Longitudinal Analysis of a Diversity Support Program in Biology: A National Call for Further Assessment

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National calls to improve the performance and persistence of students from historically underrepresented backgrounds in science have led to a surge of research on inclusive, evidence-based teaching methods. Less work has revealed the effects of diversity support initiatives that improve campus climate and community cohesion. Here, we examine whether participation in the Biology Scholars Program (BSP) at Cornell University—a diversity support program at a prominent university—affects underrepresented racial minority (URM) student performance. We found that BSP participants are less academically prepared when they enter college but typically have GPAs similar to those of their non-BSP counterparts at graduation, thereby closing achievement gaps. Although the BSP appears to help URM students, we cannot assert that the BSP alone is responsible for these effects; future work should isolate effective strategies that contribute to student success. In response to these results, we lay out strategies that support programs could implement to maximize positive impacts.

Keywords: STEM equity, science diversity program, Biology Scholars Program, minority students

Minority demographics are underrepresented in science, technology, engineering, and mathematics (STEM) disciplines (Landivar 2013), highlighting the need for effective approaches that promote and retain student diversity (Brewer and Smith 2011). Underrepresented racial minority (URM) students in the United States include African American, Hispanic, Pacific Islander, and Native American undergraduates, and each demographic faces significant inequity before and when entering university. Social challenges that disproportionately affect URM students include transitioning to college (Cooper et al. 2005), feelings of exclusion (Hurtado and Ruiz 2012), stereotype threat (Steele 1997, Cohen and Garcia 2008), and discrimination (Milkman et al. 2015). Within the classroom, URM students are more likely to struggle in large introductory science classes (Alexander et al. 2009) because of inadequate high school preparation and limited opportunities to interact with instructors (Hurtado et al. 2011). A negative learning environment can undermine self-efficacy, which reduces the number of URM students who enter STEM majors and complete a STEM degree (Olson and Riordan 2012). The gap in demographic representation widens as students progress through the STEM pathway and enter the workforce. For example, although 10.8% of the total workforce in the United States was black or African American in 2011, they held only 6.4% of STEM jobs. Similarly, 14.9% of the total workforce identified as Hispanic or Latino, but they held only 6.5% of STEM jobs (Landivar 2013). Initiatives supporting URM students in higher education therefore require creative practices rather than the replication of past practices that have yet to achieve the desired goal of improving racial and ethnic diversity in STEM.

One way that many campuses have tried to promote and retain URM students in STEM is through diversity support programs that focus on aspects of student life outside the classroom. Although few URM support programs have identified specific strategies that improve student performance or other quantitative metrics of success, a handful of programs have been successful in their efforts to support URM students in STEM (Gándara and Maxwell-Jolly 1999, Cota-Robles and Gordan 1999, Matsui et al. 2003, Barlow and Villarejo 2004, Summers and Hrabowski 2006, Buchwitz et al. 2012). The overall lack of quantitative studies on diversity support programs in STEM could be due to low numbers of participating students, unfavorable results, or the inability to disseminate their data to the wider scientific

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community. Regardless, in order to clarify positive strategies, institutional programs should rigorously and regularly self-assess student performance in a manner consistent with the way STEM researchers address their own scientific questions.

Here, we analyze a longitudinal data set of students enrolled in the biological sciences at Cornell University between fall 2008 and fall 2015. We compare performance metrics among non-URM and URM students who either participated in an institutional support initiative or did not. The Biology Scholars Program (BSP) is an undergraduate program based out of Cornell University's Office of Undergraduate Biology in collaboration with the College of Agriculture and Life Sciences and the College of Arts and Sciences. The program's mission is to increase the satisfaction, retention, and graduation of historically underrepresented students in the biological sciences and to promote the value of educating a diverse population of students in the sciences.

To assess the impact of the BSP at Cornell University, we evaluated the preparedness and performance of students who varied in their URM status and whether they participated in the BSP program using three metrics: (1) SAT scores, (2) cumulative GPAs, and (3) graduation rates. Thus, we use a quantitative approach that is modified from Matsui and colleagues (2003) to examine the variations in both preparedness and performance among biology students at Cornell.

