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What Matters in College for Retaining Aspiring Scientists and Engineers

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Abstract

In this study, we explored data drawn from the Cooperative Institutional Research Program's 2004 Freshman Survey (TFS) and 2008 College Senior Survey. First, we analyzed data for all students who took both the TFS and CSS (at the same institution), and who indicated on the TFS that they intended to major in a STEM field. This sample included 3,670 students at 217 different institutions. 1,522 respondents were White, 498 were Asian, 812 were Latino(a), 626 were Black/African American, and 196 were Native American. We examined the effects of racial group classification (i.e., self-identification as Native American, Latino, or Black) on STEM persistence. We found significant effects for Blacks and Latinos; both of these groups were significantly less likely to persist in STEM majors than were their White and Asian American counterparts. However, when controlling for pre-college characteristics the race effects disappeared. Next, we further restricted the above sample to include only underrepresented racial minority (URM) students (i.e., Black/African American, Latino/a or Native American). In total, 1,634 students were included in the URM subsample. We found that undergraduate research, participation in an academic club or organization, studying frequently with others, and having a high academic self-concept all increased the likelihood of URM student persistence. We also found that aspiring to the medical doctorate, working full-time, and faculty interactions were decreased the likelihood that a URM student would persist in a STEM major.

What Matters in College for Retaining Aspiring Scientists and Engineers

For nearly a decade, governmental agencies (e.g., AAAS, 2001 and NAS, 2007) have claimed that the productivity and strength of the U.S. economy may face a serious decline if no significant action is taken to address the racial disparities in the attainment of post-secondary degrees in science, technology, engineering, and mathematics (STEM) fields. The National Science Foundation (NSF) (2009) reported that 19.9% of Whites, 34.3% of Asian Americans, 20.9% of Blacks, and 20.6% of Latinos(as) entered college with the intention to major in a STEM field. However, only 15.4 % of Whites, 28.1% of Asian Americans, 12.1% of Blacks, and 13.5% of Latinos(as) were actually conferred degrees in that same year. Although these comparisons are cross-sectional, it suggests that Blacks and Latinos(as) (57.9% and 65.5% respectively) are less likely to persist in STEM majors as compared to their White and Asian American (77.4% and 81.9% respectively) counterparts.

Subsequently, these finding have significant implications for employing a diverse STEM workforce. The NSF (2009) estimates that STEM related employment is composed of 77.3% White, 17.2% Asian American, 3.9% Black, and 4.5% Latino(a). This is a major concern because the U.S. Census (2009) data estimates that Blacks and Latinos(as) combine to make up almost one third of the U.S. population, which suggests that a significant portion of our nation’s population is currently underutilized in STEM related sectors of the labor market.

As suggested by the NSF report, the underrepresentation of racial/ethnic minorities is not necessarily attributable to a lack of interest in science fields, but rather poor degree completion rates. In 2000, Huang, Taddese, and Walter found that Black, Latino, and Native American students or underrepresented racial minorities (URMs) had lower persistence rates (26%) in science and engineering than their White and Asian American counterparts (46%). A more recent study conducted by the Higher Education Research institute (2010) found that 33% of White and 42% of Asian American students completed their bachelor's degree in STEM within five years of entering college compared to 18.4% of Black and 22.1% of Latino students. After a decade, it appears that there are persisting challenges with the continued permeability of the STEM pipeline for underrepresented racial minorities (URMs). Although student preparation and ability are important, progress through the scientific pipeline may be strongly influenced by the types of opportunities, experiences, and support students receive in college.

Institutions of higher education can play an important role in improving the participation rates of certain segments of our nation's population in STEM related careers and subsequently, also contribute to fueling the economy. Perhaps the most immediate and obvious role that institutions can play is to do a better job retaining Black and Latino(a) undergraduates, who enter college seeking a degree in a STEM field. The purpose of this exploratory study was to indentify key individual and institutional factors that either positively or negatively predict STEM degree persistence. We first examined the extent to which a student's race contributed to the chances of persisting in a STEM major after four years of college, and then we examined patterns that uniquely contributed to the persistence of URM students.

Literature Review and Conceptual Framework

Scholars have identified a number of factors that may contribute to the retention of undergraduates in 4-year colleges and universities in general (Nora, Barlow, & Crisp, 2005; Tinto, 1993; Titus, 2004) and STEM fields in particular (Daempfle, 2003; Elliott, Strenta, Adair, Matier, & Scott, 1996; Grandy, 1998; Seymour & Hewitt, 1997; White, Altschuld, & Lee, 2006). Some of the factors that previous research have shown to affect STEM retention include students' previous academic preparation (Elliott et al., 1996), personal contact with faculty

(Daempfle, 2003), degree of racial isolation (Seymour and Hewitt, 1997), exposure to racial minority support systems (Grandy, 1998), and institution's level of selectivity (Chang, Cerna, Han, & Senz, 2008).

In a seminal study, Seymour and Hewitt (1997) interviewed 425 undergraduates, who entered college as STEM majors. In analyzing the experiences of students who changed majors and those who persisted, Seymour and Hewitt concluded that, "the educational experience and the culture of the discipline (as reflected in the attitudes and practices of [STEM] faculty) make a much greater contribution to [STEM] attrition than the individual inadequacies of students or the appeal of other majors" (p. 392). A recent set of studies has helped to clarify the impact of unique experiences and circumstances on STEM degree completion for underrepresented racial minority (URM) students.

Key Individual Experiences and Institutional Factors

For URM students who pursue undergraduate studies in STEM fields, a combination of external and internal factors facilitates their persistence. Elliott et al. (1996) found that Black students had far less preparation in pre-college sciences, which included lower rates of participating in AP Biology, Chemistry, Physics, and Caluculus courses. Russell and Atwater (2005) noted that a demonstrated competence in science and mathematics at the pre-college level is vital to Black students' successful progress through the science pipeline from high school to college. Receiving family support and teacher encouragement, developing intrinsic motivation, and maintaining perseverance are other critical factors they identified that significantly affect students' science persistence and academic achievement. Likewise, the presence of family support and guidance from faculty mentors also have been found to be associated with the development of greater academic self-efficacy and success in the sciences for Latino students (Anaya & Cole, 2001; Cole & Espinoza, 2008; Torres & Solberg, 2001).

