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Impact of Mentoring and Enrichment Activities on the Academic Careers of Underrepresented STEM Doctoral Students

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Abstract

While much national attention has been focused on increasing the participation of underrepresented minorities (URMs) in the STEM fields, considerable gaps remain in terms of educational attainment between URMs and other racial/ethnic groups. Differences are particularly stark at the doctoral levels, where underrepresented minorities accounted for only 3.3% of STEM PhDs awarded in 2005.[14] A recent longitudinal study of minority PhDs in STEM disciplines found that long-term academic success (i.e., placement and tenure for URM faculty members) requires long-term development both within and beyond graduate school. Such training must include multi-faceted professional development (e.g., grant writing, public speaking, and publishing research), as well as social dynamics such as networking within the STEM community.[10] The National Science Foundation (NSF) has responded to these challenges with the Alliances for Graduate Education and the Professoriate (AGEP) program. AGEP seeks to increase the number of underrepresented students receiving doctoral degrees in STEM disciplines—with particular attention upon increasing the number who will enter the professoriate in these disciplines and serve as mentors to promising minority scholars in the educational pipeline.

This paper seeks to examine the longitudinal impact of one such program at a large engineering school in the Southeast. The program Facilitating Academic Careers in Engineering and Science (FACES) was designed to provide a set of co-curricular enrichment activities that foster the necessary mentoring of underrepresented minorities. The research design utilized a survey of alumni (who graduated between 2003 and 2011), and it measured their employment outcomes and perceptions of career preparation. Utilizing parametric (ANOVA) and non-parametric statistical methods, participants in the program were compared to two control groups—URM STEM graduates who did not participate in the mentorship program and non-URM STEM graduates. The research questions of interest:

1) Are doctoral recipients who participated in the FACES program more likely to gain employment in academia?

2) Are there differences in self-reported professional skills for former FACES fellows when compared to other URM doctoral recipients as well as to non-URM PhDs?

Results demonstrate that FACES participants were over 2.5 times more likely to report working in a faculty or academic professional position than were the non-URM STEM graduates, and were nearly twice as likely compared with URM graduates without the program experience. Additionally, on seven of a set of 15 knowledge, skills, and abilities items, ANOVA results demonstrated higher levels of preparation for program participants. The paper will describe specific programmatic approaches that were effective in URM

graduate persistence and subsequent placement into academic (as opposed to industrial) careers.

I. Introduction

For decades, the United States has enjoyed a leadership role in science, technology, engineering, and mathematics (STEM) fields. The investment that the U.S. has made in science and engineering research in industry, universities, and government laboratories has benefited the nation in exports sold, jobs created, and increased productivity. This nation, as well as other nations throughout the world, has recognized in prior years that a highly skilled STEM workforce remains essential for economic strength.

In recent years, the level of awareness of this fact has come into question. While other nations have been taking proactive measures to increase the capacity of STEM higher education systems, attract foreign students and workers, and enhance the attractiveness of their homeland to expatriates to return to participate in growing national economies and research enterprises,[13] such activity in the U.S. has stagnated or declined. In recent years, for example, the overall production of STEM doctoral degrees in the U.S. has fallen. From 1998 through 2005, the number of U.S. citizens or permanent residents earning such degrees declined by more than 13 percent.[16] Not only do such advanced degree holders play an essential role in the education of the future STEM workforce, they are also active participants in economic development and innovation themselves.