The research participants

We gathered a longitudinal data set that spans 15 semesters from fall 2008 through fall 2015. We compared the academic performance of 3159 students distributed among four groups: (1) non-URM non-BSP (n = 2221; "the majority"); (2) non-URM BSP (n = 51; including low-socioeconomic-status or first-generation college students); (3) URM non-BSP (n = 706); and (4) URM BSP (n = 181). We considered participants of the BSP students who are either currently active members or those who remained in the program for at least four semesters; we removed 50 students because they did not fit these criteria. Through follow-up surveys with students who left the BSP, we found two emerging reasons students leave the program: because they decided to pursue a nonscience career path or because the BSP was too large of a time commitment. All students who were included in the analysis were intended biology majors or those who stated in their admissions application that they intend to study the fundamentals of biology and declare a concentration in one of the following: animal physiology; biochemistry; computational biology; ecology and evolutionary biology; genetics, genomics, and development; insect biology; marine biology; microbiology; molecular and cell biology; neurobiology and behavior; human nutrition; plant biology; or systematics and biotic diversity. Of our entire student population who graduated, 41% of all students who entered the biological sciences graduated with a bachelor of science (n = 615), and 59% graduated with a bachelor of arts (n = 877).

All experimental procedures on the participants were approved by Cornell's Institutional Research Board for human participants (protocol no. 1410005010). Anonymized data are accessible through the DRYAD digital repository.

Program description

Between 2008 and 2015, 925 of 3199 students enrolled in biological sciences at Cornell described themselves as URM (29% of the students). Of those URM students, 24% participated in the BSP, representing 7% of all Cornell biology majors. From data available between 2009 and 2015, 244 students were accepted to participate in the BSP out of a pool of 599 applicants (41%) entering biological sciences at Cornell. Prior to the program's conception, the university did not provide any unique support to historically underserved students. In response to a national call to action led by the Howard Hughes Medical Institute in 2005, teams of administrators from a number of universities across the country met to discuss the state of the nation's historically underserved student populations and to generate new ideas on how to better support them. Following that meeting, the group that attended from Cornell met regularly in order to develop what became the BSP, including an onsite visit to the Meyerhoff Scholars Program at the University of Maryland, Baltimore County. Therefore, the BSP was conceived in an effort to promote and retain URM students within the sciences, with the ultimate goal of diversifying the STEM workforce. The program is institutionally funded out of the provost's office at Cornell.

According to personal communication with program directors (Jeff McCaffrey, Bonnie Comella, Office of Undergraduate Biology, Cornell University, personal communication, 12 November 2016), incoming URM students who intend to major in biological sciences are eligible for the BSP, which serves students primarily from economic, gender, ethnic, or historically underrepresented cultural groups and first-generation college students. In the summer prior to matriculation, all incoming freshman biological sciences majors are notified about the BSP and must apply by the end of August. The program strongly encourages applicants from Cornell's pre-freshman Summer Program. The online application consists of questions and essays that help the BSP selection committee choose students who will be a good fit with BSP. The students begin the program after university matriculation in mid-September. The BSP selection committee comprises staff from the Office of Undergraduate Biology and from each of the two Cornell colleges that support biological sciences majors. The committee looks for applicants who may need academic support, and those who are able to demonstrate a commitment to diversity in science are also eligible for the program (Jeff McCaffrey, Office of Undergraduate Biology, Cornell University, personal communication 10 November 2016). Approximately 35 freshmen are accepted into the BSP each year, and they remain members as long as they meet the program's expectations and continue on a science-related career path.

Activities that characterize the BSP take place in the first four semesters, and participation is voluntary. These include the following:

Academic monitoring and support through participation in study groups. Biology Scholars are required to attend a weekly, 2-hour study group for biology, chemistry, physics, or math courses through their sophomore year. Final grades in science and math courses are monitored by program coordinators, and support is provided to any struggling students. Program coordinators are notified if struggling students perform poorly on an exam. Following the notification, the coordinators contact the students to check on them, make sure that the students know what resources are available to them (e.g., the Learning Strategies Center and tutoring through the College of Arts and Life Sciences), and develop a plan to help the students improve their study habits. The BSP study group leaders are also notified so that they can focus their efforts on struggling students.