It also appears that campuses can intentionally improve undergraduate success in STEM fields. At the programmatic level, offering undergraduates research opportunities makes a difference not only in attracting and retaining STEM majors but also in facilitating students' learning in the classroom by introducing them to what science research careers might entail (Kinkead, 2003; Lopatto, 2003). URM students who participate in well-structured undergraduate research programs can benefit in many ways, including enhancing their knowledge and comprehension of science (Sabatini, 1997); clarifying graduate school or career plans in the sciences (Hurtado, Cabrera, Lin, Arellano, & Espinosa, 2009; Kardash, 2000; Sabatini, 1997); and obtaining other professional opportunities that further develop students' scientific self-efficacy (Gándara & Maxwell-Jolly, 1999; Hurtado, et al., 2009; Mabrouk & Peters, 2000). By increasing students' tendencies to feel, think, behave, and be recognized by meaningful others (e.g., faculty role models) as a "science person," URM students stand a much better chance of believing in their abilities to succeed in the sciences (Carlone & Johnson, 2007). As such, those students are more likely to identify with a STEM field and view it as an important aspect of their self-identity, which should in the long run enhance their chances of persisting.

Several recent studies add to the knowledge about the unique individual experiences and institutional attributes that tend to significantly improve URM students' chances of completing an undergraduate degree in STEM fields. In one longitudinal survey study, Hurtado, Han, Saenz, Espinosa, Cabrera, and Cerna (2007) examined the impact of college on two key outcomes, social and academic adjustment to college. They found that the relevance of science coursework to students' lives had a greater impact on academic and social adjustment for White and Asian students than for URMs in the sciences. Although this underscores the importance of experiential learning and understanding the application of knowledge, it may also confirm previous studies, which found that URM students often leave the sciences due to the perceived lack of social value, or relevance to improving conditions for their communities (Bonous-Hammarth, 2000). Indeed, Hurtado et al. also found that hostile racial climates only seemed to hinder the academic success of URMs, whereas it had significant negative effects for the sense of belonging of all students. Lastly, URM science students seemed particularly affected by concerns about their ability to finance college, which inhibited both their academic and social adjustment. In fact, they reported that science students of all racial groups were more affected by financial concerns than their non-science counterparts.

Similarly in examining key factors that influence career aspirations in science research for students entering their first year of college, Oseguera, Hurtado, Denson, Cerna, and Saenz (2006) found that entering URM college students reported working more hours during high school and were more likely to expect to work full-time during college than their White and Asian counterparts. They argued that having financial concerns and misperceptions about the financial viability of research professions can deter students from choosing to major in STEM fields, which are especially pressing issues for URM students. However, they also found that participating in research-oriented programs prior to college substantially increased URM entering freshmen’s interests in pursuing a science research career.

Unfortunately, participating in research seems to be harder to come by for URM students when in college. In another study drawing from a similar longitudinal data set, Hurtado, Eagan, Cabrera, Lin, Park, and Lopez (2006) found that although Black students have significantly lower odds of participating in health science research during college compared to their White counterparts, Black students attending institutions offering formal health science research opportunities to first-year students were much more likely to participate in research than students at institutions without such programs. Other significant predictors of participation in science research were Black students' reliance on peer networks. Similar to findings from other studies reported earlier, students' financial concerns had a significant influence on this outcome. Black students, who indicated having more serious financial concerns about paying for college, were significantly less likely to participate in health science research than their peers, who were less concerned about finances.

The same team of researchers also examined factors that contributed to persisting in a STEM major through a student's first year of undergraduate study. Chang, Cerna, Han, and Senz (2008) found that aspiring to attain a graduate degree increased URM students' likelihood of staying in a science major through the first year of college by over 30%. More impressively, joining a pre-professional or departmental club during a student's freshman year increased the likelihood of persisting by more than 150 percent. This study also found that in the aggregate, a URM student had a 30% higher chance of departing from a science major if he or she attends an institution where the average undergraduate combined SAT score is 1100 versus one with an average of 1000. It should be noted here that in their analysis, they also found that a 100 point average undergraduate SAT score increase lowered the chances of STEM persistence by 20% for all students. So, higher selectivity negatively affects all students but the effect is stronger for URM students. Curiously, this effect does not appear to apply to those students who attended HBCUs, but the opposite tended to occur. That is, as the average undergraduate combined SAT score increased, the chances of persisting for students attending HBCUs also tended to improve.

A number of the studies reviewed above employed single-level statistical techniques that did not account for the multilelvel nature of the data (e.g., Cole & Espinoza, 2008, Elliott et al., 1996, Grandy, 1998). Data on the college student experience is by nature multi-level, as students are "nested" within institutions. Analytical techniques that do not account for this nesting are not only less robust but also risk drawing erroneous conclusions because of mis-estimated standard errors. Thus, there is a clear need for an analysis of persistence in STEM that utilizes a more robust analytical technique that can account for the multilevel nature of student data.

Conceptual Model

Taken together, the findings reported above are captured well in Nora, Barlow, and Crisp's (2005) model explaining student persistence and degree attainment. Nora et al. have provided a reformulation of the Tinto model (1993) that brings more clarity to the academic dimensions of the college environment while building upon modifications of the departure model where social and academic integration is a central tenet. They include factors that may influence minority, low-income, and non-traditional student populations such as aspects of pre-college socialization environments (school and home environment), financial assistance/need, family support, environmental pull factors (family and work responsibilities), and commuting to college. In reference to the academic and social experiences in college, they emphasize formal and informal academic interactions with faculty, involvement in learning communities, social experiences, campus climates (perceptions), validating experiences (from faculty and peers), and mentoring relationships (faculty, peer, and advising staff). As stated earlier, they include academic performance, academic/intellectual development, and non-cognitive gains (in psychosocial domains) as intermediate outcomes, which determine subsequent goals, institutional commitment, and persistence in college.

Hurtado (2007) suggests that sociological models of college impact should include four measurable domains of institutional, normative constructs: *characterizations* of the environment focusing on student perceptions of their experiences within the social and academic systems of the collegiate environment; social *interactions* that capture both the frequency and quality of informal academic and social engagement in college; formal *memberships* based on both individual interest and how the group determines entry and confers privileges on its members; and, *perceived social cohesion* or the students' own psychological sense of integration in the college community. In multi-institutional studies, it is important to include relevant structural characteristics that define distinctions between colleges such as minority enrollment and selectivity, which further shape the social and academic environment. In this study, we employed these constructs in relation to academic adjustment and perceived cohesion: successful management of the academic environment and students' sense of belonging to the college community. We have ordered our measures to reflect a model that further delineates aspects of the college environment in accordance with this literature , giving more order to an array of academic measures that may have distinct effects on academic adjustment and overall sense of belonging to the college community.

