What Matters in STEM: Institutional Contexts That Influence STEM Bachelor's Degree Completion Rates

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Introduction

To continue to perform well against growing science and technology innovation in places like China and Europe, the U.S. federal government has stepped-up efforts to review and reinvest in programs and policies related to undergraduate education in fields of science, technology, engineering, and mathematics (STEM). The National Science Foundation (NSF) and the National Institutes of Health (NIH) have sponsored a number of initiatives aimed at increasing undergraduate students' interest in studying STEM, improving STEM bachelor's degree completion rates generally, and improving STEM completion rates among underrepresented racial minority (URM) students specifically. During congressional testimony in March of 2010, Arden Bement, the director of NSF, indicated that the "number of minority students majoring in the sciences is not increasing nearly fast enough, given the overall projected rate of growth for minorities in the United States population" (Basken, 2010, p. 1). Although findings from recent analyses show that more students from all racial backgrounds enter college with an interest in STEM, the vast majority of these students either complete degrees outside of STEM or drop out of the higher education system altogether (Higher Education Research Institute, 2010).

When considering STEM completion rates across race, research has shown that White and Asian American students far outpace their Black, Latino, and Native American counterparts. A report by the Higher Education Research Institute (2010) indicated that 24.5% of White students and 32.4% of Asian American students who entered college intending to major in a STEM discipline completed a STEM bachelor's degree within four years. By contrast, just 15.9% of Latino students, 13.2% of Black students, and 14.0% of Native American students who intended to major in a STEM field completed a degree in STEM within four years of enrollment. The STEM bachelor's degree completion gap between URM students and their White and Asian

American counterparts widens when examining five-year completion rates, as 33% of White students and 42% of Asian American students who aspired to major in STEM completed a bachelor's degree in STEM within five years of college enrollment compared to 22.1% of Latino students, 18.4% of Black students, and 18.8% of Native American students. This gap in STEM completion rates between URM students and their White and Asian American peers has obvious implications for post-baccalaureate degree completion, as URM students accounted for almost 16% of all bachelor's degrees in STEM fields in 2000 even though their share of master's degrees (8.8%) and doctoral degrees (5.9%) remained substantially diminished compared to their White and Asian American peers (NSF, 2002).

Prior research has examined issues of STEM retention and completion from a student-only perspective and has demonstrated that prior academic achievement, class rank, and high school program intensity represent the most important predictors of a student's success in STEM (American Association for the Advancement of Science [AAAS], 2001). Some scholars have considered institutional characteristics in the STEM retention literature and have concluded that attending more selective institutions negatively affects URM students' chances of remaining in a STEM major (Chang, Cerna, Han, & Saenz, 2008; Chang, Eagan, Lin, & Hurtado, in press). Most studies, however, ignore institutional context in studying STEM retention and degree completion.

This study includes the important institutional context component that many previous studies have missed by examining specific institutional programmatic and policy initiatives that improve bachelor's degree completion in STEM. We draw from a national survey of first-time freshmen who entered college in 2004 and match those data with five-year degree completion information from the National Student Clearinghouse. A survey of STEM deans and department chairs provided the important institutional context representing the structure of opportunity that these students encountered when they entered college in 2004. Through multinomial hierarchical generalized linear modeling, we use individual and institutional predictors to examine how specific structures of opportunity relate to students' probability of earning a STEM degree compared to their likelihood of earning a non-STEM degree or not earning a degree within five years of college enrollment. Additionally, we examine how institutions' programmatic interventions mitigate or enhance the effect of students' background characteristics on STEM completion with specific focus given to the effects of race.

Literature Review

Much of the research on the factors affecting STEM students' likelihood to complete their bachelor's degrees focuses on individual characteristics and experiences. Some of these factors include prior academic achievement, negative experiences in introductory science courses, positive connections made through formal research programs, and interactions with peers in extracurricular activities tied to students' majors. After considering students' pre-college and college experiences, research has found that having a strong high school curriculum, achieving high test scores, and earning high grades in high school represent the three most important predictors of earning an undergraduate STEM degree (AAAS, 2001; Bonous-Hammarth, 2000; Elliott, Strenta, Adair, Matier, & Scott, 1996). Advanced courses in math and science not only prepare students for the rigor of college-level STEM courses but also provide students with the academic confidence to be successful in college (Ellington, 2006). Elliott et al. (1996) found that lower enrollment rates among Black students in advanced placement (AP) biology, chemistry, physics, and calculus courses significantly and negatively predicted to Black students' likelihood to earn a STEM degree. Anderson and Kim (2006) suggested that strong performance in pre-college math and science courses significantly relates to college student persistence beyond the first year, and these findings supported earlier work by Adelman (1998) who found that success in high school mathematics significantly predicted college persistence for students aspiring to major in STEM disciplines.

In addition to students' academic preparation, previous studies have hinted that URMs are more likely than their peers to perform poorly due to reasons related to campus climate and disengagement (Seymour & Hewitt, 1997). Encountering negative climates in the classroom, particularly in introductory STEM courses, significantly reduces students' odds of persisting in STEM to degree completion (Seymour, 1995; Seymour & Hewitt, 1997; Tobias, 1992).
The negative climate STEM students experience in gatekeeper courses may present students with a substantial obstacle in matriculating through their degree programs. Indeed, Seymour (2001) concluded that students who had negative experiences in gatekeeper courses or found little academic success in such classes often switched majors, transferred to other institutions, or withdrew from higher education. Given research on the importance of academic adjustment (Hurtado et al., 2007) and faculty connections (Cole & Espinoza, 2008) in retaining students, the current negative contexts of gatekeeper courses and institutions' increasing reliance on contingent faculty to teach these courses present first-year STEM students with significant challenges of persisting in their majors through degree completion.

