Minority Students Severely Underrepresented in Science, Technology Engineering and Math

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Abstract

This study documents the system of funded interventions employed at three public universities to support minority students studying science and examines targeted students' career paths to discern the general efficacy of these interventions and other factors influencing success toward earning Ph.D.s. Interventions, including supplemental instruction, mentoring, laboratory experiences, financial assistance, graduate school preparation, as well as program management and infrastructure are assessed in relation to student academic progression. Various factors were able to explain over 40% of the variation in student progress toward Ph.D. program entry of biomedical science students. Students supported by these intervention programs at the three public universities studied demonstrated high graduation rates and Ph.D. entry rates. Knowing the impact of interventions and other factors enables universities and funding agencies to more effectively distribute their resources in supporting underrepresented minority students in pursuit of science careers.

Introduction

Minority students, Asians excepted, are severely underrepresented in the fields of science, technology, engineering, and math (STEM) at the national level in the United States [23], [25], 26]. Overall, these students encounter greater difficulties in obtaining undergraduate and graduate degrees [25] and typically take longer to graduate than their Caucasian and Asian peers. Furthermore, minority students enter college less prepared than non-minority students [4], 21]. Data from the National Science Foundation as of 2006 on underrepresented minorities (URMs) receiving doctorates in STEM fields is presented in Figure 1 below. The proportion of doctorates awarded to URMs lags far behind their representation in the general US population. Only 8.34% of the STEM doctorates awarded in 2006 were given to URMs, despite making up approximately 28% of the US population.

Furthermore, a report to Congress by the United States Government Accountability Office [36] noted that while the percentage of underrepresented minorities nationwide increased from 13% (1994-95) to 19% (2002-03), the total number of STEM doctorates awarded to the same group dropped during this period from 8,335 to 7,310.

In response to the chronic under-representation of minorities in the sciences, the National Institute of General Medical Sciences (NIGMS) created the Minority Opportunities in Research (MORE) Division and similar academic intervention programs. The amount of funds dedicated to these programs reflects the commitment of the MORE Division in addressing this problem. In 2007, NIGMS' annual budget was $1.9 billion, of which nearly $126 million was spent on its MORE programs [22]. This amount includes the Minority Biomedical Research Support-Research Initiative for Scientific Enhancement (MBRS-RISE) program, the Minority Access to Research Careers (MARC), Post-baccalaureate Research Education Program (PREP), and the Bridges to the Baccalaureate and Bridges to the PhD programs. The present study examined the components and the effectiveness of large MORE programs at three public universities which have been supported by a variety of NIH and NSF sources.

Background to the Study: MORE programs and Effective Interventions

The MORE programs are comprised of four primary components: research experience, mentoring and advisement, supplemental instruction and workshops, and financial support. Research experiences are the cornerstone

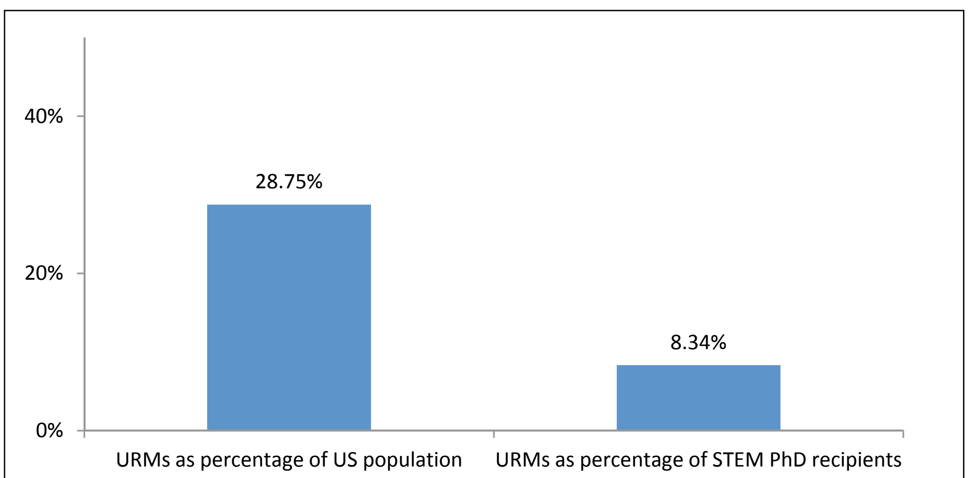


Figure 1. Underrepresented minorities as a percentage of the US population and of STEM doctorates recipients