We adopted key constructs from the Nora et al. (2005) model to detail the link between persistence in STEM and student experiences at multiple types of four-year colleges. Specifically, we posit that STEM persistence is not only a result of characteristics students bring at college entry, but is also impacted by participation in formal structures, the racial dynamics of a college, the continuing influence of family, financial concerns, and assessments of their own development and competence in their identity as a scientist. We apply this framework to identify factors that significantly contribute to STEM degree persistence.

Methods

Research Questions

This study was designed to examine individual and institutional factors that positively or negatively predict STEM degree persistence for underrepresented racial minority students. Two main lines of questioning guided this study. Specifically, we asked:

1. Among all students who started college with an interest in majoring in a STEM field, are there significant differences in the proportion of URM students (versus Whites and Asians) who follow through on these intentions? If so, can these differences be "explained away" by controlling for high school academic preparation, or college experiences?
2. What factors uniquely contribute to the persistence of URM students? That is, what background characteristics, college experiences, and institutional characteristics significantly predict the likelihood of whether a URM student will follow through on his or her intentions to pursue a degree in STEM?

Data and Sample

Data for this study were drawn from the Cooperative Institutional Research Program (CIRP)'s 2004 Freshman Survey (TFS) and 2007-08 College Senior Survey (CSS). The CIRP is a program of data collection and research housed at the Higher Education Research Institute (HERI) at the University of California, Los Angeles. The TFS and CSS are administered annually by CIRP to college students across the U.S., and each survey collects a wide variety of information about students (see Liu, Ruiz, DeAngelo & Pryor, 2009 and Sax, Hurtado, Lindholm, Astin, Korn & Mahoney, 2004 for more information about these surveys). The 2004 TFS was administered to first-year students entering college in the summer/fall of 2004, either during freshman orientation or during the first few weeks of the fall term. The 2008 CSS followed up with this same group of students in the spring of or summer after their fourth year in college. The 2008 CSS data were linked to the 2004 TFS data to form a longitudinal dataset that tracked students over their first four years of college. Our overall longitudinal response rate for the TFS-CSS was 23%. To the longitudinal database, we added institution-level data from academic year 2006-2007, drawn from the Integrated Postsecondary Education Data System (IPEDS).

Grants from the National Institutes of Health (NIH) and National Science Foundation (NSF) provided funds for a targeted sampling strategy for this study. An NIH grant allowed for the specific recruitment of students at minority-serving institutions that have strong reputations of graduating undergraduates in the biomedical and behavioral sciences. NIH grant money also allowed us to target students at institutions that have NIH-funded undergraduate research programs. Further funding from NSF allowed us to expand our sample to include students at institutions that have strong reputations for producing bachelor's degrees in STEM. The overall goal of our sampling strategy was to obtain a large and diverse sample of students from underrepresented racial and ethnic groups who were interested in STEM, as well as a set of their White and Asian counterparts for comparison.

The current study used two samples of students to answer its main research questions. For the first research question, which asks whether race significantly predicts the likelihood of persisting in a STEM degree, we used all students who took both the TFS and CSS (at the same institution), and who indicated on the TFS that they intended to major in a STEM field. This sample included 3,670 students at 217 different institutions. 1,522 respondents (41.5%) were White, 498 (13.6%) were Asian, 812 (22.1%) were Latino(a), 626 (17.1%) were Black/African

American, and 196 (5.3%) were Native American. The sample was approximately 61.3% female. For our second research question, which is the primary focus of this paper, we further restricted the above sample to include only underrepresented minority (URM) students—that is, only students who indicated they were Native American, Latino/a or Black/African American. In total, 1,634 students were included in the URM subsample; 64.6% of these students were female. Appendix B shows descriptive statistics for URM students.

Variables

The dependent variable used in this study was dichotomous and represented whether students who graduated or were still enrolled after four years of college followed through with their freshmen intentions to pursue a degree in a STEM field (1), or whether they switched majors and completed or continued to pursue a degree in a non-STEM field (0).

Nora et al.'s (2005) theoretical model informed the selection of the independent variables in the model. The chosen variables included student demographics and background characteristics, high school achievement and course-taking patterns; push/pull factors such as time spent working, financial concerns, and family support; different types of faculty-student interactions; formal and informal academic activities, such as studying with other students, and joining a major-related club; social integration; racial climate and cross-racial interactions; and students' sense of belonging on campus. Student-level characteristics were grouped into several blocks to aid analysis and interpretation. Specifically, we grouped student background characteristics into (a) demographics (race, sex and SES (as proxied by mother's education level)); (b) high school academic preparation (grades, SAT score, high school course taking patterns), and (c) other pre-college characteristics (including degree aspirations, concern about financing higher education, and student assessments of their academic and social strengths).

Finally, all college experiences were included as one block, but within the block there were measures corresponding to push/pull factors, faculty interaction, assessments of the institutional climate, psychosocial concerns, social and academic integration, and so on.

In addition to the student-level we also modeled institution-level variables. These included institutional type and control (4-year/university, public/private), institutional selectivity (measured by the average SAT score of entering freshmen), percent of students majoring in STEM fields, structural diversity (percent of student body that is Black, Native American or Latino/a), whether an institution is a historically Black college or university (HBCU), proportion of students receiving financial aid and/or federal aid, and institutional size (as measured by undergraduate FTE). Appendix A describes all variables in the analysis.

Analyses

Missing Data. Before discussing our analyses, we must first discuss the handling of missing data. We dealt with missing data in one of two ways. First, we used listwise deletion to remove all cases for which no information was available on the outcome variable, demographic characteristics, and/or dichotomous college experiences (i.e. participation in undergraduate research programs or clubs relating to a major, working full time while in school). For the remaining variables in the model, we analyzed the extent to which missing data occurred. Overall, there was very little missing data. No variable had more than 6% of cases missing, and examination of missing data patterns suggested that missing data occurred at random. The SAT variable had the highest proportion of missing data, at 5.1%. Most variables had fewer than 1% missing cases.