Although research suggests the characteristics associated with gatekeeper courses have negative implications for retention of STEM majors, recent studies consistently have found positive outcomes for students who connect with faculty and peers through formal research opportunities. Undergraduate research programs enhance students' science identity (Hurtado et al., 2009) and provide students with an idea of what the career of a scientific research entails

(Kinkead, 2003; Lopatto, 2004). By strengthening students' science identity, undergraduate research experiences may make students significantly more likely to persist to degree completion in their STEM discipline (Carlone & Johnson, 2007; Chang et al., 2010). Additionally, research experiences help to strengthen undergraduate students' commitment to graduate study (Kardash, 2000; Sabatini, 1997) and increase their likelihood to enroll in graduate school (Barlow & Villarejo, 2004; Bauer & Bennett, 2003; Eagan et al., 2010).

In addition to engagement in structured research programs, studies have found that, among engineering students, participation in cooperative education (co-op) experiences has a significant and positive effect on retention and degree completion. Nasr, Pennington, and Andres (2004) concluded that engineering students who participated in co-op experiences more strongly identified with their majors and became significantly more likely to graduate with an engineering degree. Similarly, in a quantitative examination of more than 4,300 STEM students at a large, public, four-year institution in the southeast, Jaeger, Eagan, and Wirt (2008) found a significant, positive relationship between co-op participation and STEM degree completion. In fact, participation in a co-op program made students more than five times as likely to complete their degrees compared to their peers who did not engage in such opportunities. Co-op and research experiences provide students with opportunities to connect with faculty mentors, to learn from upper-division and graduate students, and to get a sense for the type of work involved in their respective fields (Kinkead, 2003).

These findings underscore the need to examine models that include both institutional and individual measures in relation to not only retention but also "positioning" for graduate study, as such analyses can shed light on the institutional characteristics and programmatic endeavors that contribute to students' STEM completion likelihood. The vast majority of the studies examining student persistence and degree completion in STEM have focused on individual experiences of students. Specifically, this body of research has investigated the efficacy of undergraduate research programs, students' successful navigation of impersonal, challenging climates in introductory STEM courses, and the level of academic preparation that students received in high school. By providing this level of attention to the individual experience of the student, scholars have lost sight of the role of institutional context in predicting degree completion generally and STEM degree completion specifically.

Studies that have considered the role of institutional context in predicting bachelor's degree completion typically have relied on more traditional institutional characteristics, including control, size, selectivity, and institutional type. Several studies examining bachelor's degree completion for underrepresented students across all disciplines have found a significant and positive effect of attending a highly selective or elite institution on individuals' likelihood of earning a degree. Alon and Tienda (2005) examined the effect of institutional selectivity on the degree completion likelihood and found that enrolling in more selective institutions significantly and positively improved all students' odds of completing a degree, and research by Titus (2004, 2006) supported these results. Similarly, Bowen and Bok (1998) focused on a number of outcomes for Black undergraduates who attended elite institutions, and the authors found that enrollment at highly selective institutions predicted an increased likelihood of degree completion, higher future earnings, enhanced leadership outcomes, and improved satisfaction with the college experience.

Although retention to degree completion may be higher at more selective institutions, this may not be the case for persistence and completion in STEM fields. Chang et al. (2008) found that students who intended to major in the biomedical and behavioral sciences and also attended institutions where the entering freshman class has higher SAT scores are at a slightly higher, yet statistically significant, risk of departing from those majors at the end of their freshman year, and these results were also supported by Chang et al. (in press). Similarly, Chang et al. (2010) found that URM STEM aspirants at more selective institutions were significantly less likely than their URM peers at less selective institutions to be retained in their STEM majors through four years of college. By contrast, Eagan (2009) considered institutions' production of undergraduate STEM degrees and found that more selective institutions were significantly more efficient than less selective institutions at conferring STEM bachelor's degrees. Eagan suggested that more selective institutions have a higher achieving pool of students entering the STEM pipeline; thus, given that these students arrive in college with stronger levels of academic preparation, they inherently have a greater likelihood of starting and finishing a STEM bachelor's degree.

Although past studies have found benefits of attending selective or elite institutions on degree completion outcomes, underrepresented students in STEM have a greater likelihood of enrolling in and graduating from minority-serving institutions (MSIs) rather than predominantly-White institutions (Diverse,2006; Trent et. al, 2003). Hurtado et al. (in press) found that Black students who attended historically Black colleges and universities (HBCUs) reported significantly more frequent interactions with faculty than their Black peers at peers at predominantly White institutions (PWIs). Previous studies have suggested that MSIs, particularly HBCUs, provide students with a more supportive environment, as these institutions offer a student-centered mission and encouraged increased engagement between students and faculty (Allen, 1992; Hurtado, 2003; Hurtado et al., 2009; Nelson Laird et al., 2007).

Institutional stature and type may be less of a factor than actual practices on a campus that play an important role in preparing and placing URM students into STEM-related careers.