of the MORE programs; all students work on-campus in faculty-run labs. Students are paid through these research placements, freeing them from having to take part-time work off campus. All research activities are supervised by faculty, who will also often serve as mentors and advisors for the students. There are also opportunities for students to take part in supplemental instruction sessions to complement their courses, and workshops related to career options, graduate study, and test preparation.

Research experience in the undergraduate years can be a means to encourage students to think of themselves as scientists [13], [31], and to aid students in solidifying career plans in the sciences [16], [15], [18]. Research was also found to be a positive predictor of a sense of "belonging" among URMs in Hurtado et al [14], who investigated the college transition experience of URMs in the biomedical and behavioral sciences. In examining summer undergraduate research experiences at four liberal arts colleges, Hunter, Laursen, and Seymour [13] reported that 92% of participating students reported gains stemming from the research experience, with a substantial proportion of those gains reflecting their ability to think and work like scientists. This finding was corroborated by a survey of the faculty advisors, who also observed large gains in those areas.

Beyond their impact on student perception, research experience can also have a profound impact on academic achievement and student retention. In their evaluation of the Biology Undergraduate Scholars Program (BUSP) at the University of California, Davis, an undergraduate research program targeted at URMs, Barlow and Villarejo [3] reported higher retention rates among program participants than those in the control group. Nagda et al [20] had similar results in investigating the impact of an undergraduate research program on student retention. In particular, they found that the research program benefited African-American students most strongly, especially those whose GPAs were lower than the median for all African-American students. Both Astin and Astin [2] and Wright et al [37] also found research experience to be positively associated with persistence, retention, and academic performance within STEM majors.

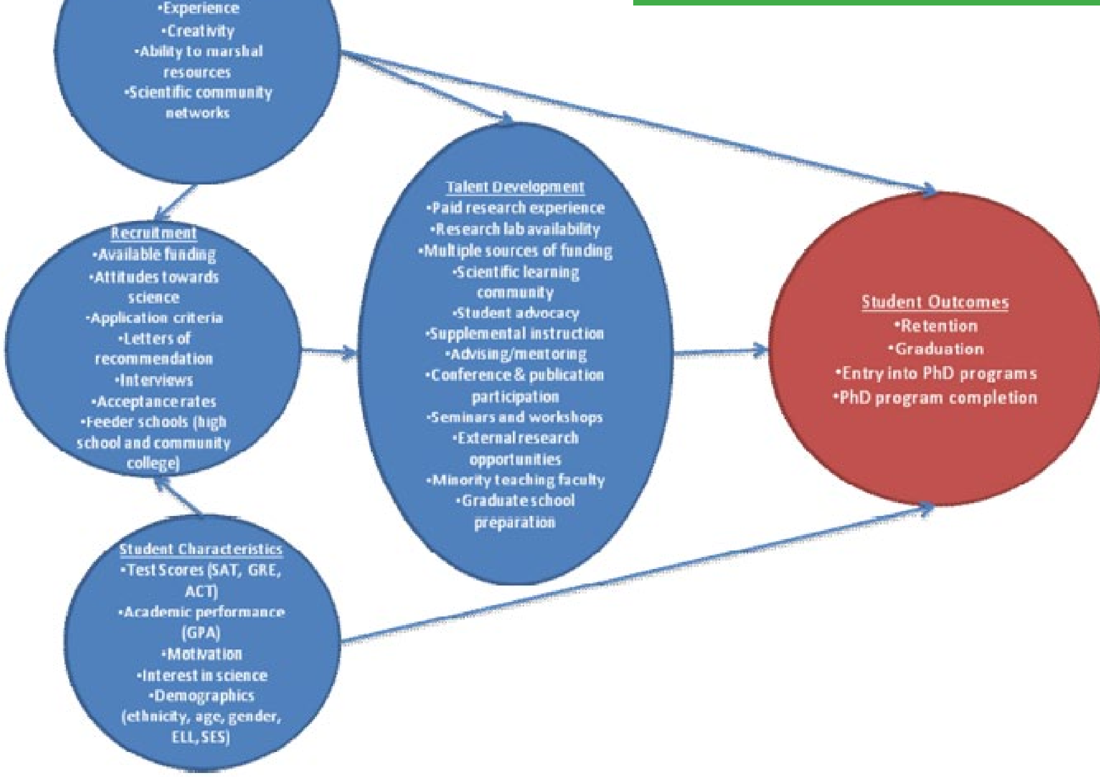
Multiple studies (e.g., [8], [10], [28], and others) stress the importance of student-faculty interaction on retention and student success. As with the research experiences themselves, relationships with faculty mentors can aid in the incorporation of students into the academic/scientific community. For minority students whose mentor is also a minority, that relationship can serve as a powerful reminder that the prevailing stereotypes of minorities in the sciences can be overcome [34]. Beyond retention, Hill, Pettus, and Hedin [12], analyzing three studies investigating minority attitudes towards science careers, found that the most significant factor in making science-related career choices was an acquaintance with a practicing scientist. Faculty mentors can fulfill multiple roles for students not just as teachers and research advisors, but also as role models and career inspirations.