Another symptom of this state of malaise is the limited progress that has been achieved in reaching parity in participation among all segments of the U.S. population in STEM education. Despite some gains in the representation of minorities in engineering and science, a parity gap persists. In 2008, 12.4% of students who earned BS degrees in engineering came from underrepresented minority (URM) populations.[14] Although this represents a modest increase over the previous decade (11.5% in 1995), minority representation drops for advanced engineering degrees, as only 7.0% of Master's and 3.3% of the PhD degrees awarded in 2005 were earned by these students.[14] This has led to a low number of tenured and tenure-track URM engineering faculty (< 5%).[2]

There is much reason to be concerned about the low participation rates of underrepresented minority groups. Demographic studies indicate that the ethnicity of the U.S. workforce is changing dramatically. According to Census Bureau projections, non-Hispanic white males will decline as a fraction of the working age (18 to 64) population from 37% in 1995 to 26% in 2050. Over that same span, the fraction of African-Americans in the workforce will increase from 12% to 14%, and that of Hispanics will increase from 10% to 24% (see Figure 1). The end result is that currently underrepresented groups will increase from about a quarter of the workforce to nearly half (47%). The current and projected need for more STEM workers, coupled with the fact that women, minorities, and persons with disabilities comprise an increasing proportion of the labor pool, argue for policies, programs, and resources that support greater participation by these groups in STEM education and careers.

It will be extremely difficult to diversify the undergraduate and graduate student bodies in STEM, however, without diversifying the environments in which these students are educated.

Thus, much of this burden rests squarely on the faculty. Efforts to change the composition of STEM faculty—that sector of the academic world with great potential to reach large numbers of students—are daunting. Among the challenges faced by today's university is how to grow and nurture a "culturally competent" faculty—irrespective of their race, ethnicity, gender, age, and other variables. Ultimately, it is the faculty that must become adept at encouraging the success of all students.

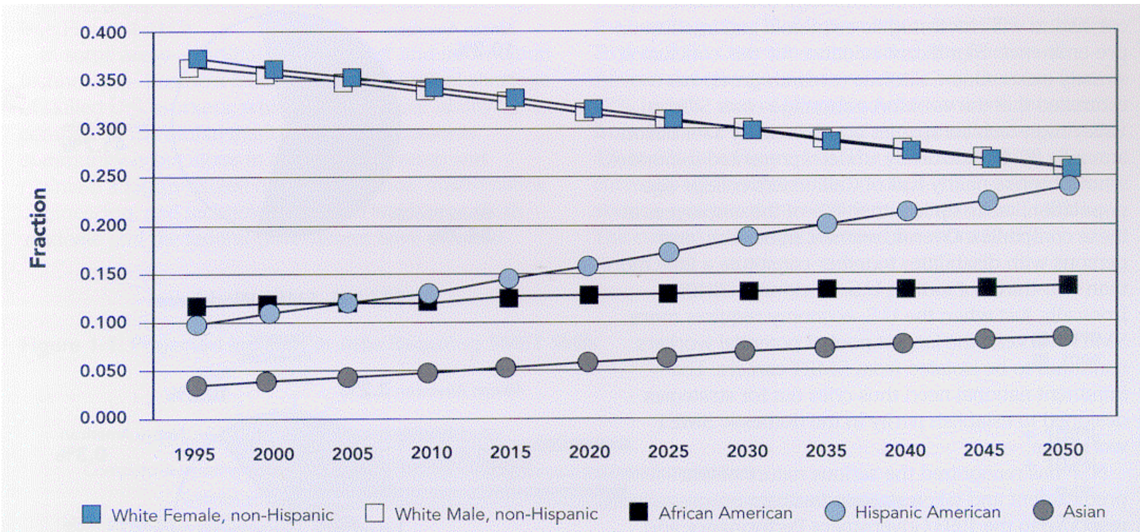

Figure 1. Population Projection for Ethnic & Gender, Ages 18–64, 1995–2050.[12]