Recognizing the need to provide an opportunity where large numbers of underrepresented students are educated, federal agencies and legislative initiatives have devoted science and engineering capacity funding to minority serving institutions (National Science Foundation, 2004). It is important to understand not only the output of these institutions but also the general practices and undergraduate experiences that result in STEM retention, and how institutions position their students for graduate school access. For example, in examining whether students' participate in undergraduate research during their first year of college, Hurtado et al. (2008) found that Black freshmen were four times as likely to take advantage of undergraduate research experiences if the institution offered structured research programs open to first-year students. By contrast, we know the importance of student-faculty connections to STEM students' successful navigation through their major (Cole & Espinoza, 2008), yet research has not investigate whether having formal opportunities facilitated by the institution significantly relates to students' likelihood of persisting to bachelor's degree completion in STEM.

In addition to being framed by the literature on individual and institutional predictors of STEM completion, we draw from provide a set of basic assumptions in conceptualizing this study (Carlone & Johnson, 2007; Hurtado et al., 2007; Nora, Barlow, & Crisp, 2005). First, we know that students' success is determined by more than a combination of individual ambition and prior success; therefore, we examine additional factors outside the individual that likely contribute to STEM completion. Carlone and Johnson (2007) suggest that, in order for students to be successful in science, they need to develop a strong science identity. This science identity is shaped by students' self-recognition and recognition by others of their ability to do science, their development of scientific competence, and their performance in science. For each of these areas of science identity to develop, students need to be given the space, opportunity, and support to develop their identities as scientists, and institutions, through the programs and policies that they implement, have a significant role in providing such space for students' development of science identities.

Second, research consistently has demonstrated the role of institutional context in influencing student outcomes, as these characteristics and opportunities serve to socialize students along their educational pathways. Finally, research has demonstrated the variation across institutions in opportunity structures (Chang et al., 2008; Hurtado et al., 2008, in press), particularly across predominantly White institutions (PWIs) and historically Black colleges and universities (HBCUs). Given these institutional differences, students become socialized in significantly varied ways during college (Bowles & Gintis, 1976; Freidenberg, 1974), and schools have an important influence in allocating future opportunities and status (Clark, 1973; Garnier & Hunt, 1976; Karabel, 1972; Kerckoff, 1975). Given the differences in opportunities structures across institutions of higher education, we seek to identify how differences in institutional context and structures of opportunity affect STEM students' likelihood to complete a bachelor's degree in STEM within five years.

Methods

Drawing from prior literature and the frameworks of Hurtado et al. (2007), Carlone and Johnson (2007), and Nora et al. (2005), this study addresses the following questions:

1. What background characteristics, pre-college experiences, and educational and occupational aspirations at college entry predict STEM students' likelihood to complete a STEM degree within five years of entering college?

2. Controlling for student-level variables, what institutional characteristics and programs account for variations across institutions in students' average probability of completing a STEM bachelor's degree within five years of entering college?
3. Do the effects of students' background characteristics, such as race, vary across institutions? If so, can institutional characteristics and programs enhance or mitigate these effects?

Data

This study examines how individual characteristics and college contexts jointly predict students' completion of a bachelor's degree in STEM relative to not completing a degree or completing a non-STEM bachelor's degree. Drawing from a national sample of students and institutions, we analyze the student- and institution-level predictors of students' likelihood to complete a bachelor's degree in STEM within five years of entering college. Our baseline sample comes from the Cooperative Institutional Research Program's (CIRP) 2004 Freshman Survey, which was administered by the Higher Education Research Institute (HERI). In 2004 during orientation or the first few weeks of the fall term, more than 400,000 first-time students from more than 700 colleges and universities completed a four-page questionnaire that asked them about their demographic and academic backgrounds, their high school activities, their educational and career ambitions, and expectations of college.

In 2009 we collected degree and enrollment data for this baseline sample from the National Student Clearinghouse (NSC). Because not all institutions provide the NSC with degree and enrollment data, our sample was reduced to just over 275,000 students in 326 institutions. These data from the NSC provided information about students' enrollment patterns, whether they completed a degree within five years of enrollment, and the discipline of their degree. From this sample, we identified all students who reported on the 2004 Freshman Survey that they intended to major in a STEM discipline, which included 62,115 students across 326 four-year colleges and universities.

Finally, we merged a third data element with the student data. In the summer of fall of 2009, we administered the Best Practices in STEM (BPS) survey to STEM deans and department chairs employed by these 326 colleges and universities. The BPS survey requested information about programs and policies targeted to STEM students and faculty that support undergraduate STEM education. The survey included questions related to pre-college outreach programs, STEM retention programs geared toward specific populations of STEM students, undergraduate research opportunities, faculty development programs, and curricular support services to students. We had 237 institutions respond to this survey, reducing our final analytic sample for this study to 55,178 students across 237 institutions. In addition to the institutional data provided by the BPS survey, we also added institutional characteristics collected from the Integrated Postsecondary Educational Data System.

Variables

The dependent variable in this study is three-part categorical variable corresponding to students' degree status five years after enrolling in college: completed a STEM bachelor's degree, completed a non-STEM bachelor's degree, or had not completed a degree. We derived this dependent variable from NSC data by cross-referencing students' five-year bachelor's degree status (i.e., graduated or not graduated) with their bachelor's degree major. In the analyses, we use "completed a STEM degree" as the reference group so that we can compare STEM degree completion to completion of a non-STEM degree and to degree non-completion.