The benefits of supplemental instruction are discussed in Peterfreund et al [29] and Rath et al [30], both of which examine the impact of the supplemental instruction on URM performance at San Francisco State University. Over a six year period, participants were found to be more likely to pass the corresponding courses than those who did not receive supplemental instruction [30]. Students who partook in supplemental instruction also demonstrated better progression through subsequent courses [29]. The impact of this intervention was particularly pronounced for URMs.

Financial support is of particular importance, given that while URMs are more likely to receive aid than their Caucasian or Asian peers, the aid they receive is on average less [24]. Hurtado et al [14] found that URMs were frequently impacted by financial and family pressures, and were likely to be more concerned with the ability to finance college. The National Science Foundation [24] reported that low-income students, which include many URMs, typically have $3,500 in unmet aid each year, which is often made up through part-time work. Gardner and Broadus [7], in investigating the factors related to retention in the engineering program at Michigan State University, reported that African American students on average worked twice as many hours outside the university to finance their education, which negatively impacted their studies as a result.

The importance of financial support notwithstanding, Fenske, Porter and DuBrock [6] studied the impact of aid on the retention of science and engineering students at a large public university and found that even the comparatively large aid packages granted to URMs are not sufficient to curb the attrition among this population. They cite the need for "…early intervention and orientation programs, and other academic and social support resources," (p. 85) to further promote retention and degree completion for underrepresented minorities. Supporting URMs

Figure 2. MORE Program Model



in the sciences requires more than just a financial investment; programs and interventions must be tailored to address the unique challenges they face.

In addition to the individual impact of each of the above interventions, of equal importance is the impact and interaction of multiple interventions and environmental factors regarding student outcomes. Research into similar programs containing multiple interventions demonstrates that the interactions between components are crucial to understanding the impact of the program as a whole. Astin [1] identified interaction between faculty and students as having a positive impact on student performance; however, the students' perception of their performance was often dependent on the type of faculty. Those faculty rated as more "student-centered" were associated with students having more positive perceptions of their academic performance, whereas faculty seen as "research-centered" were associated with negative perceptions. Gilmer [9] also examined a multiple-component STEM education program, and found differing levels of impact for each of the program components. The Summer Bridge component for incoming freshman, for instance, was found to have a substantial impact on academic performance.