Given the relatively few instances of missing data across the variables used in the analysis, we elected to fill in missing data using the expectation maximization (EM) algorithm.

The EM algorithm employs maximum likelihood estimation techniques to impute values for cases with missing data, and because it uses most of the information available in the dataset to produce the imputed values, it is a more robust method of dealing with missing data than listwise deletion or mean replacement (Allison, 2002; Dempster, Laird, & Rubin, 1997; McLachlan & Krishnan, 1997).

Weighting. Because the longitudinal response rate for the TFS-CSS sample was only 23%, we calculated and applied response weights to the data to adjust for any non-response bias that might be present. The aim of this weighting was to adjust our CSS sample of respondents to look more like the original population targeted by the CSS—that is, like the TFS participants (Babbie, 2001). Our response weights were calculated in two steps. In step 1, we used data from the National Student Clearinghouse and institutional registrars to identify the students that did not complete at least four years of higher education. We removed these students from the 2004 TFS data to make the initial sample consist of only those students who persisted for at least four years.

In step 2, we used the persisting cohort of students and logistic regression to predict the probability of responding to the CSS. Predictor variables came from the 2004 TFS, and included indicators of race, gender, high school achievement, and reasons for attending college (a full list of variables in the model is available upon request). We then used the coefficients from the significant predictors in the model to calculate out the probability that a student would respond to the CSS, and these response probabilities were inverted to develop response weights.[1]

After calculating response weights, we compared the weighted and un-weighted samples from 2004 to determine whether our weights inappropriately skewed any of the 2004 Freshman Survey variables. After confirming that the weight had not adversely affected the distributions of

[1] The general formula for developing a non-response weight is: weight = 1/(probability of response).

variables from the 2004 Freshman Survey, we created a final weight that was normalized to account for sample size. This was calculated by dividing each student's response weight by the average population response rate, and was done in order to avoid inflating any statistics calculated in regressions or other analyses on the weighted sample. All analyses performed for this study were done using data weighted by the final, normalized weight.

Multivariate Analyses. The clustered, multi-level nature of our data and the dichotomous outcome variable warrant the use of hierarchical generalized linear modeling (HGLM). HGLM is an ideal statistical technique for our data, as it can separate individual and institutional effects so that we can determine how individual characteristics interact with institutional contexts to affect STEM major persistence. Further, performing single-level analyses with multi-level data can underestimate the standard errors of model parameters, which can inflate Type-I statistical error (de Leeuw & Meijer, 2008; Raudenbush & Bryk, 2002). To ensure the use of HGLM was justified, we ran a fully unconditional model to assess whether students' average probabilities of persisting in STEM majors varied across institutions. For both the whole sample and for the URM subsample, we confirmed that these average probabilities of persistence varied—specifically, we found that the between-institution variance component significantly varied across institutions.

Our modeling process proceeded in several stages, according to our research questions. We first focused on student-level predictors of STEM persistence for the larger sample of Whites, Asians, and URMs. Specifically, we examined the effects of racial group classification (i.e., self-identification as Native American, Latino, or Black) on STEM persistence, controlling for gender and mother's level of education. We found significant effects for Blacks and Latinos; both of these groups were significantly less likely to persist in STEM majors than were their

White and Asian American counterparts. To examine whether these differences were due to disparities in high school academic preparation, we then ran another model, controlling for all of the above demographic characteristics and high school academic preparation. Because colleges and universities can do little to affect the academic preparation of their students, we were also curious to see whether adding just college experience variables to the model (without high school academics) would also affect the significance of race. Therefore, we ran a third model with the overall group that included just demographics and college experiences. Finally, to more fully explore the impact of background characteristics, college experiences, and institutional context on the persistence of URM students in STEM, we used HGLM to model STEM persistence for just URM students, using all of the variables listed in Appendix A.

Additional modeling considerations. When using hierarchical modeling such as HGLM, analysts must make choices regarding the centering effects of variables. We were interested in the average effect of each predictor on students' likelihood of persisting in STEM, so we chose to grand-mean center all continuous variables. Grand-mean centering subtracts the mean of the variable for the entire sample from each individual observation, and allows the model intercept to be more easily interpreted (Raudenbusch & Bryk, 2002). Dichotomous variables were left un-centered.

In order to most easily interpret the results of the final model for URMs, we report the HGLM results for significant predictors as delta-p statistics. Delta-p statistics represent the expected change in probability of persisting in a STEM major (versus not persisting), that is associated with a one-unit change in the predictor variable. The formula provided by Petersen (1985) was used to calculate delta-p statistics.

Limitations

Before presenting and interpreting the results of our analyses, it is important to take note of some limitations of this study. First and foremost, our sample includes only students who were still enrolled or were graduating after four years of college. In other words, students who withdrew or stopped out are not included in the sample, and thus our results apply only to those students who were successful in persisting for four years. In addition, our study had a relatively low longitudinal response rate (23%), and thus the extent to which our results are generalizable to a larger group of students may be limited. Although we attempted to correct for the nonresponse bias that may have been introduced by the low response rate, our correction was necessarily limited to the information we had available, and may not have taken all important factors into consideration.

Another limitation of our study is that it defines “STEM persistence” as “following through on first-year intentions to major in STEM.” Entering freshmen who take the TFS may not have a comprehensive idea of what kind of major options are available to them, and thus it may be a stretch to expect that all students who initially thought they would major in STEM would follow through on these aspirations. Nevertheless, the fact that there are noticeable differences in our measure of STEM major persistence between students of different race/ethnicities (as outlined below) suggest that even this somewhat limited measure of STEM persistence is measuring an important part of the STEM pipeline.

Results

Descriptive Statistics: STEM persistence

Among the students in our overall sample, 62.5% persisted in STEM majors. This figure was noticeably lower among URM students (58.4%) than it was among Asian and White students (65.9%). Disaggregating by racial group, we see that Asian students had the highest levels of STEM major persistence (73.5%), while Blacks had the lowest (56.5%). Figure 1 displays the STEM persistence rates among the five racial/ethnic groups examined in this study.