The analyses account for several student-level independent variables, including demographic characteristics, prior academic preparation, identification with STEM, educational and career aspirations, and pre-college experiences. Among the demographic characteristics, we include dummy variables representing Black, Asian American, Latino, and Native American with White as the reference group. We also account for gender (male as the reference group) and a composite variable representing students' socioeconomic status. We measure prior academic preparation with several variables: high school GPA, standardized test scores, and the years of study students completed in high school in biological science, chemistry, and mathematics. STEM identity corresponds to a factor composed of the following four items: goal of wanting to make a theoretical contribution to science, wanting to be recognized as an authority in the field, wanting to be recognized for contributions to the field, and wanting to find a cure to a health problem, and Chang et al. (in press) provide additional information about this factor.

The model also accounts for two constructs representing students' academic self-confidence at college entry and the extent to which students' reported that their institution's reputation influenced their decision to attend that particular college or university. Sharkness et al. (2009) provide technical information about the creation of these two constructs. Additionally, we account for pre-college experiences related to the amount of time students spent studying in high school, interacting with teachers, and participating in a variety of extracurricular activities as well as whether students participated in pre-college research opportunities.

In addition to the student-level variables, the analyses also account for a number of institutional characteristics and opportunities available to undergraduate students in STEM. For example, we control for institutional selectivity, control, and whether the institution is classified as an HBCU. We measure selectivity as the average SAT scores (or ACT-equivalent scores) of entering students in 2004 and re-scale this variable so that a one-unit change corresponds to a 100-point change in average SAT scores. We use dichotomous variables to represent an institution's status as private (compared to public) and an HBCU (compared to a PWI). We draw variables from the BPS survey corresponding to the extent to which institutions offer structured undergraduate research program, structured faculty-student mentoring programs, and retention programs geared to all STEM students

Analyses

Before proceeding with our multi-level analysis, we accounted for missing data at the student level. We deleted cases with missing data on the outcome variable and demographic variables. After removing these cases, we used multiple imputation to replace missing values with estimated, imputed values. Descriptive analyses indicated that no student-level variable in our data had missing data on more than 12% of cases, which we judged to be relatively small. Multiple imputation uses a Monte Carlo technique to replace missing values with simulated data (Rubin, 1987). Because data varies, multiple imputation provides for the natural variation and uncertainty regarding missing values (Little & Rubin, 1987), and, because multiple imputation takes into account this uncertainty, it represents a more robust method for handling missing data than the expectation maximization algorithm, particularly when more than 5% of cases contain missing data (Schafer, 1997). For this study, we used the multiple imputation program in Stata to create five imputed datasets. We analyzed our statistical model across these five datasets and combined the results following the method prescribed by Rubin (1987).

After accounting for missing data, we ran a series of descriptive statistics to develop a better understanding of the relationships among our variables, In addition to examining means and standard deviations of our independent variables, we also conducted a series of cross-tabs between institutions' average STEM completion rates and the various programs that institutions made available to support students and faculty in STEM. These crosstabs provided descriptive estimates of the differences in institutional STEM completion rates by variations in the prevalence of specific programmatic interventions.

Following these descriptive analyses, we proceeded with multivariate analyses of our data. The data in this study have a clustered design, as students are nested within institutions. To accurately estimate the contextual effects of institutions on students' likelihood to complete a STEM degree within five years of initial college enrollment, we utilize multinomial hierarchical generalized linear modeling (HGLM). Multinomial HGLM partitions the variance between individuals (students) and groups (institutions) in analyses with multi-level data and a categorical outcome variable (Raudenbush & Bryk, 2002). Studies that employ single-level statistical techniques, such as logistic regression, on multi-level data do not account for the unique clustering effect of the complex sample design, which increases the risk of making a Type I statistical error by erroneously concluding the significance of a parameter estimate (Raudenbush & Bryk).

Our model building occurred in several stages. First, we estimated a fully unconditional model to confirm that the average probability of completing a non-STEM degree and not completing any degree significantly varied across institutions. This analysis indicated that the average probability of earning a non-STEM degree and of not earning any degree significantly varied across colleges and universities, so we proceeded with building our level-1 model. We controlled for background characteristics, pre-college experiences, and goals and intentions at college entry in three separate blocks. Next, we added all institutional characteristics and programmatic variables, except for selectivity, to the level-2 model. Our next model included the selectivity measure. Finally, to address the third research question, we created slopes-as-outcomes models where we first determined whether individual effects (e.g., race) significantly varied across institutions. In cases where we found significant variation, we tried to account for that variation in the slope by adding institutional predictors. This slopes-as-outcomes modeling represents another benefit of using multinomial HGLM, as analysts can efficiently consider cross-level interactions in their statistical models (Raudenbush & Bryk, 2002). In all models, we grand-mean centered the continuous variables and left all of our dichotomous variables un-centered (Raudenbush & Bryk).

Limitations

A primary limitation of this research is the use of secondary data analysis, as we are limited by the variables and their definitions on the 2004 CIRP Freshman Survey. Additionally, only 75% of our institutional sample responded to the BPS survey, which required us to eliminate approximately 90 schools and 7,000 students from our initial STEM student sample. Furthermore, we analyze STEM degree completion through five years, as the six-year data from the NSC does not become available until the end of the 2010 calendar year.