Considerable work has been performed to understand the unique challenges URM students face in the path to academic careers in STEM disciplines. Within the past decade, major efforts to review URM participation in the STEM workforce have been performed by George, Neale, Van Horne, and Malcom[8] and Poirier, Tanenbaum, Storey, Kirshstein, and Rodriguez.[16] Earlier reviews include Clewell and Anderson.[6] Much of the literature describes a pipeline that begins in middle-grade education and culminates in graduate and post-doctoral decisions to pursue tenure-track faculty or other STEM career opportunities. As students traverse each stage of their education (i.e., from middle school to high school, high school to undergraduate, from undergraduate to graduate, and from graduate to career), they confront various obstacles that can deter them from STEM careers. For example, at the high school level, research has identified course-taking behavior (e.g., lack of adequate math and science coursework),[1] performance on standardized tests,[4] and lack of encouragement by teachers or family.[3] At the undergraduate level, lack of adequate financial aid, inadequate academic preparation, and a similar lack of encouragement by faculty and college staff have been identified as posing particular challenges for URM students.[5, 18, 20] At the graduate level, lack of adequate financial aid and scarcity of minority peers, mentors, and role models are commonly cited as barriers to academic careers.[17, 19, 9]

A recent longitudinal study of minority PhDs in STEM disciplines found that long-term academic success (i.e., placement and tenure for URM faculty members) requires long-term development both within and beyond graduate school. Such training must include multi-faceted professional development (e.g., grant writing, public speaking, and publishing research), as well as social dynamics such as networking within the STEM community.[10]

Logically, the challenges posed by the lack of financial resources and lack of peer and faculty mentorship are cumulative from high school through graduate school and beyond. URM students are more likely to complete their baccalaureate educations with higher debt burdens than their majority peers, thus the prospect of a long slog to a STEM doctorate with the likely prospect of further training at the postdoctoral level makes the alternative of a career in medicine or a STEM job in industry more appealing. Meanwhile, the attrition of minority students through the pipeline tends to leave URMs isolated and without either student or faculty peers to guide their career development.

In 1998, the National Science Foundation (NSF) responded to these challenges described by researchers with its Minority Graduate Education program, which subsequently transitioned to the Alliances for Graduate Education and the Professoriate (AGEP) program. AGEP seeks to increase the number of underrepresented students receiving doctoral degrees in STEM disciplines.[15] The scarcity of role models and mentors constitutes a significant barrier to producing minority graduates, so the NSF is particularly interested in increasing the number who will enter the professoriate in these disciplines. The specific objectives of the AGEP program have been to: (1) develop and implement innovative models for recruiting, mentoring, and retaining minority students in doctoral programs; and (2) develop effective strategies for identifying and supporting underrepresented minorities who want to pursue academic careers. AGEP also supports a research effort to identify major factors that promote successful transition of minority students from: (1) undergraduate through graduate study; (2) course-taking in the early years of the graduate experience to independent research required for completion of a dissertation; and (3) the academic environment to the workplace. Thirty AGEP alliances, involving more than 100 universities and colleges, have been established.

One such alliance is Facilitating Academic Careers in Engineering and Science (FACES), which is one of the original cohorts of AGEP programs formed in 1998. FACES is a collaborative effort between {institutions withheld} that is comprised of several components, each designed to assist underrepresented engineering and science students with navigating the path to an academic career. These components include support at a variety of points along the career pipeline: undergraduate research scholarships; fellowship supplements; and career initiation grants or “portable” post-doctoral fellowships, which graduating doctoral students use as start-up funds to assist in establishing their research programs in their initial academic appointments. The FACES program has been substantially successful. Since its inception, more than 300 minority students have received PhD degrees in science or engineering at {institution withheld}, ten percent of which entered academia as direct beneficiaries of FACES, and ten of which received meritorious young investigator awards.[11]