Full Sample HGLM Results

The first HGLM model we ran focused on the effects of racial classification on STEM persistence, controlling only for gender and mother's level of education. We found significant effects for both Blacks and Latinos; both of these groups were significantly less likely to persist in STEM majors than were their White and Asian American counterparts. To find out whether this persistence difference was due to differential high school academic achievement, we next added a set of variables representing high school academic preparation to the model. When these academic variables were included as predictors, the significant effects of race disappeared (Table 1). Colleges and universities can do very little about the academic preparation that students bring with them to college, so we also wanted to find out whether experiences in college could also "explain away" the race differences. Therefore, we next dropped high school academics from the model and examined only the effect of college experiences (and demographics) on the significance of the race effects. Encouragingly, we found that when predictor variables included only demographics and college experiences, there were again no significant effects of race on STEM persistence. This indicates that colleges and universities can and do have a role to play in encouraging and assisting students of all races, but especially URMS, in following through on initial STEM aspirations.

URM Subsample HGLM Results

Table 2 presents the results from the full model of the HGLM analysis, for the URM sub-sample. We found several interesting results. Focusing first on student demographic characteristics, we found no significant difference in the probability of STEM persistence among

Latinos, Native Americans, and Blacks. Student gender and SES (proxied by mother's education) also had no significant effects. Among the high school academic preparation predictors, only one variable was significantly associated with the likelihood of STEM persistence: SAT score. For every 100-point increase in total (i.e., combined math and verbal) SAT, our model suggests that students will be 6.86% more likely to persist in a STEM degree. High school GPA and the number of years students spent taking high school mathematics, physical science, and biological science did not significantly affect STEM persistence.

Three more pre-college variables were significantly associated with the likelihood of a student persisting in their STEM major. The largest of these was student aspirations to a medical degree. Students who came to college with aspirations of getting a medical degree were 11.5% less likely to persist in a STEM field than were those who came with aspirations of only a Bachelor's degree. Students who came in with aspirations for a Master's degree or Ph.D., on the other hand, were no more or less likely than their Bachelor's-aspiring counterparts to persist in STEM majors. Entering students' academic and social self concepts also significantly predicted the likelihood of STEM persistence. Having a higher academic self-concept when beginning college positively predicted persistence, while having a higher social self-concept negatively predicted persistence.

In terms of college experiences and URM STEM persistence, only five factors significantly predicted whether students followed through on their first-year intentions to major in STEM. The largest of these predictors was participation in an undergraduate research program. URM students who participated in programs that exposed them to research were 17.38% more likely than those who did not, to persist in STEM. Similarly, though less striking, a positive effect was also shown for joining a club or organization related to students' majors.

Students who joined such organizations were 9.32% more likely to persist in STEM. Students who studied with other students were also more likely to persist in STEM; this effect is particularly pronounced for students who "never" studied with others compared to those that "frequently" studied with others—those who frequently did this were 27% more likely than those who never did, to persist in STEM.

Two negative effects of college experiences on persistence were seen in the model. Specifically, students who worked full-time while attending school (at any point in their college career) were 9.74% less likely to follow-through with intentions to major in STEM than were those who never worked full-time. Further, students who had more interaction with faculty were less likely to persist in STEM than were students with less faculty interaction. This finding is somewhat puzzling (if not counterintuitive), and it, as well as many of the other college experience variables in the model, must be interpreted with caution. In many cases we do not know what came first—did students interact with faculty and then switch out of a STEM major? Or did they change their minds about majoring in STEM, switch to a non-STEM major, and *then* interact more with faculty? All we can say for certain is that students who persist in STEM seem to have lower rates of faculty interaction. Whether or not this discourages students from persisting in STEM majors cannot be tested using the variables in this model.

Two measures of the institution-level college context were also significant predictors of persistence, one positive, and one negative. First, we found that the proportion of the student body that majors in STEM fields at an institution significantly contributes to the average likelihood of STEM persistence at that institution. For every 10-point increase in the proportion of undergraduates majoring in STEM at an institution, the average likelihood of a URM student persisting in STEM increases by 5.57%. However, on the negative side, institutional selectivity, as measured by the average math plus verbal SAT scores of entering students, negatively predicts STEM persistence. For every 100-point increase in the selectivity of an institution, the average likelihood of students persisting in STEM majors drops by 13.0%. We found no significant effects of institutional control, type, HBCU status, research expenditures, structural diversity, or size. The institutional predictors accounted for 69.4% of the between-institution variance in students' average probability of following through with their initial intentions to major in STEM.

Discussion

This study examined if a student's race contributed to the chances of following through with her/his intention to major in a STEM field and whether college characteristics and experiences moderate that effect. Our first set of findings suggest that a student's racial classification does contribute significantly to one's likelihood of persisting in a STEM major at the same college the student enrolled in four years earlier. Both indentifying as Black or Latino reduced the chances that those who indicated an intent to major in a STEM field as an entering freshman also indicated four years later that they were either still majoring in a STEM field or had graduated with a STEM degree. The effect of race was however moderated by college experiences. That is, after controlling for those set of variables, the effect of indentifying as either Black or Latino was no longer statistically significant. This finding may be explained by Seymour and Hewitt (1997) who reported four themes that summarized the challenges URMs had to overcome in their STEM college experiences, which are differences in cultural values and socialization processes, internalization of stereotypes, isolation and perceptions of racism, and inadequate program support. Likewise, controlling for academic preparation also moderated the effect of race. There seem to be persisting pre-college disparities, which often inadequately prepare some URM students for the rigors of the undergraduate STEM curriculum. Outreach programs and university-community partnership programs are clearly needed to continue to chip away and the persisting achievement gaps.

Our second set of analyses focused on just URM students and was guided by Nora et al.'s (2005) conceptual framework. The findings show that precollege factors made a difference in URM students' chances of following through with their original intent to major in STEM fields. Similar to the findings of a number of other studies, having higher SAT scores and a higher academic self-concept as an entering freshman contributed in positive ways to persisting in or graduating from a STEM field. Conversely, aspiring toward a medical degree and having a higher academic self-concept as an entering freshman contributed in negative ways to achieving the same outcome. The former is especially noteworthy because those URM students who chose STEM fields as freshmen and were also interested in attending medical school are nearly 12 percent less likely to persist in STEM than those who chose STEM fields but did not aspire to obtain a Medical degree as a freshman. Pre-medical students may find themselves in intensely competitive environments. The highly competitive nature of medical school application processes may be the driving force in pushing students to be less collaborative and more competitive. As a result, pre-med students may find less support and fewer students to study with, which we found was another significant predictor of persistence in STEM.