Finally, because we surveyed all STEM deans and department chairs within our institutional sample, we had many institutions that contained more than one response about the extent to which they provided various opportunities to students and faculty. Given the potential variation with these responses within institutions, we conducted sensitivity analyses in our statistical modeling. We analyzed three separate institutional models: the lowest value for each BPS response within an institution; the average value for each BPS response within each institution; and the largest value for each BPS response within each institution. We found similar results across the three different datasets (least, average, greatest); thus, the results we report in our findings correspond to the model choosing the highest values from the BPS variables.

Findings

Descriptive statistics, shown in Table 1, indicate that nearly one-third (33%) of the students in the sample earned a STEM degree within five years of enrolling in college. This figure compares to 23% of students who earned a degree in a non-STEM field and approximately 45% of aspiring STEM majors from 2004 who had not yet earned a degree. A portion of the non-completers were still enrolled in a higher education institution after five years; however, the NSC data did not provide information of these retained students' current academic discipline.

Considering students' racial and ethnic backgrounds, the sample was 71% White, 13% Asian American, 6% Latino, 8% Black, and 2% Native American. Approximately 47% of students were women. Students' average high school GPA ranged between a B and a B+. On average, respondents completed four years of high school math and slightly fewer than two years of high school biology and chemistry, respectively. Approximately 9% of respondents indicated they had participated in a pre-college summer research program, and 49% of first-year students reported plans for a career in a STEM-related field.

Institutions in our sample were moderately selective, as average SAT scores of entering students were 1,140. Nearly 80% of the institutions were privately controlled, and just 4% had a designation as an HBCU. Colleges and universities reported offer many opportunities for undergraduate research but appeared to offer fewer retention programs geared to all undergraduate STEM students. Approximately 83% of institutions offered formalized student-faculty mentoring programs.

The results of the multinomial HGLM are reported in Tables 2 and 3. Table 2 compares earning a STEM degree to not earning any degree within five years of enrollment. To improve interpretability, we transformed all coefficients and delta-p statistics to represent so that a one-unit change in the independent variable corresponds to the resulting change in probability of earning a STEM degree relative to not earning any degree. Model 1 includes all student- and institution-level predictors with the exception of institutional selectivity, and Model 2 adds the selectivity measure. The institutional results for Model 1 indicate that the number of undergraduate research opportunities offered by institutions significantly and positively relates to institutions' average STEM degree completion rate. Institutions that offer some research opportunities outperform those colleges and universities without any undergraduate research experiences by as much as 20 percentage points, and this effect becomes even more pronounced for institutions that offer many undergraduate research opportunities. After adding selectivity to the level-2 model, we see that selectivity accounts for the positive benefits of undergraduate research programs. A 100-point increase in institutional selectivity corresponds to a 12.64 percentage-point increase in institutions' average five-year STEM degree completion rate. This finding suggests that undergraduate research opportunities are much more prevalent at more highly selective institutions.

Considering student-level characteristics, we find that underrepresented racial minority students have significantly lower probabilities of completing STEM degrees compared to their White colleagues. Specifically, Native American students are 8.90 percentage points less likely than their White peers to complete a STEM degree, relative to completing no degree, whereas Black students and Latino students are 11.28 percentage points and 8.32 percentage points less likely to earn a STEM degree relative to no degree. Students from higher socioeconomic backgrounds have significantly greater odds of completing a STEM degree relative to no degree, as a one standard deviation increase in the socioeconomic status factor corresponds to a 4.12 percentage point increase in students' probability of earning a STEM degree. Women had significantly higher probabilities than their male classmates of earning a STEM degree relative to no bachelor's degree (delta-p = 3.03). Students who reported greater concerns about financing their college education experienced significantly reduced probabilities of completing a STEM degree relative to not completing any degree.

Similar to prior research (AAAS, 2001), students' prior academic preparation significantly and positively predicted their probability of earning a STEM bachelor's degree relative to not earning any bachelor's degree. Additional years of high school math, chemistry, and biology significantly predicted higher probabilities of STEM degree completion. Likewise, students who earned higher high school GPAs tended to be significantly more likely to earn a STEM bachelor's degree. Specifically, a one-unit increase in the high school GPA variable corresponded to a 10.53 percentage point increase in students' probability of earning a STEM bachelor's degree relative to not earning a bachelor's degree.

Arriving at college with a greater level of academic self-confidence corresponded to significantly higher probabilities of earning a STEM degree; however, this relationship was substantially weaker than other predictors in the model. Interestingly, students' identification with the STEM major and goals of pursuing a career in a STEM-related career did not significantly predict their probability of earning a STEM degree relative to not earning any degree. Students who reported having studied more hours each week in high school had significantly higher probabilities of earning a STEM bachelor's degree within five years of enrollment.

Table 3 presents the results of the multinomial HGLM that compares earning a STEM bachelor's degree to earning a bachelor's degree in a non-STEM field. Similar to Table 2, Model includes all student- and institution-level predictors except for institutional selectivity. The results suggests that institutions that offer more retention programs geared to all students have significantly higher STEM completion rates, relative to completion of non-STEM bachelor's degrees, than campuses that offer these programs to a lesser extent. After adding selectivity to the model, the extent to which institutions offered STEM retention programs no longer significantly predicted institutions' STEM completion rates. Instead, after accounting for institutional selectivity, HBCU status became significant. Therefore, after controlling for the average SAT scores of entering students, students who attended an HBCU had significantly higher probabilities of completing a STEM degree, relative to completing a non-STEM degree, compared to their peers at PWIs. In contrast to the findings comparing STEM completion versus no degree completion, the findings in Table 3 indicate that selectivity does not significantly relate to STEM completion rates relative to non-STEM degree completion rates.

