nation, US schools have resegregated. The previously narrowed racial gaps in outcomes have widened once again. Desegregation as an educational reform strategy has been replaced by market-inspired approaches such as school choice, despite the preponderance of research showing school diversity is an effective improvement strategy (Johnson & Nazayan, 2019; Mickelson & Bottia, 2010; Mickelson & Nkomo, 2012), especially for students from the more socially marginalized race, ethnic, and SES groups.

Our results cannot definitively answer the question of why sequential exposure to racially diverse educational contexts leads to success in STEM outcomes. Based on our theoretical framework, we suggest that several mechanisms are likely in play: (1) the cumulation of educational experiences in diverse contexts provides all students the opportunity to acquire high levels of social and cultural capital, exposure to high-quality teachers, academically oriented peers; access to rich curricular resources, and other factors that relate to students' choice of major; (2) exposure to diverse educational contexts likely fosters students' creativity, encourages problem-solving, and increases critical thinking skills—skills that are positively related to success in STEM; (3) and racially diverse educational institutions undercut norms and stereotypes that undermine Black, and Latinx youth's sense of belonging in STEM and all students' beliefs about gender, ethnicity, SES, and the pursuit of STEM. Other mechanisms could also help account for our findings. Future research that identifies how the mechanisms of cumulative advantages from a sequence of diverse schools and colleges foster better STEM outcomes is necessary. In a global economy that requires increasing numbers of students with STEM degrees, it is important to find ways to expand the number of students who are prepared to enter STEM careers. STEM careers, particularly technologies such as artificial intelligence (AI), require an inclusive workforce capable of avoiding practices that exacerbate racism, sexism, and classism currently encoded into many technologies used in education, criminal justice, and medical fields (Christian, 2021; Mickelson et al., 2023; Shneiderman, 2022). Youth majoring in STEM fields who have experienced diverse educational pathways are more apt to embrace human-centered, just, and trustworthy STEM that can mitigate against the development and spread of resurgent authoritarianism. A diverse sequence of schools is also a matter of distributive justice given the opportunities for social mobility associated with a STEM degree. Ensuring that students have a chance to attend a sequence of racially diverse educational institutions appears to be a potentially effective strategy for reaching these outcomes.

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ENDNOTES

[i] Between 1998 and 2016, levels of segregation increased slightly in the state overall and grew significantly in urban areas where a third of North Carolina students attend school. For example, in Mecklenburg County, the state's second most populous county, the segregation rate between White and nonwhite students rose from 0.21 to 0.37 on a scale of 0 to 1, with 0 reflecting completely balanced racial enrollments across the county's schools and 1 representing a segregated educational experience for every student (Clotfelter et al., 2021).

[ii] Some research suggests a possible inverse relationship between attending diverse secondary schools and enrollment in higher track versions of courses among Black students (Mickelson & Bottia, 2010; Tyson, 2011, 2013).

[iii] Although the demographic characteristics of North Carolina public schools are changing rapidly, the sample we use from the 2004 high school graduating class that went on to attend 1 of the 16 campuses of the UNC system only had sufficient observations to test this hypothesis for Black and White students.

[iv] We utilize information about the major students declared between the years 2005 and 2011. The vast majority of the students declared their majors when they were in their sophomore or junior year. In several cases students declared more than one major. Approximately 24% of our sample never declared a major (either dropped out of college before declaring a major, transferred to a community college, transferred to a campus out of the North Carolina system or died)

and are not included in our analysis. Therefore, our sample is one of college-bound students who declared a major and attended middle and high school in North Carolina.

[v] Note that the outcome of graduation with a STEM degree is conceptually distinct from persistence in STEM, which would necessitate a separate analysis and set of predictors tied specifically to students' college experiences. In other words, persistence is an outcome that is more dependent on the college context alone, with an entirely separate literature on its predictors.

[vi] We also tried different operationalization based on the mean and standard deviation of the per cent of White students at the educational institutions. Our results were similar.

[vii] The terms racially diverse, desegregated, and integrated frequently are used interchangeably in much of the social science literature to the detriment of historical and analytical precision. The terms desegregated and racially diverse tend to be used synonymously in the literature. Desegregation is a *process* that produces schools whose student composition approximates a heterogeneous community's demographic mix. The concept of integrated education refers to inclusive schooling where students, faculty, curricula, disciplinary practices, extracurricular activities, counseling, gifted programs, special education, and curricular tracking are not racially/ethnically imbalanced relative to the community's demographic mix. Desegregated or diverse schools are often not fully integrated because they are not inclusive across all these criteria.

[viii] Due to the very small sample size of Latinx students (*N* = 100 Latinx students who declared a STEM major and 40 Latinx students who graduated with STEM degrees), we show findings for the combined subsample of Black/Latinx students.