A key aspect of the FACES program is the extensive use of mentoring and enrichment activities. Monthly enrichment seminars expose FACES fellows to training in traditionally pivotal topics such as grant writing, interviewing skills, and research ethics; as well as more recently highlighted social sensitivities such as work-family balance and effective networking within one’s discipline. These seminars have primarily been led by URM STEM faculty, thus adding a role model component to the monthly gatherings. A teaching practicum program has sponsored some of the FACES fellows to take specialized courses on instruction in the {institution withheld} Center for the Enhancement of Teaching and Learning, and participants subsequently co-instruct university classes. Additionally, FACES fellows are encouraged to disseminate their scholarship via publications and presentations, inclusive of set-aside conference travel funds for them to present. Upon completion of their doctoral studies, FACES fellows who pursue academic careers are again eligible for postdoctoral fellowships and/or supplemental start-up funds that can be utilized at their respective institutions. These support mechanisms facilitate the transition from graduate school to the early academic career, and several recipients have gone on to further success by receiving junior faculty awards such as NSF CAREER grants and Department of Defense Young Investigator awards.

Now that FACES has matured and its student participants have had time to move through the program into their early careers, longitudinal assessments of the program's efficacy are underway. The research questions of interest are:

1) Are doctoral recipients who participated in the FACES program more likely to gain employment in academia?

2) Are there differences in self-reported professional skills for former FACES fellows when compared to other URM doctoral recipients as well as to non-URM (i.e., white and Asian) PhDs?

Identifying answers to these research questions is the objective of the current study. The study is organized as follows: Section II describes the evaluation methodology used to do so. Section III presents quantitative results, and these results are discussed in greater detail in Section IV. Conclusions are provided in Section V.

II. Methodology

To address the research questions, a survey was administered to alumni who received their PhD between 2003 and 2011. {Institution withheld} routinely administers a Graduate Alumni Survey to its PhD recipients between three and five years after their graduation. The most recent survey was conducted in 2011, and it included those who completed degrees between 2006 and 2008. In order to obtain a sufficient sample of FACES participants, survey administration was broadened to include a larger group of FACES graduates: PhD recipients between 2003 and 2011. In the subsequent analyses, three groups were compared: STEM graduates that participated in the FACES program (graduating 2003–2011); URM STEM graduates who did not participate in the FACES program (graduating 2006–2008); and non-URM (White and Asian) STEM graduates (graduating 2006–2008).

The authors are mindful of the fact that comparisons between these groups are complicated by the fact that the FACES degree recipients span a greater range of time since graduation (one to eight years), while the control groups have all graduated between three and five years. Collecting data from more recent (and older) FACES graduates was necessary in order to obtain a sufficient sample size for analysis. Analysis of variance was performed on the control groups to determine if there were any differences in mean response based on graduation year (within the three years in the sample). No significant differences were found, which supports the assumption that respondents' opinions and perceptions are relatively stable across time.

Chi-square tests for sample representativeness revealed no significant differences between the groups based on gender or college. Table 1 highlights the demographic composition of the three groups.

Table 1

Demographic Composition of Survey Participants

	FACES	URM Non-FACES	Non-URM STEM
Degree Received			
2003–2005	28.1%	0.0%	0.0%
2006–2008	32.2%	100.0%	100.0%
2009–2011	40.7%	0.0%	0.0%
Female	37.5%	33.3%	22.4%
College			
Computing	3.1%	0.0%	10.2%
Engineering	78.1%	81.0%	76.9%
Sciences	18.6%	19.0%	12.9%
Race/Ethnicity			
Asian	0.0%	0.0%	44.7%
Black	100.0%	42.9%	0.0%
Hispanic	0.0%	47.6%	0.0%
Multiracial	0.0%	9.5%	0.0%
White	0.0%	0.0%	55.3%
N	32	21	255

III. Results

The first research question addresses the job placement of FACES PhD recipients. The alumni survey asks respondents to describe their current employment status and job function. For this analysis, a larger set of data was obtained by including a previous alumni survey conducted in 2006, as well as the one conducted in 2011. Thus, the results include STEM PhD recipients between 2003 and 2008. This control group was compared to the reported job function of the FACES alumni. Determining whether FACES graduates were more likely to pursue careers in academia as opposed to government agencies or industry was of specific interest. The survey contained eight categories for job function, which were collapsed into two categories to increase the statistical power of the test. Because the FACES sample contains more recent graduates than the control groups, post-doctoral positions were included as "academic professionals." As seen in Table 2, FACES alumni were over 2.5 times more likely to report working in a faculty or academic professional position than were the non-URM STEM graduates, and nearly twice as likely to be in an academic field compared with URM graduates without the FACES experience.