Leadership development. The leaders of the study groups described above are BSP members who received high grades in the courses they tutor. They are required to attend weekly training sessions in which they discuss that week's study group experience and mentor more junior study group leaders or are provided guidance by more senior study group leaders. BSP members may also serve on the BSP Executive Board. Approximately half of the students continue to serve in some leadership capacity within the BSP after the first 2 years of support, but this varies dramatically depending on the cohort.

Interaction with faculty. Biology Scholars are required to participate in two one-credit seminar courses in their first and second years, in which they meet and work with faculty to learn how to interpret and articulate scientific literature. During this time, the students may tour labs and are encouraged to pursue undergraduate research. Because we do not know the number of students who engaged in an authentic research experience as part of the BSP, we do not know the impact of this experience on GPA or the probability of graduating.

Career and professional development. The seminars also provide information about medical and graduate school and advice for pursuing medical degrees. For example, the BSP offers trips to visit graduate and medical schools, as well as financial support to attend off-campus science-related conferences.

Sense of community. The students are required to participate in community service and social events each semester and have access to a study space housed within the Office of Undergraduate Biology. Required activities for BSP participants only go through the first four semesters, and continuation in the BSP is voluntary.

The effect of underrepresented racial minority status and Biology Scholars Program participation on academic performance

We used generalized linear models to quantify differences among the four previously described student groups with respect to three metrics: combined math and verbal SAT scores, cumulative GPAs at graduation or at the time of data collection, and graduation rates. We constructed a generalized linear model with a Gaussian distribution to quantify the main and interactive effects of URM status and participation in the BSP program on combined SAT scores and cumulative GPA. We calculated a marginal R^2 value for our generalized linear models as an indicator of model fit and variance explained (Nakagawa and Schielzeth 2012) using functions in the MuMIn package (Bartoń 2009). We urge readers to exercise caution in comparing R^2 values for generalized linear models across studies, however, because substantial variation in methods for generating these summary statistics and their underlying assumptions preclude widespread generalizations (Nakagawa and Schielzeth 2012, Johnson 2014). We also computed the least-square means among all four groups to determine the statistical significance of each pairwise comparison. To examine variation in the graduation rates among the groups, we determined whether each student graduated from the university and modeled this binary response variable with a logistic regression using the same predictor variables: URM status, BSP participation, the interaction effect between these two factors, and combined SAT scores. We also calculated a marginal R^2 value for this logistic regression of graduation rates (Nakagawa and Shielzeth 2012).

The effect of underrepresented racial minority status and Biology Scholars Program participation on academic preparedness and performance

Comparing the incoming SAT scores of the URM BSP students and the URM non-BSP students by computing the least-squares means revealed a significant difference between each student group (figure 1a, table 1). The non-URM non-BSP students had the highest combined SAT scores (mean [M] = 2167, standard error [SE] = 3.32), followed by the non-URM BSP students (M = 2033, SE = 22.04), the URM non-BSP students (M = 1967, SE = 5.94), and the URM BSP students (M = 1885, SE = 11.25). Computing the least-squares means for each of the four groups revealed statistically significant differences in mean cumulative GPAs (figure 1b, table 1). We found that the cumulative GPAs of the non-URM non-BSP students (M = 3.49, SE = 0.01) and the non-URM BSP students (M = 3.44, SE = 0.07) were significantly higher than those of both the URM non-BSP students (M = 3.04, SE = 0.02) and the URM BSP students (M = 3.10, SE = 0.03). There was no statistically significant difference in least-squares means between the non-URM non-BSP students and the non-URM BSP students nor between the URM non-BSP students and the URM BSP students.