The primary focus of the majority of research into the effectiveness of interventions has been academic performance and student retention [2], [3], [8], [11], [32]. While retention is indeed of vital importance with respect to increasing the number of underrepresented minorities entering the STEM fields, it is not the only consideration. Of equal, if not greater, importance is the ability of interventions to propel URMs beyond undergraduate study into master's and PhD programs, and ultimately into careers as research scientists. Some studies (e.g. [3], [17], [19]) do examine the impact of undergraduate research programs on graduate program entrance with positive results; however, more research is needed in order to develop a more comprehensive model of those factors that influence the entrance of URMs into graduate study and beyond. To address that need, Slovacek et al. [33] developed a model relating student outcomes to specific interventions, student characteristics, university recruitment strategies and program leadership. That model is reproduced above and serves as the theoretical basis for the current study.

Methodology

Previous research strongly suggests that research-based interventions like the MORE programs can have a positive impact on student achievement. The current need is for research investigating the impact of multiple, simultaneous interventions on their target populations. Studying multiple interventions not only better mimics the academic environment that many underrepresented minorities exist in, but will allow institutions to better leverage resources and curricula to increase student success. Furthermore, a shift in emphasis away from research regarding student retention and towards student entrance into and success in PhD programs would provide institutions with information regarding the more long-term impacts of their programs. To that end, the current study is concerned with the following research question:

What program interventions and other factors contribute the most toward underrepresented minority college students' progress in biomedical fields toward earning their Ph.D.s?

Participants

The participants in this study were drawn from three public universities: California State University, Los Angeles (CSULA), New Mexico State University (NMSU) and San Francisco State University (SFSU). The current study involved the participation of 430 undergraduate and graduate students enrolled at the three universities and funded by at least one of the MORE programs. Data was initially to be collected on all MORE students enrolled at the three universities between 2004 and 2007, though some students were excluded due to opting out of the data collection process. Table 1 provides the breakdown of students by institution and student status.

Both CSULA and SFSU are part of the California State University system and offer both undergraduate and master's level programs. NMSU offers programs up to and including the doctoral level, and all three serve large populations of minority students. These three universities were selected because of their capacity to sustain funded support programs for minority students in the biomedical fields during the past 15 to 35 years and for their ability to successfully prepare students for doctoral studies. To test the overall impact of the MORE logic model (see Figure 2 above), Slovacek et al. [33] found that in 2005-2006 87% of graduates from the MORE programs continued on to an advanced degree program (PhD, MD, or MS), with the majority opting to begin work towards a PhD.

At the time the data were collected, the students in the study had a median age ranging from 26 to 30 at the three institutions, (average age was 27). The majority (60%) was female, and largely Hispanic (42%) though there were significant minorities of Pacific Islanders, African American and Native American students.

All participants were students supported through NIH MORE funded programs. Students could participate in more than one MORE program over the course of their time at the institution (the average number was 1.5 funding programs for the whole set of participants), and many graduate students had received funding from MORE or similar programs as undergraduates as well.

Data Collection

Data collection consisted of two stages. The authors first collected information on students' backgrounds, demographics and academic history, and program participation. The second stage focused on students' current highest level of education, as well as applications and entrance into PhD programs.

Data on student background demographics, interest in the sciences, motivation, participation and experiences in the various MORE program interventions was collected from a series of surveys taking place between 2005 and 2007. Specifically, the project employed the following surveys to gather student information:

- Three student surveys
- Institutional student portfolios with student

		Institution		
	Total	**SFSU**	**CSULA**	**NMSU**
Bridge students from a community college	**28**	0	0	28
Undergraduates from the institution	**198**	73	50	75
Post-baccalaureates	**29**	24	5	0
Graduate students	**175**	70	74	31
Total	**430**	**167**	**129**	**134**

Note: Graduate students at NMSU include individuals in both master's and doctoral programs.