Considering student-level variables, the results in Table 3 suggest that Black and Latino students are nearly seven percentage points less likely than their White peers to earn a STEM degree compared to a non-STEM degree whereas Asian American students are about nine percentage points more likely that White students to earn a STEM degree. Women are significantly less likely than men to earn a STEM degree relative to a non-STEM degree. Additionally, students from higher SES backgrounds have significantly higher probabilities of earning a STEM degree compared to earning a degree in a non-STEM field.

Consistent with the findings in Table 2, the results in Table 3 suggest that pre-college preparation significantly and positively predicts students' likelihood of earning a STEM degree.

Additional years of high school math and chemistry predicted significantly higher probabilities of earning a STEM degree in five years relative to a degree in a non-STEM field. Likewise, students who earned higher grades in high school had significantly better chances of earning a STEM degree, as a one-unit increase in the high school GPA variable corresponded to a 6.12 percentage point increase in their probability of earning a STEM degree relative to a non-STEM degree.

In contrast to the analysis comparing STEM degree completion to not completing a degree, the findings comparing STEM completion to non-STEM degree completion suggest that having a STEM career goal at college entry makes students more than 12 percentage points more likely to earn a bachelor’s degree in STEM. Additionally, students who spent more time studying in high school and tutored peers in high school had significantly higher probabilities of earning a STEM degree relative to a non-STEM degree. Respondents who expected that they would switch out of their intended STEM major were nearly seven percentage points less likely to earn a STEM degree relative to earning a degree in a non-STEM field.

To answer the third research question, we examined the extent to which the effect of identifying with a particular race significantly varied across institutions. We first examined whether the four variables pertaining to race significantly varied depending on where a student attended college. This analysis indicated that the effect of identifying as a Black student significantly differed across institutions; given this variation, we attempted to model this slope. Table 4 presents the results of modeling the effect of being Black across institutions when comparing STEM degree completion to not completing any degree. The results suggest that Black students who attend HBCUs are 12.79% more likely to complete a STEM degree relative to not completing any degree compared to their Black peers who attend PWIs or Hispanic-

Serving institutions (HSIs). No other institutional variables significantly predicted STEM degree completion relative to non-STEM completion or not completing any degree.

Discussion and Implications

This study examined how institutional contexts related to undergraduate STEM degree completion by using a nationally representative sample of first-time freshmen who entered college with the intention to major in a STEM field. With degree and enrollment data from the National Student Clearinghouse and information about institutions' activities designed to support students in STEM collected through the Best Practices in STEM survey, we created an unprecedented database of entering student characteristics, student degree information, and institutional characteristics. The findings from the multinomial HGLM analyses suggest that, in regard to STEM completion rates, institutions that offer a number of undergraduate research opportunities significantly outperform peer institutions that offer fewer research opportunities to undergraduates. Not surprisingly, the significance of undergraduate research opportunities in relation to STEM degree completion is eliminated after accounting for the average SAT scores of entering first-year students.

The fact that selectivity fully accounted for the relationship between undergraduate research experiences and institutional STEM completion rates suggests that formalized undergraduate research programs are much more prevalent at more selective institutions. In other words, institutions that could benefit from offering more undergraduate research opportunities, which typically are less selective and more open access colleges and universities, tend to have fewer of these experiences available to students. Given the level of funding that NIH and NSF invest in these programs, the findings from this study suggest that their dollars could be more effectively disseminated to institutions of lower selectivity.

Similarly, the findings in Table 3 indicate that, after accounting for selectivity, the positive effects from offering more formalized STEM student retention programs on STEM degree completion relative to completion of a non-STEM degree is eliminated. To the extent possible, less selective institutions would be well served to devote resources to implementing undergraduate STEM retention programs. A limitation of this data is that we are unable to discern the types of STEM retention programs that are more effective than others; instead, we can only identify that the presence of these programs make students significantly more likely to complete a STEM degree relative to completing a degree in a non-STEM field.

The relationship between institutional selectivity and STEM completion rates supports prior research that concluded students at more selective institutions graduate at significantly higher rates than their peers at less selective institutions (Eagan, 2009; Titus, 2004, 2006). Prior research, such as Chang et al. (2008) found a negative relationship between institutional selectivity and academic major retention of first-year science students; however, the authors of that study looked only to the end of the first year and considered only retention in a major. Thus, the effects of selectivity on STEM student performance may have substantial variation over time.

Another institutional context that significantly related to STEM degree completion was HBCU status. Students of all races who attended an HBCU were significantly more likely to earn a STEM degree, relative to a non-STEM degree, compared to their peers at non-HBCU campuses. More importantly, the slopes-as-outcomes analysis suggested that Black students at HBCUs have significantly higher probabilities of completing their STEM bachelor's degree, relative to not completing any bachelor's degree, compared to their peers at PWIs and HSIs. This finding supports prior research regarding the positive climate that students encounter at HBCUs (Allen, 1992; Hurtado, 2003; Hurtado et al, 2009).