Table 2

Self-Reported Job Function of PhD Alumni

	FACES	Other URM STEM	Non-URM STEM
Faculty/Academic Professional/Postdoctoral	45.2%	24.3%	17.8%
Other job function	54.8%	75.7%	86.6%
N	31	37	415

Notes: $X^2 = 13.87$; $df = 2$; $p = .001$

The second research question addressed whether there were differences in terms of preparation in a variety of knowledge, skills, and abilities. The survey asked alumni to reflect on their graduate education as well as to describe their current career situation. Retrospectively, alumni were asked the extent to which they agreed that {institution withheld} adequately prepared them in a variety of skills, abilities, and attributes. A priori, 15 of the 33 items were selected as being those most likely impacted by the FACES program. The responses were in the form of a six-point Likert scale ranging from "Strongly Agree" to "Strongly Disagree." Analysis of Variance (ANOVA) was performed on these selected items to compare the mean response for the FACES alumni, URMs who did not participate in FACES, and the non-URM STEM PhDs.

The ANOVA results are presented in Table 2. Post-hoc tests (LSD or Games-Howell, as appropriate) were performed for any *F* values that were found significant at $p < 0.10$ and are presented in Table 3. (Due to the lack of power resulting from relatively low sample sizes in the FACES and URM groups, the more liberal alpha level of $p < 0.10$ was chosen to indicate a significant finding).

Table 3

Analysis of Variance

		N	Mean	Std. Dev.	Std. Error		Sum of Squares	*df*	Mean Square	*F*	Sig.	η^2
Writing for academic publications (journals, etc.)	FACES	32	5.38	.833	.147	Between Groups	4.297	2	2.149	2.780	.064	0.018
	Other URM STEM	21	4.95	1.322	.288	Within Groups	234.199	303	.773			
	Non-URM STEM	253	5.42	.840	.053	Total	238.497	305				

Table 3

Analysis of Variance (continued)

		N	Mean	Std. Dev.	Std. Error		Sum of Squares	*df*	Mean Square	*F*	Sig.	η^2
Writing grant proposals	FACES	30	4.03	1.159	.212	Between Groups	1.217	2	.609	.296	.744	
	Other URM STEM	18	3.89	1.641	.387	Within Groups	576.387	280	2.059			
	Non-URM STEM	235	4.14	1.449	.095	Total	577.604	282				
Communi-cating in a business environment	FACES	31	4.74	1.032	.185	Between Groups	7.933	2	3.966	2.819	.061	0.019
	Other URM STEM	21	3.95	1.117	.244	Within Groups	416.515	296	1.407			
	Non-URM STEM	247	4.48	1.209	.077	Total	424.448	298				
Preparing a research or project proposal	FACES	32	5.00	.718	.127	Between Groups	.485	2	.242	.246	.782	
	Other URM STEM	21	5.19	.981	.214	Within Groups	297.567	302	.985			
	Non-URM STEM	252	5.05	1.022	.064	Total	298.052	304				
Giving research or project presentations (brown bags, conference presentations)	FACES	32	5.53	.761	.135	Between Groups	.194	2	.097	.188	.829	
	Other URM STEM	21	5.43	.811	.177	Within Groups	155.917	302	.516			
	Non-URM STEM	252	5.53	.705	.044	Total	156.111	304				
Teaching a college-level course in my discipline	FACES	30	5.23	.898	.164	Between Groups	8.324	2	4.162	2.914	.056	0.020
	Other URM STEM	20	5.20	.834	.186	Within Groups	404.211	283	1.428			
	Non-URM STEM	236	4.77	1.251	.081	Total	412.535	285				

