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EDITED BY
Roya Pashmforoosh,
Texas A and M University, United States

REVIEWED BY
Tyrslai Williams,
Louisiana State University, United States
Zakiya Wilson-Kennedy,
Louisiana State University, United States

*CORRESPONDENCE
Nancy Diaz-Elsayed
✉ nancyd1@usf.edu

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Building inclusive excellence in STEM: a 15-year analysis and Lessons Learned of the Alfred P. Sloan Foundation Minority Ph.D. Program at the University of South Florida

Nancy Diaz-Elsayed[1]*, Jorge A. Acuna[2,3], Michelle Henderson[4], Wainella Isaacs[4], Daniela Cantarino[2], Jennifer K. Bosson[5], Tramaine Polk[2,6], Patricia Robinson[6,7], Bernard Batson[6] and José L. Zayas-Castro[2,6]

[1]Department of Mechanical Engineering, University of South Florida, Tampa, FL, United States, [2]Department of Industrial and Management Systems Engineering, University of South Florida, Tampa, FL, United States, [3]Faculty of Engineering and Sciences, Universidad Adolfo Ibáñez, Viña del Mar, Valparaíso, Chile, [4]Department of Civil and Environmental Engineering, University of South Florida, Tampa, FL, United States, [5]Department of Psychology, University of South Florida, Tampa, FL, United States, [6]College of Engineering, University of South Florida, Tampa, FL, United States, [7]University College of the Cayman Islands, George Town, Cayman Islands

In 2016, only 7 percent of African American and Hispanic students earned research doctorates in the critical disciplines of engineering, computing, and the physical sciences. In academia, diversity fairs even worse as historically underrepresented minorities represented just 6.1 percent of tenured and tenure-track faculty in engineering. The aim of this effort is to understand the "best practices" for the recruitment and mentoring of minority doctoral students in science and engineering disciplines. This was achieved through a literature review, surveys and focus groups with members of the University of South Florida's (USF's) Sloan University Center of Exemplary Mentoring (UCEM), and interviews with faculty champions. Between 2005 and 2020, 136 graduate students have been supported (43% African American, 56.2% Hispanic, 0.8% Native American), of which 87 percent are expected to earn doctorate degrees. Results indicate that the decision to apply and enroll at USF was largely driven by the alignment of research interests with potential advisors, the quality of funding, and positive interactions with mentors, enrolled students, and alumni who provide evidence of a welcoming climate. Ten practices for mentoring doctoral students are provided, which include creating and promoting an inclusive environment and providing a student-centered approach to mentoring. Our effort to build inclusive excellence and foster social justice in graduate education for African American and Hispanic doctoral students in science, technology, engineering, and mathematics (STEM) is one that can be modeled and adapted by other institutions to align with their institutional culture and values.

KEYWORDS

recruitment and retention, doctoral institutions, graduate education, student diversity, mentoring

1. Introduction

More than half of the nation's children were expected to come from minority or ethnic groups by, 2020 according to the U.S. Census Bureau (United States Census Bureau, 2015). In response to this shift in the country's demographics, the National Academies (NAS and NAEM, 2011; NASEM, 2019) and the White House's Office of STEM Education (CoSTEM, 2018) have documented the need to increase the participation of individuals from historically underrepresented groups in science and engineering (S&E) to help maintain the nation's competitiveness in technology and research innovation. Although we have witnessed a steady increase in the enrollment of historically underrepresented minority (URM) students within S&E graduate programs in recent years (Kang, 2015), as a whole, their numbers remain low compared to their representation in our country (NSF NCSES, 2019b). In 2016, only 7 percent of African American and Hispanic students earned research doctorates in the critical disciplines of engineering, computing, and the physical sciences (NSF NCSES, 2019b). In academia, diversity is even worse as historically underrepresented minorities represented just 6.1 percent of tenured and tenure-track faculty in engineering (Roy, 2019). Sadly, the numbers are even worse at the postdoctoral level as African Americans and Hispanics in 2019 accounted for less than 4 percent of individuals in these positions at federally funded research centers (NSF NCSES, 2020).