Our next set of findings suggests that institutions can shape URM student experiences in ways that improve their chances of completing a degree in a STEM field. Most importantly, we found that URM students who participated in a research program such Minority Access to Research Careers (MARC), Minority Biomedical Research Support (MBRS) and others often funded by NIH and NSF, dramatically improve persistence. Those URM students who participated increased their chances of obtaining or continuing to progress toward completing a STEM degree by an impressive 17.38 percent. Students in these programs are often given the opportunity to engage in the practical application of their coursework, which Carlone and Johnson (2007) suggest improves these students' science identities through "performance and competence." As students feel more personally connected to STEM they are more likely to persist in their respective majors.

Additionally, those URM students who joined a club or organization related to their major significantly improved their chances of persisting in STEM. Clubs like the National Society of Black Engineers (NSBE) and the Society of Hispanic Professional Engineers (SHPE) are examples of undergraduate student organizations that provide their membership with a number of academically enriching experiences, which may promote socially and academically supportive networks. Conversely, working full-time while attending school reduced students' chances by nearly 10 percent and so did interacting more frequently with faculty. The latter finding is especially perplexing since one would expect positive outcomes related to greater contact with faculty. One major limitation of this study is that the causal relationships between variables are not entirely clear, especially in this case. It may be that those who had initially majored in a STEM field then switched to another area of study increased their contact with faculty after having switched out of STEM rather than that having higher levels of interacting with STEM faculty necessarily discourages URM students from persisting in their intended field of study. On the other hand, there may be an inaccurate assumption that all faculty interactions are positive. Newman (2009) found that a number of Black engineering students in his study had negative relationships with faculty members, which was more the norm than the exception. Whatever the case, faculty members do appear to make a difference in URM students' chances of achieving their intended academic goals.

Lastly, two institutional characteristics affect URM students' chances of following through with their intent to degree in a STEM field. Similar to Chang et al.'s (2008) findings, we also found that the average student body SAT score or selectivity had a negative effect on persisting in a STEM field. Each 100-point increase in the aggregated average student body SAT score reduced the chances of persisting in a STEM field by 13 percent. Given the controversy over suggestions that race conscious admissions encourage less qualified URM students to enroll in more rigorous colleges for which they are ill-prepared to succeed, we should also note here that in a full HGLM analyses using all students (identical to the URM model, but not shown in this paper), we found that the effect of selectivity was also negative and equally strong. That is, for every 100-point increase in the aggregated average student body SAT score, the chances of persisting in a STEM field were reduced by over 11 percent. So, the negative effect of selectivity was not limited to just URM students but tends to affect all students as also indicated by Chang et al.

The percent of students at an institution who are majoring in a STEM field also had a positive effect on URM stem persistence. Supporting Seymour and Hewitt's (1997) claim, the proportion of the student body majoring in STEM incrementally improves the chances of persisting. All things being equal, a URM freshman who indicated intentions of majoring in a STEM field will be about 11 percent more likely to follow through with that intention four years later at an institution where 50 percent of the students are majoring in STEM fields than at an institution with 30 percent of such students. As Seymour and Hewitt maintained, this improvement may be related to the educational experiences and the culture of STEM disciplines, which are especially unique compared to other areas of study. An institution with a larger proportion of STEM majors might also have a stronger normative STEM orientation that provides fewer distractions to and fuels one's STEM related career goals, which significantly contributes to the completion of a STEM degree. Although it is unclear from the findings of this study how exactly the proportion of science majors contributes to persistence, this finding does point to the importance of institutional specialization. Attending an institution that has a large proportion of science majors and by definition is more science oriented makes a positive difference in the chances that a URM student with initial interest in pursuing a STEM major will actually complete a science degree.

Conclusion

As theorized in our conceptual model, students' chances of persisting in a STEM major is influenced by key student characteristics, behaviors, and experiences. Certainly, students bring pre-college characteristics with them as entering freshmen, including their demographic background, high school experiences, and prior academic achievement, that influence their engagement with their chosen major and subsequent progress toward degree completion. While these precollege characteristics make a difference in URM students' chances of following through with their intent to complete a degree in a STEM field, there is also much that colleges can do to improve those chances once students begin their course of study. The most important factor seems to be the opportunity to participate in well-structured research programs that enable students to work on a professor's research project and encourage them to study with other students and identify more with their chosen major. Added together, those experiences significantly improve URM students' chances of persisting in a STEM major, independent of their precollege academic preparation and experiences. Even more ideally, such opportunities should offer students some kind of pay. Since engagement in research requires a high level of commitment, when students work too many hours for pay outside of those commitments, this environmental pull can negatively impact their initial academic goals.

In examining institution level variables, we found that the proportion of STEM majors made a significant and positive difference in persistence. Perhaps at these institutions there is a stronger "culture of science," which may both raise the frequency and quality of those experiences that foster persistence. Whereas on more selective institutions, there may generally be another type of culture working simultaneously, which increases the rate of departure from STEM majors not only for URM students but also for White and Asian students. The complex dynamic on those highly selective institutions should be of great concern because those colleges presumably enroll the most promising STEM students, yet appear to be less likely to retain them in those majors.

Overall, our findings suggest that colleges do not have to wait idly for high schools to send them talent to increase the numbers of STEM degree completers. It appears that much can be done to shape students' experiences and level of engagement and to improve institutional circumstances for students, especially for those students at greatest risk of not completing their intended academic goals. The findings from this study add to what we already know by identifying more promising areas for developing structured interventions. Fortunately, some of these interventions are already being applied on some campuses, so a promising line of inquiry for future research would be to more closely examine their educational efficacy.