Table 3

Analysis of Variance (continued)

		N	Mean	Std. Dev.	Std. Error		Sum of Squares	*df*	Mean Square	*F*	Sig.	η^2
Interviewing for jobs	FACES	32	4.72	1.023	.181	Between Groups	4.067	2	2.034	1.276	.281	
	Other URM STEM	20	4.35	1.089	.244	Within Groups	479.670	301	1.594			
	Non-URM STEM	252	4.34	1.301	.082	Total	483.737	303				
Giving job talks	FACES	32	5.06	.948	.168	Between Groups	9.960	2	4.980	3.235	.041	0.021
	Other URM STEM	21	4.52	1.078	.235	Within Groups	454.134	295	1.539			
	Non-URM STEM	245	4.47	1.285	.082	Total	464.094	297				
Think critically and logically	FACES	31	5.81	.402	.072	Between Groups	2.380	2	1.190	3.934	.021	0.025
	Other URM STEM	21	5.38	.669	.146	Within Groups	91.041	301	.302			
	Non-URM STEM	252	5.58	.555	.035	Total	93.421	303				
Understand my professional and ethical responsibilities	FACES	32	5.50	.672	.119	Between Groups	6.355	2	3.178	4.078	.018	0.026
	Other URM STEM	21	4.81	1.289	.281	Within Groups	236.116	303	.779			
	Non-URM STEM	253	5.14	.866	.054	Total	242.471	305				
Engage in lifelong learning and self-critique	FACES	32	5.63	.492	.087	Between Groups	3.044	2	1.522	2.730	.067	0.018
	Other URM STEM	21	5.29	.845	.184	Within Groups	168.956	303	.558			
	Non-URM STEM	253	5.30	.764	.048	Total	172.000	305				

Table 3

Analysis of Variance (continued)

		N	Mean	Std. Dev.	Std. Error		Sum of Squares	*df*	Mean Square	*F*	Sig.	η^2
Function in culturally and ethnically diverse environments	FACES	31	5.55	.995	.179	Between Groups	2.989	2	1.494	1.971	.141	
	Other URM STEM	20	5.15	.988	.221	Within Groups	227.414	300	.758			
	Non-URM STEM	252	5.23	.845	.053	Total	230.403	302				
Mentor others	FACES	31	5.19	1.046	.188	Between Groups	3.981	2	1.991	1.851	.159	
	Other URM STEM	21	4.76	1.375	.300	Within Groups	314.039	292	1.075			
	Non-URM STEM	243	4.82	1.003	.064	Total	318.020	294				
Exercise leadership skills	FACES	32	5.25	.762	.135	Between Groups	7.472	2	3.736	3.368	.036	0.022
	Other URM STEM	21	4.81	1.167	.255	Within Groups	333.884	301	1.109			
	Non-URM STEM	251	4.74	1.075	.068	Total	341.355	303				
My education at {institution withheld} prepared me to practice my discipline in academia	FACES	32	5.47	.718	.127	Between Groups	2.424	2	1.212	1.493	.226	
	Other URM STEM	21	5.29	.956	.209	Within Groups	241.056	297	.812			
	Non-URM STEM	247	5.18	.917	.058	Total	243.480	299				

Table 4

Post Hoc Tests for Significant Items

	N	FACES Mean (1)	Other URM STEM Mean (2)	Non-URM STEM Mean (3)	Post-Hoc
Writing for academic publications	305	5.38	4.95	5.42	3 > 2*
Communicating in a business environment	298	4.74	3.95	4.48	1 > 2*
Teaching a college-level course in my discipline	285	5.23	5.20	4.77	1 > 3*
Giving job talks	297	5.06	4.52	4.47	1 > 3**
Think critically and logically	303	5.81	5.38	5.58	1 > 2* 1 > 3*
Understand my professional and ethical responsibilities	305	5.50	4.81	5.14	1 > 2** 1 > 3*
Engage in lifelong learning and self-critique	305	5.63	5.29	5.30	1 > 3**
Exercise leadership skills	303	5.25	4.81	4.74	1 > 3*