Historically underrepresented students in Science, Technology, Engineering, and Mathematics (STEM), which we define in this article as individuals from African American, Hispanic, and Indigenous communities, experience unique challenges in the process of attaining their educational goals. They can face environmental and institutional barriers, such as high student to faculty ratios, a lack of structural diversity, as well as unsupportive psychological and behavioral climates, during their path toward higher education (Whittaker and Montgomery, 2012; Anderson et al., 2020). These challenges are further compounded for first-generation college students who may experience financial hardships, have a gap in mentorship, and/or have limited social capital relative to continuing-generation college students (Terenzini et al., 1996; Wilbur and Roscigno, 2016; Fruiht and Chan, 2018).

In light of this important context, this project aims to answer the following research question: What are the major factors contributing to the enrollment and retention of minority Ph.D. students in STEM doctoral programs? Data will be analyzed through a case study of the University of South Florida's (USF's) Sloan University Center of Exemplary Mentoring (UCEM). Moreover, data will be supplemented by a literature review, surveys and focus groups with members of the USF Sloan UCEM, and interviews with faculty champions. This article is organized as follows: firstly, the history of the program and cohort demographics are presented; secondly, best practices for the recruitment and mentoring of historically underrepresented Ph.D. students in S&E are suggested; thirdly, the outcomes of the Sloan programs are evaluated; and, lastly, the conclusions from this research are presented.

2. Overview of the UCEM

The UCEM at the University of South Florida had the following aims from 2014 to, 2020 (Years 1 to 6 of the program):

1. Recruit at least 60 historically underrepresented doctoral students and provide five-year funding packages to these students,
2. Establish a new multi-dimensional mentoring (MDM) model to reduce the sense of academic isolation among African American and Hispanic Ph.D. students in STEM departments,
3. Implement a Professional Development Certificate for increased intellectual exchange and stronger community building between historically underrepresented and non-historically underrepresented graduate students on both campuses,
4. Develop a blueprint of UCEM Best Practices for the recruitment and retention of historically underrepresented graduate students and institutionalize the best practices in STEM graduate departments, and
5. Establish private fundraising campaigns to support UCEM institutionalization.

Table 1 below provides student demographical information by race and ethnicity during the USF Sloan award periods. The demographics for students between 2006 and, 2020 (Legacy and UCEM years 1–6) were 47% male and 53% female; 44% African-American/Black, 56% Hispanic/Latino, and 0.8% Native American. Notably, the overall percentages of African American and Hispanic scholars for the USF UCEM (Years 1 to 6) are comparable to the Legacy award period; in addition to the totals summarized in Table 1, one Native American Ph.D student joined the College of Engineering in the 2016–2017 academic year.

3. Methods

The aim of this article is to recommend and discuss best practices for recruiting and mentoring historically underrepresented minority Ph.D. students in STEM disciplines. In doing so, our goal is to augment the opportunities for minority students to obtain advanced STEM degrees and support these Ph.D. students during their academic path.

This study implemented qualitative methods consisting of a survey and focus groups with Sloan Scholars from the University of South Florida, and interviews with faculty mentors. Sloan Scholars are Ph.D. students of historically underrepresented minority backgrounds in science and engineering. At the time of this study, the students were enrolled in a Ph.D. program within either the College of Engineering or the College of Marine Science. The faculty mentors that were interviewed had been identified by the Sloan Scholars as excellent mentors within USF. In addition to the survey and focus groups,

TABLE 1 Student demographics for the USF Sloan programs by ethnicity.

Period	African American	Hispanic
Legacy	31 (41%)	45 (59%)
UCEM Years 1–3 (2014–2017)	17 (57%)	13 (43%)
UCEM Years 4–6 (2017–2020)	8 (38%)	13 (62%)
UCEM Years 1–6	25 (49%)	26 (51%)
Total	56 (44%)	71 (56%)

published literature was reviewed to provide a holistic perspective on the mentoring and recruitment of historically underrepresented doctoral students in STEM.

Three one-hour focus groups were conducted in the fall of 2019. Two focus groups were conducted in person with six and three Sloan Scholars in each session from the USF College of Engineering. A third focus group was conducted on Skype with four Sloan Scholars from the USF College of Marine Science. To facilitate dialoge around mentorship in doctoral programs and understand the factors that contributed to their enrollment in their Ph.D. program, the questions discussed during these sessions included: Why did you decide to enroll at USF for your doctoral studies? What are some qualities of a good mentor? Are there any excellent mentors at USF that come to mind? What makes them an excellent mentor? Students were also provided with a list of graduate school activities categorized into "Classes," "Research," "Writing," and "Others" and were asked: What outcomes are most important to you? Are there specific activities you would like to receive more guidance on? No statistical methods were applied to the analysis of the focus groups; instead, the focus groups were analyzed thematically.