Several interesting findings emerged from the student-level model. For example, women appear to have significantly higher probabilities than men of earning a STEM degree relative to not earning any degree within five years of enrollment, yet they appear significantly less likely to earn a STEM degree relative to earning a degree in a non-STEM field compared to their male classmates. Not surprisingly, the effect of identifying with particular underrepresented racial groups in STEM negatively predicted students' likelihood of earning an undergraduate STEM degree. Black, Latino, and Native American students had significantly lower probabilities of earning a STEM degree in five years compared to their White classmates. These effects of race persisted even after accounting for students' socioeconomic status, prior academic preparation, and prior academic achievement. Given students' significant and negative effects of identifying as an underrepresented racial minority in STEM, institutions have an opportunity to implement programs that specifically target retaining these populations in STEM. Future research needs to disaggregate data by race and ethnicity to examine the individual and institutional predictors of STEM completion across race.

Finally, the results related to prior academic preparation support findings from previous research that suggest prior academic preparation represents one of the strongest predictors of STEM students' likelihood to complete a degree in STEM (AAAS, 2001). These findings beg the question whether current STEM curricula merely serves to sort, rather than develop, scientific talent. If colleges and universities serve to educate aspiring scientists, engineers, and mathematicians, they have an opportunity to improve the ways in which they assist these individuals in matriculating through college. Whether institutions adjust their STEM curriculum or implement additional support services and research opportunities for undergraduate STEM students, colleges and universities have a significant role in facilitating students' progression along the STEM pipeline.

Because of this study's focus on the institutional context, we chose to analyze students' pre-college characteristics as well as the institutional characteristics and opportunity structures they encountered when they entered college. Admittedly, offering students the opportunity to participate in undergraduate research programs or to take advantage of STEM retention programs does not equate to the actual experience of taking part in these experiences. However, if students lack the choice to pursue these opportunities, they may very well be at a disadvantage when compared to their peers who are enrolled at campuses that better support undergraduate STEM students. Students, as resilient as they are, can only make so much progress toward achieving a degree in STEM; policymakers have an opportunity to fund colleges and universities that would most benefit from offering programs to support undergraduate STEM students, institutions have a responsibility to provide the support networks necessary for them to achieve this goal, and future scholars have an obligation to examine the effectiveness of these institutional endeavors.

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Table 1

Descriptive statistics of dependent and independent variables

	Mean	S.D.	Min.	Max
Outcomes				
Completed a STEM degree	0.32	0.46	0.00	1.00
Completed a non-STEM degree	0.23	0.42	0.00	1.00
Did not earn a degree	0.45	0.50	0.00	1.00
Demographic Characteristics				
Native American	0.02	0.13	0.00	0.00
Black	0.08	0.27	0.00	0.00
Latino	0.06	0.24	0.00	0.00
Asian American	0.13	0.34	0.00	0.00
Socioeconomic Status	-0.03	1.00	-2.92	1.77
Sex: Female	0.47	0.50	0.00	1.00
Concern about Finances	1.80	0.65	1.00	3.00
Prior Academic Preparation				
Average High School Grade	6.60	1.36	1.00	8.00
Mathematics	5.96	0.56	1.00	7.00
Physical Science	3.99	1.24	1.00	7.00
Biological Science	3.68	1.01	1.00	7.00
Pre-College Experiences				
Was Bored in Class	2.37	0.56	1.00	3.00
Tutored Another Student	1.79	0.67	1.00	3.00
Felt Overwhelmed by All I Had to Do	2.08	0.62	1.00	3.00
Studying or Homework	4.30	1.56	1.00	8.00
Expectation of changing major field	2.38	0.86	1.00	4.00
Participated in Summer Research Program	0.09	0.28	0.00	1.00
College Expectations				
Academic Self-Concept Score	51.35	8.09	12.65	66.92
College Reputation Orientation Score	48.81	7.59	32.01	57.71
STEM ID	-0.01	1.00	-2.20	2.32
STEM Career	0.49	0.50	0.00	1.00
Institutional Characteristics				
Control: Private	0.78	0.42	0.00	1.00
HBCU	0.04	0.26	0.00	1.00
Selectivity	11.40	1.22	8.61	15.10
Retention programs for all STEM students	2.14	0.75	1.00	3.00
Undergraduate research programs	2.74	0.48	1.00	3.00
Formal faculty-student mentoring programs	0.83	0.38	0.00	1.00

Table 2

Multinomial HGLM Results Comparing STEM Degree Completion to No Degree Completion