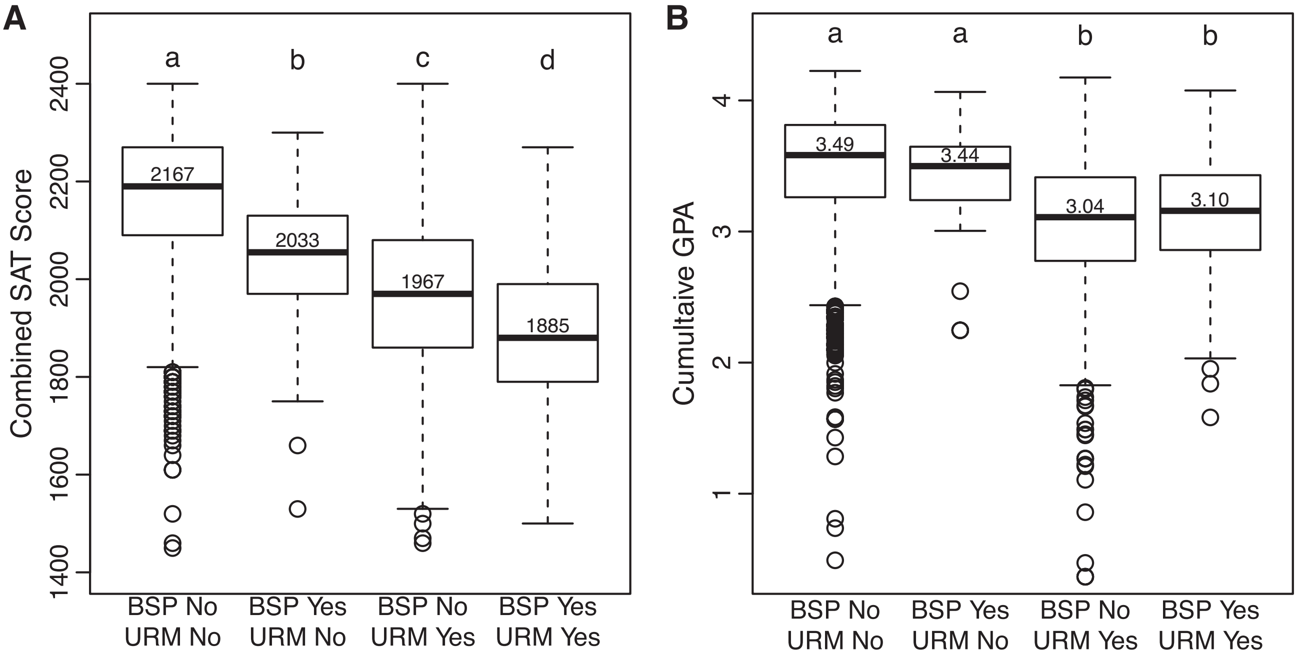

Figure 1. Differences in preparedness as estimated with the (a) combined SAT scores and (b) cumulative GPAs among students who varied in minority status and participation in the Biology Scholars Program (BSP). The mean values are shown for each group above the median bar in the bar plot. The outliers are shown as circles. The significant differences in pairwise comparisons of least-squares means estimates are shown above each box plot. Abbreviation: URM, underrepresented racial minority.

Within our generalized linear models, we found a significant effect of URM status ($ß_{URM}$ = −0.45, t = −21.99, p = 8.57 × 10^{-100}) on cumulative GPA. BSP participation ($ß_{BSP}$ = −0.05, t = −0.75, p = 0.45) and the interaction effect between BSP participation and URM status were not significant ($ß_{URM \times BSP}$ = 0.11, t = 1.42, p = .16). The marginal R^2 value for this model was .15. We found a significant effect of URM status ($ß_{URM}$ = −0.87, z = −3.67, p = 2 × 10^4) on the probability of graduation with a degree. BSP participation ($ß_{BSP}$ = 13.65, z = 0.025, p = .980) and the interaction effect between these two predictor variables ($ß_{URM \times BSP}$ = −13.65, z = −0.024, p = .981) were not significant. The marginal R^2 value for this model was .49. These results suggest that there is a decrease in the probability of graduation for the URM students but that there is no statistically significant difference among the URM students who participate in the BSP program and those who do not.

The effect of incoming preparedness on academic performance

When we included SAT scores as an index of incoming preparedness in our generalized linear models, we found a significant effect of SAT score ($ß_{SAT}$ = 1.02 × 10^{-3}, t = 17.658, p = 3.37 × 10^{-66}) and URM status ($ß_{URM}$ = −0.24 × 10^{-3}, t = −10.20, p = 5.53 × 10^{-24}) on cumulative GPA (figure 2). BSP participation ($ß_{BSP}$ = −0.24 × 10^{-3}, t =1.42, p = .156) and the interaction effect between URM status and BSP participation ($ß_{BSP \times URM}$ = −0.03, t = 0.426, p = .670) were not significant predictors of cumulative GPAs when SAT scores were included in the model. The marginal R^2 value for this model was .23.