For the survey used in this study, the following questions were asked in an online platform (Qualtrics).

- Program Selection: We are trying to understand best practices for recruiting future scholars. The following questions are aimed at helping us understand why you chose USF for your graduate studies.
  - o What led you to apply to your PhD program at USF? (Open-ended response)
  - o Why did you decide to enroll at USF for your PhD? (Open-ended response)
- Personal Experience and Feedback: Please express your opinion about…
  - o Faculty support while developing a research idea. Select one (ratings from Very Poor to Very Good).
  - o Support provided from faculty in terms of coursework. Select one (ratings from Very Poor to Very Good).
  - o What other activities do you believe would help you become a more effective researcher? (Open-ended response)
  - o Faculty mentoring to help you advance your research. Select one (ratings from Very Poor to Very Good).
  - o Faculty mentoring to help you identify and achieve your goals. Select one (ratings from Very Poor to Very Good).
  - o How would you like to see your mentoring experience with your faculty mentor(s) improve, if at all? (Open-ended response)

Survey questions that had open-ended responses were analyzed thematically to generate strategies for enhancing the recruitment and retention of URM Ph.D. students in S&E. For the questions that offered a five-point scale (from Very Poor to Very Good), we conducted two sets of item-level analyzes. First, we compared mean responses across the four "faculty support" questions to determine if students perceived some types of support as significantly better than others. To do this, we submitted ratings of the four support types to a one-way, repeated measures Analysis of Variance (ANOVA). Second, using chi-square tests, we compared the proportions of ratings, given to each type of faculty support, that fell in the *not good* end of the scale (i.e., "very poor," "poor," "fair") versus those that fell in the *good* end of the scale (i.e., "good," "very good").

Through this analysis, our team sought to (1) understand the factors contributing to the enrollment of minority Ph.D. students in their doctoral program and (2) identify the ideal mentorship qualities and climate needed for their success. To measure the impact of the practices implemented for recruiting and mentoring underrepresented minority Ph.D. students in STEM, the study presents a comparative analysis between national metrics and USF official data obtained through the InfoCenter system and the College of Engineering. A blend of literature and reports from national agencies were used to align the years and areas of specialization. For example, the publication *"Engineering by the Numbers"* from the Department of Institutional Research & Analytics of the American Society for Engineering Education (ASEE) was used to analyze doctoral enrollment in engineering per ethnicity in, 2018 (Roy, 2019). In addition, for the same year, we considered the National Science Foundation (NSF) *"Survey of Earned Doctorates"* from the National Center for Science and Engineering Statistics (NCSES) to study the time to degree per race and field of study (NCSES, 2019a).

To analyze the UCEM success and the scholars' academic and professional achievements, time to degree, enrollment, completion rates and employment statistics were considered for the cohorts of Sloan Scholars analyzed in this study as they are indicators that are presented at a national level for science and engineering graduates (NASEM, 2019). Furthermore, to keep reliable metrics, the UCEM at USF has established a consistent communication record with graduated Ph.D. students to track their progress and the long-term impact of the SLOAN initiative. For instance, the UCEM asks alumni to complete an employment survey and update their contact and LinkedIn information annually.

4. Results and discussion

This section summarizes the findings from this study for the recruitment and mentoring of historically underrepresented students in science and engineering.

4.1. Recruitment practices

4.1.1. Coordinating institutional resources to achieve a critical mass

Previous research has documented the importance of adequate financial aid in the enrollment of STEM graduate students (Blume-Kohout and Clack, 2013; Bersola et al., 2014). Given the societal, cultural, and economic challenges confronted by URM students in graduate STEM departments outlined in the Introduction, fellowship funding often provides validation and legitimacy for their enrollment decisions (Mendoza et al., 2014; Mantai and Dowling, 2015; NASEM, 2018). Achieving a critical mass of historically underrepresented graduate students in STEM to reduce their academic and social isolation (Whittaker and Montgomery, 2012; Allen-Ramdial and Campbell, 2014; Berry and Fenn, 2018) has been the overarching objective of USF

faculty champions since the inception of the Alfred P. Sloan Foundation Legacy (2005–2013) and UCEM (2014-present) grant awards.