Table 1. Breakdown of Students in the Study by Institution and Student Status

background data from university records

- Two surveys of the students' faculty research advisors

Information on student degree status and academic achievement was acquired from both institutional records kept at each university as well as records from each of the MORE program offices. All surveys and forms were developed by the research team expressly for this project, drawn from the case studies, previous evaluative surveys, and other work performed prior to the receipt of the grant. As per Institutional Review Board requirements, only students from whom consent forms were obtained are included in the studied database. A summary of the data collected through each instrument can be found in Table 2.

The types of questions asked on each of the three student surveys varied depending on the time at which they were administered; the 2005 Fall Survey focuses on background information while the 2006 Spring Survey focused more on end-of-year reflections. The 2007 Spring Survey was designed to include information from both the previous Spring Survey as well as the Fall Survey. Response rates for each of the surveys varied by campus, and most students supplied unique identifiers which allowed surveys to be linked across administrations while preserving anonymity.

Students' research advisors (generally faculty members who ran the labs in which the students worked) were also surveyed to gather their opinions regarding students' ability to obtain an advanced degree, as well as to reflect on their experiences working with the students in a research setting. The background data form collected data on participation in specific MORE interventions, conference attendance and journal publications, as well as their history in attending institutions of higher education.

Updates regarding students' current level of education and progress towards a PhD were made through each of the MORE program offices. Information included graduation dates, the highest degree attained, whether the student had applied or been accepted into a graduate degree program. Variables included status towards each type of degree (baccalaureate, Masters, PhD) and whether or not the student was still pursuing education in the sciences.

Data from all surveys was combined with that from institutional and program records to create a single dataset. Survey data was updated as necessary using unique student identifiers, and in the case of questions asked over multiple surveys, preference was given to the most recent data. The resulting dataset contained 430 students funded by the MORE programs. Variables were then organized into four groups corresponding to the four factors outlined in Figure 2 above.

Analysis

To facilitate analysis, a single outcome variable was calculated, coded as follows:

0: The student does not plan on getting a PhD

Instrument	Date	Students completing			Student characteristics			Research interventions		Academic indicators			Other
		CSULA	SFSU	NMSU	Gender	Ethnicity	Pre-institution history	Program support	Research activities	Course completion	GPA	Standardized test scores	Success toward Ph.D.s
Student Survey	Fall 05	38	52	49	✓	✓		✓	✓		✓		✓
Student survey	Spr 06	47	80	29	✓	✓		✓	✓		✓		✓
Student survey	Spr 07	67	32	60	✓	✓		✓	✓		✓		✓
Institutional portfolio	Spr 07	103	120	123	✓	✓	✓	✓	✓	✓	✓	✓	
Background data form	Spr 06	64	101	53	✓	✓	✓	✓	✓	✓	✓	✓	
Institutional portfolio	Spr 07	86	56	122	✓	✓	✓	✓	✓	✓	✓	✓	
Research advisory survey	Spr 06	53	34	30				✓	✓				✓
Research advisory survey	Spr 07	41	25	36				✓	✓				✓
Student Degree Status and Progress	Wint 08	107	128	101									✓

Data Categories Collected

Table 2. Summary of Survey Instruments and Respondents

Variable Block	Variables	Significant within block	In Final Model
Student Characteristics	Student Status (i.e. year in college)	Yes	Yes
	GPA prior to receiving support	Yes	Yes
	Determination to obtain an advanced degree	Yes	Yes
	Time spent on outside job	Yes	No
	Age	No	No
	Gender	No	No
	Years of undergraduate education	No	No
	Supporting others (i.e. family)	No	No
	English language learner	No	No
Talent Development (Interventions)	Number of years funded by MORE	No	No
	Participation in specific MORE interventions	Mixed (see below)	No
	Number of programs giving funding	No	No
	Mentoring and advisement participation and rating	Mixed (see below)	Mixed (see below)
	Research Activities	Mixed (see below)	Mixed (see below)
Leadership	Years of program director leadership	No	No

Table 3. Variables by Block

(includes both current students and graduates)

1: The student plans on getting a PhD, but has not entered a doctoral program

2: In the process of completing a doctoral program,

3: Completed a doctoral program.