*$p < 0.05$; **$p < 0.01$

The ANOVA results demonstrate a significant omnibus effect for eight of the 15 items. Of these, four were significant at $p < 0.10$, and four were significant at $p < 0.05$. Post hoc tests conducted on these items demonstrated significant differences between the FACES alumni and at least one of the comparison groups in 7 of the 8 items. FACES alumni expressed higher levels of preparation compared to non-URM STEM alumni in *teaching a college level course in their respective disciplines*, *giving job talks, thinking critically and logically, understanding professional and ethical responsibilities*, *engaging in lifelong learning*, and *exercising leadership skills*. FACES alumni expressed higher levels of preparation compared to other URM alumni on three items—*communicating in a business environment*, *thinking critically and logically*, and *understanding professional and ethical responsibilities*. On the remaining item—*writing for academic publications*—FACES alumni were statistically equivalent to the non-URM group. Effect sizes for the significant items were small[7] with η^2 values near 0.02.

IV. Discussion

The need to increase the number and percentage of URMs pursuing careers in academia has been noted by many researchers and has been explicitly placed as a policy priority by the United States government.[13] AGEP programs such as FACES have worked for over a decade to increase the number of students moving through the educational pipeline with the ultimate goal of improving the odds that young scholars might join the academic ranks as fully prepared with respect to research and professional skills. The co-curricular interventions undertaken by the FACES initiative appear to be successful on at least two dimensions. First, placement data collected by alumni surveys clearly indicate a significantly larger proportion of FACES doctorates were working in an academic setting. Indeed, FACES graduates were two and a half times more likely to be working in the academy than their majority (i.e., Asian and white) counterparts. Additionally, FACES graduates were almost twice as likely to be working in academia as were URM doctorates that did not participate in the FACES program.

Second, the ANOVA results of self-reported preparation on a variety of knowledge, skills, and abilities indicate that in six of the fifteen selected items, FACES participants reported higher levels of preparation than their majority (i.e., Asian and White) counterparts. FACES participants reported higher preparation than non-FACES URMs on three of the selected items. It should be noted there were no items in which the majority group rated their skills higher than the FACES group. In other words, the FACES graduates were either statistically similar to the majority group or considered themselves better prepared in all of the items analyzed. The types of skills stressed by the FACES program—such as college-level teaching, giving job talks, or exercising leadership skills—are those that might provide a competitive edge for one beginning an academic career. The fact that FACES graduates exhibit a higher level of confidence in their graduate preparation than do their majority counterparts is an indicator of success for the FACES approach to academic career preparation.

V. Conclusion

A multi-faceted approach has been developed to retain, encourage, and prepare URM STEM graduate school talent for subsequent service in academia. This is in response to the critical need to increase the presence of such demographics in the STEM professoriate. The NSF AGEP program FACES has engaged such doctoral students in various enrichment activities that focus upon greater insights and preparedness regarding academia. These intervention measures have included monthly enrichment seminars during the school year, wherein URM STEM faculty convey insights and skills needed for academic success; teaching practica opportunities for graduate students to receive formal support en route to co-instructing university classes; travel support to present at STEM research conferences; and ultimately additional “start-up” resources for early career efforts related to academia.

These investments have resulted in statistically relevant indications that the participants’ confidence in, and subsequent pursuit of, service in academia compares favorably to other groups in {institution withheld}’s STEM graduate programs. The challenge of addressing the “leaky pipeline” of STEM talent requires both retention during formal education and career direction after the attainment of the terminal degree. Efforts such as FACES that further motivate URM STEM talent to target academic careers can substantially impact the diversity of our nation’s STEM professionals.

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