Our Fall 2019 survey of UCEM Scholars underscored the importance of these fellowship resources as depicted in Table 2. Out of 24 scholars surveyed, nearly 46 percent (11 out of 24) cited the quality of funding as a significant factor in their decision to enroll at USF. The importance of fellowship funding is further observed in data reported by the NCSES as 45.0% of Hispanics and 41.5% of African Americans identified fellowships as their primary source of support while fewer than 35% of majority students were funded primarily through fellowship support (only 34.1% of White and 33.6% of Asian students; NCSES, 2018). In fact, historically underrepresented students are less likely to be supported by research assistantships (Hispanics: 33.7% and African American: 26.2%) relative to majority students (Asians: 49.2% and White: 46.8%; NCSES, 2018).

Toward this objective, a cornerstone of the "USF approach" has been coordinating fellowship resources to provide five-year funding for historically underrepresented doctoral students. Institutional programs outlined below in Table 3 were managed separately by one Principal Investigator (PI)/Director/Associate Dean in the College of Engineering, College of Marine Science, and the Office of Graduate Studies to maximize student support. By coupling two-year Bridge to the Doctorate activity funding (96 NSF and 65 USF-funded matching fellowships), Sloan Legacy/UCEM fellowships, and external fellowships such as McKnight (McKnight Foundation, 1953), NSF Graduate Research Fellowship Program (GRFP, 1952), National Consortium for Graduate Degrees for Minorities in Engineering and Science (GEM, 1976), National Aeronautics and Space Administration (NASA), and others, USF recruited nearly 200 URM graduate students (M.S. and Ph.D.) in engineering, computer science, chemistry, physics, and oceanography. An overwhelming number of students continued onward as scholars within the Sloan Legacy (Pre-UCEM) and UCEM programs.

4.1.2. Intentional recruitment at MSI programs and national diversity conferences

Partnerships with MSIs have been suggested by literature as foundational for revitalizing the domestic STEM workforce (Allen-Ramdial and Campbell, 2014; NASEM, 2019; CoSTEM, 2021). Aligned with these recommendations and research, national data indicates many of these universities are top baccalaureate producers for both historically underrepresented S&E doctoral (NCSES, 2019b) and masters engineering recipients (American Society of Engineering Education, 2021), respectively. Diversity meetings organized by professional societies can play a critical role in fostering STEM inclusivity (Casad et al., 2016; Hulede, 2018; Primus et al., 2022) by providing safe spaces for students to give research talks, build community, and engage role models and mentors.

As noted in Table 4, more than half (59%) of USF Legacy and UCEM scholars (80 of 136) were recruited from Minority Serving Institutions (MSIs), and 18% (24 of 136) were identified at national diversity STEM conferences. For each Sloan scholar recruited, a three-step process was used: (1) Identify applicant pool with targeted outreach, (2) Proactively engage students and program directors, and (3) Provide follow-up support for application submission and program admission. Research-oriented minority STEM students from MSIs were identified from programs such as Ronald McNair Postbaccalaureate Achievement Scholars, NSF Louis Stokes Alliance for Minority Particiation (LSAMP), NSF Historically Black College and Universities Undergraduate Program (HBCU-UP), Maximizing Access to Research Careers (MARC), and others, and during national conferences with high attendance of underrepresented students such as the Annual Biomedical Research Conference for Minority Students (ABRCMS), Emerging Researchers National in STEM (ERN), Society for the Advancement of Chicano/Hispanics and Native Americans in Science (SACNAS), and others. Program directors were asked to recommend potential applicants and share a copy of their resume with the UCEM. The students were then engaged via emails, phone calls, MS Teams or Zoom (during the pandemic), targeted visits to universities or during seminars (on-campus and virtual) by UCEM faculty and scholars.

During the follow-up stage, students were directed to the UCEM's program website, brochures, and social media sites, which have been "intentionally" curated to welcome prospective students from historically excluded groups. Inclusive media entails including UCEM scholars, alumni, and faculty from underrepresented groups in videos

TABLE 2 Factors influencing the decision for current Sloan Scholars to apply and enroll at USF for graduate studies (data from 2019 to 2020 academic year; sample size = 24 student responses).

	Research and/or PI	Funding	Graduate program	Visit/Environment	USF REU	Location
Mentioned by scholars	17	11	9	7	3	3

TABLE 3 Major fellowships and resources of historically underrepresented College of Engineering and College of Marine Science graduate students at USF (2004–2021).