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Appendix A

Description of Variables and Measures

Variables	Scale Range
Dependent variable	
Persistence in a science, technology, engineering or math major through fourth year of college	0 = no, 1 = yes
Independent Variables	
Student Background Characteristics	
Racial/Ethnic background: Native American, Latino, Black (In All Students regression, White and Asians are reference group; in URM regression, Black students are reference)	0 = no, 1 = yes
Student's Gender	1 = male, 2 = female
Mother's Education	1 = grammar sch., 8 = graduate deg.
Average High School Grade	1 = D, 8 = A or A+
Math + Verbal SAT Score (in 100-point increments)	Continuous, min = 5.00, max = 16.00
Years of mathematics in high school	1 = none, 7 = five or more
Years of physical science in high school	1 = none, 7 = five or more
Years of biological science in high school	1 = none, 7 = five or more
Participated in Summer Research Program	1 = no, 2 = yes
Degree aspirations: Master's Degree, PhD, Medical Degree (Bachelor’s only is reference group)	0 = no, 1 = yes
Entering Science Identity*	Continuous, min = -1.94, max = 1.86
TFS Academic Self-Concept**	Continuous, min = 12.65, max = 66.92
TFS Social Self-Concept**	Continuous, min = 18.06, max = 68.14
Concern about financing college education	1 = note, 3 = major
College Experiences	
Worked full-time while attending school	1 = no, 2 = yes
Felt family support to succeed	1= not at all, 3 = frequently
Faculty interaction factor*	Continuous, min = -2.01, max = 1.60
Asked a professor for advice outside of class	1= not at all, 3 = frequently
Felt intimidated by your professors	1= not at all, 3 = frequently
Faculty feel that most students here are well-prepared academically	1 = strongly disagree, 4 = strongly agree
Studied with other students	1= not at all, 3 = frequently
Sense of Belonging*	Continuous, min = -3.18, max = 1.35
Positive Cross Racial Interaction*	Continuous, min = -2.60, max = 1.40
Negative Cross Racial Interaction*	Continuous, min = -1.05, max = 2.97
Hostile Racial Climate*	Continuous, min = -1.31, max = 2.59
There is strong competition among most of the students for high grades	1 = strongly disagree, 4 = strongly agree
Felt overwhelmed by all I had to do	1= not at all, 3 = frequently
Participated in an undergraduate research program (e.g. MARC, etc.)	1 = no, 2 = yes
Joined a club or organization related to your major	1 = no, 2 = yes

Worked on a professor's research project	1= not at all, 3 = frequently
Institution-Level Variables	
Institutional Control	1 = public, 2 = private
Institutional Type	1 = university, 2 = four-year
HBCU	1 = no, 2 = yes
Selectivity (in 100-point increments)	Continuous, min = 7.80, max = 15.10
Percent of students on financial aid in 2006 (in 10-point increments)	Continuous, min = 0.0, max = 10.0
Percent of students receiving federal aid in 2006 (in 10-point increments)	Continuous, min = 0.0, max = 10.0
Any research expenditures in 2006	0 = $0, 1 = more than $0
Percent of students majoring in STEM in 2006 (in 10-point increments)	Continuous, min = 0.0, max = 8.90
Percent of student body that is American Indian, Black or Latino in 2006	Continuous, min = 0.28, max = 9.94
Log(Undergraduate FTE in 2006)	Continuous, min = 6.00, max = 10.51

* See Appendix C for factor items
** See Sharkness, DeAngelo & Pryor (2010) for more details

Appendix B

Descriptive statistics (URM Students Only, Student N = 1634; Institution N = 194)

Variables	Mean	S.D.	Min.	Max.
<u>Dependent variable</u>				
Persistence in a science, technology, engineering or math major through fourth year of college	0.58	0.49	0	1
<u>Independent Variables</u>				
Student Background Characteristics				
Native American	0.12	0.33	0	1
Latino	0.5	0.5	0	1
Black/African American	0.38	0.49	0	1
Student's Gender	1.65	0.48	1	2
Mother's Education	5.05	2.07	1	8
Average High School Grade				
Math + Verbal SAT Score (in 100-point increments)	11.44	1.75	6.1	16
Years of mathematics in high school	6	0.57	2	7
Years of physical science in high school	3.88	1.27	1	7
Years of biological science in high school	3.74	1.05	1	7
Participated in Summer Research Program	1.14	0.35	1	2
Master's Degree	0.22	0.41	0	1
PhD	0.29	0.45	0	1
Medical Degree	0.29	0.45	0	1
Entering Science Identity*	0.03	0.85	-1.94	1.86
TFS Academic Self-Concept*	51.86	7.8	23.86	66.92
TFS Social Self-Concept*	48.35	9.35	18.06	68.14
Concern about financing college education	1.97	0.63	1	3
College Experiences				
Worked full-time while attending school	1.22	0.41	1	2
Felt family support to succeed	2.54	0.63	1	3
Faculty interaction factor*	-0.03	0.95	-2.01	1.6
Asked a professor for advice outside of class	2.01	0.64	1	3
Felt intimidated by your professors	1.66	0.63	1	3
Faculty feel that most students here are well-prepared academically	2.94	0.63	1	4
Studied with other students	2.43	0.58	1	3
Sense of Belonging*	0.02	0.92	-3.17	1.35
Positive Cross Racial Interaction*	0.13	0.91	-2.6	1.4
Negative Cross Racial Interaction*	0.07	0.88	-1.01	2.97
Hostile Racial Climate*	0.16	0.85	-1.31	2.59
There is strong competition among most of the students for high grades	2.9	0.8	1	4
Felt overwhelmed by all I had to do	2.27	0.58	1	3
Participated in an undergraduate research program (e.g. MARC,	1.21	0.41	0.96	2

etc.)				
Joined a club or organization related to your major	1.6	0.49	1	2
Worked on a professor's research project	1.51	0.7	1	3
Institution-Level Variables				
Institutional Control	1.56	0.5	1	2
Institutional Type	1.61	0.49	1	2
HBCU	1.09	0.29	1	2
Selectivity (in 100-point increments)	11.15	1.48	7.8	15.1
Percent of students on financial aid in 2006 (in 10-point increments)	8.01	1.71	0	10
Percent of students receiving federal aid in 2006 (in 10-point increments)	2.78	1.81	0	9.5
Any research expenditures in 2006	0.81	0.39	0	1
Percent of students majoring in STEM in 2006 (in 10-point increments)	1.66	1.5	0	8.9
Percent of student body that is American Indian, Black or Latino in 2006	2.57	2.5	0.28	9.94
Log(Undergraduate FTE in 2006)	8.62	0.94	6	10.51

Source: Cooperative Institutional Research Program 2004 Freshman Survey, 2008 College Senior Survey, and 2006 Integrated Postsecondary Data System