The variable was designed as such to include both students who had sufficient time over the research period to graduate from their respective programs and enter PhD study, and those who have not yet finished their programs at the three participating universities.

Multiple linear regression analysis was performed using the above dependent variables to determine which variables most strongly predicted the planning of, acceptance into, and completion of a PhD program in the biomedical sciences. To test the model shown in Figure 2, independent variables were first organized into three of the four major blocks of the MORE model: Talent development, Student characteristics, and Leadership/philosophy as discussed above. Variables related to the fourth block, Recruitment and Intake, were not collected during this phase of the study. Stepwise regression was then performed in each block separately to determine which variables within each block contributed most to the variance in the outcome variable. Variables were entered into the regression model provided the F-ratio was significant at the .05 level, and removed if the F-ratio significance level rose above .10. A second stepwise regression was then conducted containing only those variables which had been significant in each block, again using the same criteria for entrance and removal. After determining which variables were no longer significant predictors in this second model, a third and final linear regression was performed using only those variables which were significant at the .05 level in both previous models. Table 3 gives the variables used in each block, as well as whether it was significant within its block and whether it was retained in the final regression model. In all three models, missing cases were removed from the analyses via pair-wise deletion of variables for subjects with missing data.

There were a number of variables which coded participation in each of specific interventions, as well as mentoring and advisement and specific research activities. Some of the variables within these groups were significant within their block, though none of the variables related to participation in specific interventions were retained in the final regression model. The results section below details the variables included in the final model.

Results

The final regression model contained seven variables among two blocks. Table 4 below displays these variables by block. Within the talent development block, three of the mentoring variables, (having a mentor, receiving aid from that mentor in applying for graduate school, and having a faculty member who helped deal with university issues), and one of the research activity variables (participating in communicating research to others) were significant predictors of the outcome variable. Likewise, a student's own rating of their determination to obtain an advanced degree, their GPA prior to receiving funding, and their student status were also significant predictors.

Standardized and unstandardized beta weights, along with t-scores and significance levels for each of the variables in the regression model are given below in table 5.

Given that all variables were significant at the $p < .05$ level, it is unlikely that their status as predictors is due to chance or sampling error. Note that all variables were positive predictors of the outcome variable, with the exception of having a faculty member who helped with university issues.

Table 6 details the results of the regression analysis as each block was entered into the

Block Name	Significant Variables
Student Characteristics	• Student determination to obtain an advanced degree • Undergraduate GPA prior to funding • Student status
Talent Development	• Having a research mentor • Aid from mentor in applying for graduate school • Research activities – communication of research • Faculty Member Helped with University Issues

Table 4. Predictors by Block

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	-2.506	.554		-4.524	.000
Student Determination to Pursue an Advanced Degree	.176	.081	.171	2.180	.032
UG GPA Before Funding	.270	.122	.176	2.210	.029
Student Status	.124	.033	.302	3.734	.000
Mentor - Applying for Grad School	.300	.129	.195	2.320	.022
Faculty Member who Helps with University Issues	-.254	.122	-.164	-2.075	.041
Research Activities 1 - Research Communication	.715	.271	.213	2.641	.010
Research Mentor - Participation	.783	.234	.265	3.351	.001

Table 5. Coefficients

Block	R	R Square	Adjusted R Square	Std. Error of the Estimate
Student Characteristics	.527	.278	.257	.666
Talent Development	.668	.447	.407	.595

Table 6. Model Summary

model. At the final step of the model, the adjusted R2 was .407, meaning that the adjusted model was able to account for approximately 41% of the variance in the outcome variable.

Discussion

The independent variables in the regression model indicate several important factors in increasing the likelihood of a student pursuing a PhD. The first is that while all MORE program students are required to participate in some form of research, certain activities have a greater impact than others in motivating and preparing a student towards doctoral graduate study. In our analysis, students who participated in communicating their research experience and findings through a poster or a talk at a conference were more likely to plan on and pursue PhDs. This is perhaps not surprising as this sort of activity is precisely what students know will be expected of them in graduate doctoral studies. Secondly, having a faculty member act as a research mentor to guide the student through the research experiences made a significant impact on student outcomes. While having a mentor itself was clearly important, being able to use the mentor as a source for information and advice regarding applying for graduate school was also a strong indicator of student success.