When we included SAT scores in our logistic regression of graduation probability, we found that SAT score was the sole statistically significant predictor of graduation probability ($ß_{SAT}$ = 2.30 × 10^{-3}, z = 3.11, p =.002). The remaining predictor variables, including URM status ($ß_{URM}$ = −0.484, z = −1.64, p = .10), BSP participation ($ß_{BSP}$ = 0.14, z = 13.93, p = .981), and the interaction effect between these two predictors ($ß_{BSP \times URM}$ = −13.02, z = −0.02, p = .982) were not statistically significant. The marginal R^2 value for this model was .50.

Conclusions

Recent calls to action urge educators and institutions to increase the retention and performance of all students in STEM fields (e.g., Brewer and Smith 2011). Our longitudinal study adds to a growing body of literature that highlights the need for national efforts to quantitatively assess diversity support programs and institute effective practices. After URM students participated in the BSP program at Cornell, we found that the statistically significant gaps in academic preparedness among the URM students closed in terms of actual academic achievement. However, BSP participation does not improve the GPAs of URM students beyond those

Table 1. Results from generating least-squares means to compare the incoming SAT scores and cumulative GPAs of students who differ on the basis of their racial minority status and their participation in Cornell's Biology Scholars Program.

	URM				Non-URM			
	BSP (*n* = 181)		Non-BSP (*n* = 706)		BSP (*n* = 51)		Non-BSP (*n* = 2221)	
	Mean (M)	Standard error (SE)	M	SE	M	SE	M	SE
SAT score	1885.33	11.25	1967.01	5.94	2032.95	22.04	2166.85	3.32
GPA	3.10	0.03	3.04	0.01	3.44	0.07	3.49	0.01

Abbreviations: URM, underrepresented racial minority; BSP, Biology Scholars Program participant.

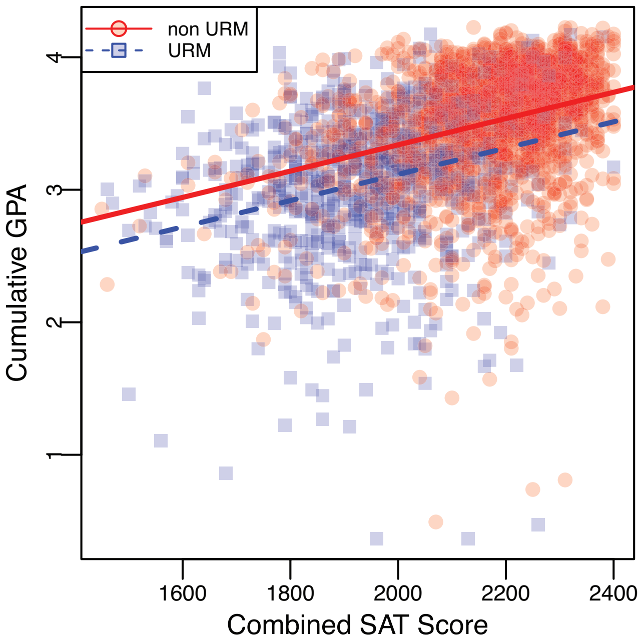

Figure 2. A scatterplot of combined SAT score and cumulative GPA, which shows a positive correlation between these two metrics. The red circles and the red dotted line represent non-URM students, whereas the blue squares and the blue dotted line represent URM students.

of nonparticipants. Future research should identify which strategies among diversity support programs contribute most to URM student success.

We acknowledge one limitation to this study could be the self-selection of high-performing students to the BSP, because more motivated students may be more likely to apply to such a program. However, participation in the BSP program did not affect graduation rates. Furthermore, when we included SAT scores as a measure of incoming preparedness in our model, we found that SAT scores and URM status strongly predict GPA at graduation. SAT score was also the sole positive predictor of student graduation rates.