	Log Odds	S.E.	Sig.	Delta-P	Log Odds	S.E.	Sig.	Delta-P
Institutional Characteristics								
Intercept	2.68	1.15	0.02		0.43	1.13	0.70	
HBCU	0.53	0.38	0.16		-0.18	0.33	0.58	
Selectivity					-0.51	0.12	0.00	12.64%
Control: Private	-0.36	0.24	0.14		0.36	0.25	0.16	
Retention programs targeted for all students	-0.11	0.21	0.58		-0.05	0.19	0.80	
Formalized student-faculty mentoring opporutnities	0.22	0.36	0.56		0.42	0.35	0.23	
Undergraduate research opportunities	0.84	0.32	0.01	20.68%	-0.38	0.33	0.25	
Student Characteristics								
Native American	-0.39	0.13	0.00	-8.90%	0.39	0.13	0.00	-8.90%
Black	-0.50	0.10	0.00	-11.28%	0.50	0.10	0.00	-11.28%
Latino	-0.36	0.08	0.00	-8.32%	0.36	0.08	0.00	-8.32%
Asian American	0.07	0.09	0.43		0.07	0.09	0.43	
Socioeconomic status	0.17	0.03	0.00	4.12%	-0.17	0.03	0.00	4.12%
Sex: Female	0.12	0.05	0.01	3.03%	-0.12	0.05	0.01	3.03%
Financial concerns about financing college	-0.06	0.02	0.01	-1.45%	0.06	0.02	0.01	-1.45%
Years of HS math	0.12	0.03	0.00	2.87%	-0.12	0.03	0.00	2.87%
Years of HS chemistry	0.03	0.01	0.05	0.62%	-0.03	0.01	0.05	0.62%
Years of HS biology	0.04	0.02	0.03	0.92%	-0.04	0.02	0.03	0.92%
High school GPA	0.43	0.02	0.00	10.53%	-0.43	0.02	0.00	10.53%
Pre-college summer research program	0.07	0.06	0.21		0.07	0.06	0.21	
Academic self-confidence	0.01	0.00	0.00	0.23%	-0.01	0.00	0.00	0.23%
College reputation orientation	-0.01	0.01	0.07		0.01	0.00	0.05	-0.12%
STEM identification	-0.04	0.02	0.06		0.04	0.02	0.06	-0.85%
STEM career goal	-0.05	0.10	0.63		-0.05	0.10	0.63	
Was Bored in Class	0.02	0.03	0.60		0.02	0.03	0.60	
Tutored Another Student	-0.02	0.03	0.40		-0.02	0.03	0.40	
Felt Overwhelmed by All I Had to Do	0.00	0.03	0.93		0.00	0.03	0.93	
Hours per week spent studying in high school	0.07	0.01	0.00	1.74%	-0.07	0.01	0.00	1.74%
Expectation of changing major field	-0.03	0.03	0.29		-0.03	0.03	0.29	

Table 3

Multinomial HGLM Results Comparing STEM Degree Completion to Completion of a Non-STEM Degree

	Log Odds	S.E.	Sig.	Delta-P	Log Odds	S.E.	Sig.	Delta-P
Institutional variables								
Intercept	0.45	0.49	0.36		0.39	0.52	0.45	
HBCU	0.01	0.10	0.94		0.32	0.10	0.01	7.93%
Selectivity					0.01	0.01	0.80	
Control: Private	0.14	0.10	0.15		0.55	0.10	0.58	
Retention programs geared to all students	0.14	0.07	0.03	3.44%	0.08	0.06	0.23	
Formalized student-faculty mentoring programs	0.10	0.15	0.50		-0.13	0.16	0.40	
Undergraduate research opportunities	0.19	0.13	0.13		-0.19	0.14	0.17	
Student-level variables								
Native American	-0.13	0.15	0.40		-0.13	0.15	0.40	
Black	-0.27	0.08	0.00	-6.65%	-0.27	0.08	0.00	-6.65%
Latino	-0.27	0.07	0.00	-6.62%	-0.27	0.07	0.00	-6.62%
Asian American	0.39	0.07	0.00	9.06%	0.39	0.07	0.00	9.06%
Socioeconomic status	0.06	0.02	0.01	1.34%	0.06	0.02	0.01	1.34%
Sex: Female	-0.24	0.04	0.00	-6.05%	-0.24	0.04	0.00	-6.05%
Concerns about financing college	0.08	0.02	0.00	2.01%	0.08	0.02	0.00	2.01%
Years of high school mathematics	0.17	0.03	0.00	4.13%	0.17	0.03	0.00	4.13%
Years of high school chemistry	0.03	0.01	0.02	0.69%	0.03	0.01	0.02	0.69%
Years of high school biology	0.01	0.02	0.77		0.01	0.02	0.77	
High school GPA	0.26	0.02	0.00	6.12%	0.26	0.02	0.00	6.12%
Pre-college summer research program	0.02	0.05	0.73		0.02	0.05	0.73	
Academic self confidence	0.02	0.00	0.00	0.59%	0.02	0.00	0.00	0.59%
College reputation orientation factor	-0.01	0.00	0.00	-0.33%	-0.01	0.00	0.00	-0.33%
STEM identification	-0.01	0.02	0.62		-0.01	0.02	0.62	
STEM career goal	0.54	0.05	0.00	12.27%	0.54	0.05	0.00	12.27%
Was Bored in Class	-0.06	0.03	0.05	-1.54%	-0.06	0.03	0.05	-1.54%
Tutored Another Student	0.07	0.02	0.00	1.76%	0.07	0.02	0.00	1.76%
Felt Overwhelmed by All I Had to Do	-0.06	0.02	0.02	-1.41%	-0.06	0.02	0.02	-1.41%
Hours per week spent studying in high school	0.04	0.01	0.00	1.01%	0.04	0.01	0.00	1.01%
Expectation of changing major field	-0.27	0.02	0.00	-6.66%	-0.27	0.02	0.00	-6.66%

Table 4

Examining the Variation of the Effect of Identifying as Black on STEM Degree Completion vs. no Degree Completion across Institutions

Institutional Characteristics	Log Odds	S.E.	Sig.	Delta-P
HBCU	0.57	0.24	0.02	14.15%
Selectivity	0.02	0.01	0.87	
Retention programs geared to all students	0.03	0.12	0.79	
Undergraduate research opportunities	0.17	0.25	0.50	