Another related variable in the interventions block was having a faculty member who helped students navigate university-related issues and challenges. This would include cutting through "red tape," for instance regarding registering for classes, receiving promised financial aid checks, and generally dealing with the type of bureaucracy found at universities. This variable contributed negatively to the regression; its presence was more strongly associated with those students who chose not to pursue PhD study. This result suggests that those students who encountered such serious issues that they needed help from a faculty member to resolve were less likely to plan on or pursue a higher degree.

In addition to the MORE program interventions, a student's own determination to obtain an advanced degree proved to be a strong predictor of PhD study. This is promising in that among the goals of the MORE programs, and of many academic interventions, is increasing that determination. However, that goal is based on the assumption that individual determination is in fact correlated with future success, which this analysis shows to be the case. Two additional variables in the regression model reflect this determination: academic background and current level of education.

The students' undergraduate GPA prior to entering the MORE program played a role in predicting eventual PhD study, and likely serves as an indicator for those who are academically successful enough to get into doctoral programs in the biomedical sciences. The student status variable encodes the current educational status of each student (years of undergraduate and graduate study), and is used in this analysis as a form of control with respect to time. The time limitations of the data collection were such that it was not possible to allow time for all students involved in the study to have the opportunity to apply for and complete a PhD. Therefore the student status variable serves to control for those students who remained undergraduates at the last time of data collection, and hence were not yet eligible for PhD study.

Excluded Variables

Given that the database used in this analysis included approximately 200 unique variables, of which only seven remained in the analysis, some mention should be given to those excluded variables. Among the variables not found to be significant predictors of PhD study were age, ethnicity (all the participants were underrepresented minorities), parents' educational background, having to provide support to family members while in school, working outside of school, standardized test scores (SAT, ACT, GRE, and AP credits), and several other MORE interventions. Reasons for exclusion varied. While it is certainly the case that some variables simply had no impact on students' plans, others may have been excluded due to multicollinearity or a lack of variance in response. All students involved in the analysis were funded by MORE or similar programs, and therefore most would give similar responses to, for instance, variables relating to participation in MORE program interventions. Participation in research, for example, was answered in the affirmative by nearly all of the 430 students in the analysis, and as such was of limited use in the analysis.

The final reason a variable might have been excluded from model was an excessive number of missing values. While the response rate on the combined survey data was generally favorable, approaching 85%, data on academic characteristics collected from university records were more sparse. In particular, values for standardized test scores were not well accounted for in the final database, thus limiting the predictive power of those variables.

Further Research

The authors concur with the recommendations in the NIGMS white paper addressing MARC programs [27] suggesting that more research is needed to better understand the effectiveness of interventions. The next logical step in the research based on these findings is to conduct a longitudinal study of these students and graduates, tracking their progress in graduate studies at the doctoral level and through their careers as scientists. The current study was limited in scope to the years for which data were available; this meant there was an insufficient amount of time to longitudinally track the majority of students as they earned their baccalaureates and pursued, then completed, an advanced PhD. degree. A study which examines students as they begin their studies within MORE funded programs and follows a cohort(s) to the completion of PhD study would yield more thorough evidence regarding the effectiveness of research interventions than this study is capable of offering. Although there have been numerous publications that address the issue of a lack of under-represented minority students pursuing or completing advanced degrees [5] few research studies have been conducted on the career paths of those who have earned advanced (doctoral) degrees in the biomedical sciences. Such research of underrepresented minorities on PhD. holders would be a step forward. The research team is currently conducting a resume analysis [35] of over 100 MORE RESULTS students who have completed their doctorates in order to better understand their career arcs.

A final suggestion for broadening this line of research would be to include more universities and colleges that provide support programs in the sciences for under-represented minority students. This would enhance the generalizability of this work.

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