Changing strategies. The persistent performance gap between URM and non-URM students highlights the importance of implementing specific strategies that promote URM demographics. Measuring a range of programs in thoughtful and deliberate ways will allow us to identify the most effective approaches. Institutional support programs that have quantitatively assessed student performance offer points of comparison but also differ widely in their approaches to supporting students. To further support URM students, Cornell University's BSP plans to experimentally implement a number of new evidence-based strategies. In addition to an annual quantitative assessment using the data presented here as a baseline comparison, the BSP will implement multiple approaches that are described below. These actions were chosen on the basis of their success in other programs that improved the academic performance or other relevant metrics for URM participants.

One experimental strategy will be to increase student engagement with research opportunities for undergraduates. Although the BSP currently encourages students to conduct research, students may be more willing to pursue these opportunities if they are financially supported to do so or are given directed research credits. Research experiences place students in the middle of ongoing research in active laboratories on campus (Matsui et al. 2003, Villarejo et al. 2008, Maton et al. 2012, Olson and Riordan 2012, Hernandez et al. 2013). Through research opportunities, students are exposed to the process of discovery through an authentic project and engage with professors and graduate students. This strategy may lead to publications, presentation opportunities, and other activities that serve as important steps in building a CV and academic confidence for students. This also places students in close proximity to faculty, who serve as important role models and collaborators. Hernandez (2013) showed in a longitudinal analysis of interventions across 38 institutions that the single most effective strategy that significantly contributes to the positive academic motivation of minority students was engagement in undergraduate research.

Another common strategy employed by successful programs—and one that Cornell's BSP will implement starting fall 2016—is student guidance through mentorship by graduate students and faculty. Mentors can be people with whom students develop supportive relationships and from whom they receive professional advice throughout their undergraduate career. Positive role models and regular contact with faculty are considered key experiences in higher education associated with student retention and development (Wilson et al. 2012, Epstein et al. 2015), including degree aspirations (Kim and Sax 2009), potential for degree completion (Newman 2011), and academic performance (Kim and Sax 2009).

Finally, the BSP will incorporate established learning theory into practice. For example, the BSP plans to extend programming to include juniors and seniors, with a focus on the continued use of collaborative learning with peer groups (Toven-Lindsey et al. 2015). In this scenario, we expect increased motivation and persistence through elements of social constructivism, in which learning happens through social interactions with others (Au 1998). Beyond quantifying persistence and performance, an appropriate assessment tool for the BSP to quantify the effects of extended programming on motivation is the Motivated Strategies for Learning Questionnaire (Pintrich et al. 1993). Other established learning theories that the BSP will employ is the growth-mindset and lay-theory approaches to learning (Yeager and Dweck 2012, Yeager et al. 2016). In practice, teaching students about *growth mindset* is to stress that intelligence and performance are malleable; *lay theory* stresses the high prevalence of emotional challenges experienced by other students as they enter college. These types of interventions reduce the susceptibility of stereotype threat and narrow institutional achievement gaps (Levy et al. 1998, Yeager et al. 2016).

Challenges and opportunities for STEM. The crucial importance of effective diversity programs for minority students has strong implications for the achievement of equity in STEM disciplines. In order to reveal positive outcomes and efficient use of resources, more quantitative research is required. One difficulty for many universities is selecting how to distribute funds for URM support programs. Although most large universities have URM support programs, few studies have explored the optimal allocation of limited resources to best serve students: Does a university invest a finite amount of resources across a large pool of students or into a few individuals? If they choose the latter option, is it better to invest in low-achieving students who most need the intervention or in top-achieving students who are most likely to succeed? There may be a crucial financial threshold below which the amount of funding will not benefit students or above which programs should consider widening their pool of recipients.

Another area that would benefit from further study is the exploration of nuanced quantitative metrics beyond GPA and retention rate that capture the positive effects of URM support programs. Such metrics may include measures of intellectual breadth, extracurricular depth, self-efficacy and motivation, academic or extracurricular accomplishments, and lifelong impacts. The lack of studies on these other metrics means that we cannot test how Cornell's BSP affects different facets of student success; however, the BSP may affect URM students in ways we have not quantified. Rigorous research on alternative metrics of performance is required if our field aims to evaluate the generality of different program impacts.

This assessment presents the BSP with the unique opportunity to apply and monitor evidence-based methodologies to close the majority–minority gap. In spite of inherent challenges, the promotion of diversity in STEM fields will be made possible through continued collaborative assessment and systemic change.

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