[ix] To test the reliability of our findings, we also ran similar multilevel binomial analyses with a different measure of diverse educational pathways, our key independent variable. In this case, to identify a nondiverse secondary school or college we added and subtracted one standard deviation from the mean of the percent of White students at educational institutions. Findings with this different operationalization of diverse educational pathways based on the percent of White students at an institution are consistent with those obtained with the original measure of diverse educational pathway, no race/ethnicity (either White or the sum of Black plus Latinx) above the 75% threshold. These results suggest that there is a significant positive relationship with students' attending a diverse sequence of educational institutions and declaration and graduation with a STEM degree (See Appendix B).

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APPENDIX A

See Table A1

TABLE A1 Multilevel models predicting students' odds of declaring and graduating with a STEM major (odds ratios) no college GPA included.

	Dichotomous dependent variable					
	Declare a STEM major			Graduate with a STEM major		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Dummy attended a sequence of racially diverse educational institutions	1.226 (0.080)***	1.232 (0.092)***	1.280 (0.100)***	1.191 (0.094)**	1.144 (0.097)*	1.21 (0.088)**
Demographic characteristics						
Race/ethnicity	Included	Included	Included	Included	Included	Included
Gender	Included	Included	Included	Included	Included	Included
SES	Included	Included	Included	Included	Included	Included
Academic achievement measures						
Math SAT		Included	Included		Included	Included
College GPA		NOT Included	NOT Included		NOT Included	NOT Included
High school class rank		Included	Included		Included	Included
Took physics when in high school		Included	Included		Included	Included
Identified as academically gifted		Included	Included		Included	Included
High school-level characteristics			Included			Included
Teacher related characteristics			Included			Included
High school SES			Included			Included
High school in rural area			Included			Included

(Continues)

TABLE A1 (Continued)

	Dichotomous dependent variable					
	Declare a STEM major			Graduate with a STEM major		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Average SAT at HS			Included			Included
Percent of female students			Included			Included
Attended magnet school			Included			Included
Attended a school with a math and science focus			Included			Included
Attended community college before joining 4-year college			Included			Included
Type of college fixed effects						
Attended UNC Chapel Hill	Included	Included	Included	Included	Included	Included
Attended North Carolina State University	Included	Included	Included	Included	Included	Included
Attended historically Black college	Included	Included	Included	Included	Included	Included
Random-effects parameters—high school	0.2084 (0.0483)	0.230 (0.048)	0.144 (0.073)	0.204 (0.067)	0.226 (0.068)	0.084 (0.174)
random-effects parameters—middle school	0.187 (0.064)	0.139 (0.090)	0.198 (0.072)	0.274 (0.065)	0.249 (0.079)	0.283 (0.075)
Log likelihoods	−6979.8	−6298.8	−5796.5	−5335.5	−4810.6	−4466.8
LR test versus logistic model: χ^2	33.76	27.33	14.32	38.03	31.74	16.16
N	14,980	14,030	12,910	12,630	11,900	11,010

Note: Numbers in parentheses are standard errors.

*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$ (two-tailed tests).

APPENDIX B

See Table B1

TABLE B1 Results of multilevel binomial models predicting odds of declaring and graduating with a STEM degree by two different measures of exposure to diverse educational institutions, with two different ways of operationalizing a diverse educational institution.

Outcome		Type of measure	Using diverse = no race more than 75%	Using diverse = % White ±1 s.d. of the mean (between 37% and 91% for MS and HS, 51% and 85% CC, and 27% and 90% colleges)
STEM declaration	Dummy	Attended a sequence of diverse educational institutions	1.285*** (0.100)	1.333*** (0.091)
	Categorical	Segregated White		
		Other	1.144 (0.082)*	0.741 (0.096)**
		Diverse	1.453 (0.152)***	1.241 (0.106)**
		Segregated Black/Latinx	0.831 (0.227)	0.68* (0.140)
STEM graduation	Dummy	Attended a sequence of diverse educational institutions	1.235** (0.116)	1.461*** (0.118)
	Categorical	Segregated White		
		Other	1.231 (0.101)**	0.629 (0.095)***
		Diverse	1.51 (0.188)***	1.312 (0.132)***
		Segregated Black/Latinx	1.022 (0.356)	0.698 (0.192)

Note: Numbers in parentheses are standard errors.

*p < 0.10; **p < 0.05; ***p < 0.01 (two-tailed tests).

APPENDIX C

See Table C1

TABLE C1 Correlations between racially diverse educational pathway and other student-level characteristics.

	Dummy followed diverse educational pathway
Declared a STEM major	−0.031
Graduated with a STEM major	−0.038
Male	−0.049
Black	0.045
First-generation college student	0.023
Math end-of-grade score	0.069
Class rank in high school	0.095
Took physics	0.062
Identified as intellectually gifted	0.048
Took chemistry	0.045
Participated in extracurricular science/math-related activities	0.029
Attended science and math-focused school	0.027
Average parental education	0.023