Fellowship program	Fellowship awards	USF [$M]	External [$M]	Total [$M]
NSF bridge to the doctorate	96		$8.0	$8.0
USF matching bridge	65	$4.0		$4.0
Sloan legacy/UCEM*	100		$4.0	$4.0
McKnight**	70	$1.2	$2.0	$3.2
GEM, NSF, NASA, NIH, and others	60		$2.0	$2.0
Total	391	$5.2	$16.0	$21.2

*Additional $1 million was provided for recruitment/student programming. **Both external and internal.

TABLE 4 Sloan Ph.D. recruitment by institution type.

	MSI	Non-MSI	Total	MSI%
Legacy Program: 2006 to 2013	53	31	84	63
UCEM Years 1–3: 2014 to 2017	22	8	30	73
UCEM Years 4–6: 2017 to 2020	5	17	22	23
Totals	80	56	136	59

MSI, minority-serving institution.

and images, to strategically engage with the communities of students and scientists from underrepresented racial and ethnic groups (e.g., @BLACKinEngineering, @BlackinComputing, @BlackinMarineScience, @SACNAS (Society for Advancement of Chicanos/Hispanics & Native Americans in Science), @CienciaPR (Ciencia Puerto Rico), @PRicansinSTEM (Puerto Ricans in STEM), and others). To complete the recruitment cycle, the UCEM follows-up with students by providing application fee waivers (if needed), answering questions about the graduate admissions process, and facilitating one-to-one exchanges with graduate departments and potential faculty mentors.

Building upon this approach, UCEM faculty champions encourage a holistic review of students from historically underrepresented applicants as evidence (Miller and Stassun, 2014; Kuo, 2017; Moneta-Koehler et al., 2017) has indicated that quanatitive measures (undergraduate grade point average, GRE scores) may not be the best predicators of graduate school productivitity. In contrast, non-cognitive variables such as "grit and persistence" (Stassun et al., 2011; Tanenbaum et al., 2020), social responsibility and desire to serve others (Smith et al., 2014; Garibay, 2015; Thoman et al., 2015; McGee et al., 2016), and fit with department and faculty research areas are also prioritized by carefully examining recommendation letters, personal statements, and past research experiences. Thereafter, admitted applicants are invited as a cohort for campus visits to meet with faculty, UCEM scholars, and other students. A primary goal is to highlight the supportive environment and resources available that will foster their sense of belonging within the institution, doctoral completion, and post-graduate success.

4.2. Feeder and bridge programs

In addition to providing financial support, feeder programs help foster science identity and a sense of community, develop academic and professional development skills, and offer authentic research experiences and graduate school application assistance (Bingham et al., 2003; Clewell, 2006; Maton et al., 2016; McIntee et al., 2018; Camacho et al., 2021) for historically underrepresented students. Similarly, bridge programs support the transition of underrepresented STEM students from undergraduate to graduate studies (BS-to-MS-to-PhD) with fellowship funding or paid research traineeships, individualized undergraduate or master's program coursework, structured professional development and cohort-building programming (Moreira et al., 2019; Wright et al., 2019; Preuss et al., 2020; Tanenbaum et al., 2020; Donovan et al., 2021). Importantly, Bridge programs may use the MS degree as a "reset" to address possible gaps in undergraduate preparation and provide enhanced research experiences (Bhansali et al., 2006; Stassun, 2017; Cochran et al., 2018; Hinton et al., 2020; Tanenbaum et al., 2020) for Ph.D. admissions. More broadly, both feeder and bridge programs have an intentional focus on reducing structural barriers (Estrada et al., 2016; NASEM, 2016; Curry and DeBoer, 2020) such as finanical need, lack of access to research opportunities, academic and social isolation, and emphasis on quantitative measures (GRE and GPA) in graduate admissions to expand STEM pathways for underrepresented students.