Appendix C

Multi-Item factors

Scale & Items	All Students Factor Loadings	URM Students Factor Loadings
<u>Science Identity (Freshman Year)*</u>		
Alpha	*.673*	*.653*
Become Authority in My Own Field	.590	.546
Obtain Recognition from Colleagues	.694	.632
Make Theoretical Contribution to Science	.579	.586
Work to Find Cure for Health Problem	.488	.510
*All items on a 4-point scale, 1 = Not important, 4 = Essential		
<u>Student-Faculty Interaction*</u>		
Alpha	*.896*	*.894*
Encouragement to pursue graduate/professional study	.692	.684
An opportunity to work on a research project	.590	.567
Advice and guidance about your educational program	.787	.776
Emotional support and encouragement	.747	.753
A letter of recommendation	.644	.628
Help to improve your study skills	.651	.665
Feedback about your academic work (outside of grades)	.724	.722
An opportunity to discuss coursework outside of class	.656	.651
Help in achieving your professional goals	.825	.828
*All items on a 3-point scale, 1 = Not at all, 3 = Frequently		
<u>Positive Cross-Racial Interactions*</u>		
Alpha	*.897*	*.891*
Dined or shared a meal	.779	.746
Had meaningful and honest discussions about racial/ethnic relations	.762	.758
Shared personal feelings and problems	.825	.794
Had intellectual discussions outside of class	.814	.802
Studied or prepared for class	.710	.685
Socialized or partied	.730	.725
Attended events sponsored by other racial/ethnic groups	.618	.646
*All items on a 5-point scale, 1 = never, 5 = very often		
<u>Negative Cross-Racial Interactions*</u>		
Alpha	*.771*	*.762*
Had guarded interactions	.661	.670
Had tense, somewhat hostile interactions	.810	.795
Felt insulted or threatened because of your race/ethnicity	.721	.701
*All items on a 5-point scale, 1 = never, 5 = very often		

Hostile Racial Climate*

Alpha	*.682*	*.690*
I have been singled out because of my race/ethnicity, gender, or sexual	.698	.728
I have heard faculty express stereotypes about racial/ethnic groups in class	.657	.623
There is a lot of racial tension on this campus	.586	.610

*All items on a 4-point scale, 1 = Strongly disagree, 4 = Strongly agree

Sense of Belonging

Alpha	*.879*	*.882*
I see myself as part of the campus community	.790	.786
I feel I am a member of this college	.855	.872
I feel I have a sense of belonging to this campus	.884	.881

*All items on a 4-point scale, 1 = Strongly disagree, 4 = Strongly agree

Source: Cooperative Institutional Research Program 2004 Freshman Survey and 2008 College Senior Surveys

Table 1
Hierarchical Generalized Linear Modeling (HGLM) Results for all students, looking at main effects of race

	All Students (N = 3,668)		
Model #	1	2	3
Race Main Effects (Whites and Asians are reference group)		*Significant Effects?**	
Native American	No	No	No
Latino	Yes	No	No
Black/African American	Yes	No	No
*Blocks of variables included in the model***			
Other demographic characteristics (gender, mother's education)	X	X	X
High School Academic Preparation		X	
College Experiences			X
Baseline probability of STEM major persistence		0.63	

*Effect significant, p < .05
**See Table 2 for lists of variables in each block

Table 2

Hierarchical Generalized Linear Modeling (HGLM) Results for URM persistence in a Science, Technology, Engineering or Math (STEM) major

	URM students only (N = 1,634)			
	Log Odds	S.E.	Δ P	Sig.
Demographic Characteristics				
Native American	-0.16	0.25		
Latino	0.00	0.16		
Student's Gender	-0.08	0.16		
Mother's Education	0.04	0.04		
High School Academic Preparation				
Average High School Grade	0.08	0.06		
Math + Verbal SAT Score (in 100-point increments)	0.29	0.07	6.76%	0.00
Mathematics	0.08	0.14		
Physical Science	0.03	0.06		
Biological Science	-0.02	0.08		
Participated in Summer Research Program	0.16	0.19		
Other pre-college Characteristics				
Aspire to Master's Degree	0.06	0.21		
Aspire to PhD	0.01	0.27		
Aspire to Medical Degree	-0.46	0.23	-11.50%	0.04
Entering Science Identity	0.06	0.10		
TFS Academic Self-Concept	0.04	0.01	0.98%	0.00
TFS Social Self-Concept	-0.03	0.01	-0.81%	0.00
Concern about financing college education	0.14	0.12		
College Experiences				
Worked full-time while attending school	-0.39	0.18	-9.74%	0.03
Felt family support to succeed	-0.11	0.13		
Faculty Interaction factor	-0.27	0.09	-6.79%	0.00
Asked a professor for advice outside of class	-0.08	0.12		
Felt intimidated by your professors	-0.13	0.13		
Faculty feel that most students here are well-prepared academically	0.08	0.12		
Studied with other students	0.60	0.12	13.57%	0.00
Sense of Belonging	0.17	0.09		
Positive Cross Racial Interaction	-0.12	0.09		
Negative Cross Racial Interaction	-0.21	0.11		
Hostile Racial Climate	0.01	0.10		
There is strong competition among most of the students for high grades	0.14	0.09		
Felt overwhelmed by all I had to do	0.09	0.15		
Participated in an undergraduate research program (e.g.	0.80	0.22	17.38%	0.00

MARC, etc.)				
Joined a club or organization related to your major	0.40	0.14	9.32%	0.01
Worked on a professor's research project	0.19	0.12		
Institutional Characteristics				
Institutional Control (Private keyed higher)	0.39	0.32		
Institutional Type (4-year keyed higher)	0.07	0.27		
HBCU (HBCU's keyed higher)	-0.20	0.76		
Selectivity in 100-point increments	-0.52	0.12	-13.00%	0.00
Percent of students on financial aid (in 10-point increments)	-0.03	0.06		
Percent of students receiving federal aid (in 10-point increments)	-0.03	0.09		
Indicator of whether institution has any research expenditures (>$0)	-0.01	0.26		
Percent of students majoring in STEM (in 10-point increments)	0.23	0.06	5.57%	0.00
Percent of student body that is American Indian, Black or Latino	-0.06	0.10		
Log(Undergraduate FTE)	-0.10	0.18		
Intercept	-0.87	1.08		
Model Statistics				
Chi-square				
Intercept reliability	0.09			
Explained variance at level 2	0.694			
Baseline probability of STEM major persistence	0.58			

Figure 1: Proportion of students following through in first-year intentions to major in STEM after four years of college, by racial/ethnic group