The UCEM has leveraged reciprocal collaborations with feeder programs and developed a USF Florida Georgia Louis Stokes Alliance for Minority Participation (FGLSAMP) Bridge to the Doctorate for recruitment of historically underrepresented graduate students. The USF Sloan UCEM recruited 52% (71 out of 136) and 57% (77 out of 136) of scholars from feeder and bridge programs, respectively (see Table 5). Of the 77 bridge students, 74 transitioned from the USF MS-to-PhD Bridge program. For external recruitment, faculty champions communicate directly (e.g., one-to-one email exchanges, MS Teams and Zoom calls) with prospective applicants and program directors of NSF and NIH feeder and bridge programs (e.g., Clinical Research Education, Support, and Training Program (CREST), Historically Black Colleges and University – Undergraduate Program (HBCU-UP), LSAMP [Alabama, Florida-Georgia, Illinois, North Carolina, Louisiana, Maryland], Maximizing Access to Research Careers (MARC), Initiative for Maximizing Student Development (IMSD), Postbaccalaureate Research Education Program (PREP), McNair, Partnerships for Research and Education in Materials (PREM), and others). MSI faculty from feeder and bridge programs are hosted for USF campus visitations and seminars to explore collaborations of mutual interest. More recently during the pandemic (2000–2022), outreach has expanded to include virtual seminars by UCEM faculty, students, and alumni for direct engagement with potential students and their program directors. By continuing to nurture key stragetic partnerships, the UCEM has demonstrated its long-term commitment to educating the next generation of scientific learners, role models, and leaders from underrepresented groups.

4.2.1. Summer undergraduate research experiences

Research has shown that undergraduate research experiences (UREs) are "high-impact" practices that foster science self-efficacy, science identity, and persistence in STEM for underrepresented students (Chemers et al., 2011; NASEM, 2017; Atkins et al., 2020; Faber et al., 2020; Morgan et al., 2021). UREs also can help to "fire the creative juices" and increase the motivation of students for graduate school (Estrada et al., 2016). Overall, participating within summer UREs, also known as Research Experiences for Undergraduate (REU) programs, enable historically underrepresented students to explore new research interests, learn aboout campus life at other universities, participate in cohort building activities, and possibly engage supportive mentors for graduate admissions (Hernandez et al., 2018; Stiner-Jones, 2021).

The UCEM has sought to foster a "shared responsibility" for Ph.D. recruitment of historically underrepresented students by deepening the engagement of faculty champions in REU activities. They are encouraged to be "intentional" in submitting REU site

TABLE 5 Students recruited from minority-serving institutions (MSIs), feeder or bridge programs, and Summer Undergraduate Research Experiences (SUREs) participants.

	MSI	URE Participation		Programs	
		Summer REU	USF	Feeder	Bridge
Percentage of students	59%	29%	18%	52%	57%
No. of students	80	39	25	71	77

Student count based on the USF Legacy and UCEM scholars (2006 to 2020). Note that an overlap of students between programs exists.

proposals and supplements to host students from minority-serving institutions (Labrador et al., 2008). To support these efforts, the UCEM provides enhanced programming (e.g., graduate admissions workshops, Sloan scholar seminars, social events, near-peer mentoring activities) as well as covers food costs for the Annual REU Summer Symposium. As previously mentioned, faculty are also invited to attend diversity meetings (SACNAS, ABRCMS, National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE), and others) and/or present virtually to engage directly with underrepresented students from minority-serving institutions who have prior undergraduate research experiences. Nearly 30 percent of the UCEM scholars (39 out of 136) participated in at least one summer NSF REU, with 18 percent (25 out of 136) of the students participating in a USF REU (see Table 5). As a whole, our recruitment from REUs may not be vast; nonetheless, they offer a compelling argument for the "intentional" approach of providing summer undergraduate research experiences for historically underrepresented undergraduates.

4.3. Mentoring practices

Mentoring has been described as "the process of transferring knowledge from a person with more experience and expertise in a field (mentor) to a less experienced person (protégé or mentee) to help them grow personally and professionally" (Crumpton-Young et al., 2014). The survey responses related to faculty support and mentoring are summarized in Figure 1. The ANOVA yielded only a non-significant effect of support type, $F(3, 66) < 1.00$, $p = 0.650$. Thus, average ratings of faculty support did not differ across developing research ideas ($M = 3.74$, SD = 1.01), doing coursework ($M = 3.96$, SD = 0.83), advancing research ($M = 3.83$, SD = 0.94), or identifying and achieving career goals ($M = 2.35$, SD = 0.94).

The chi-square tests were significant (and identical) for developing research ideas, $\chi^2(1, N = 23) = 5.26$, $p = 0.022$, doing coursework, $\chi^2(1, N = 23) = 5.26$, $p = 0.022$, and advancing research, $\chi^2(1, N = 23) = 5.26$, $p = 0.022$. This indicates that these three types of faculty support received statistically significantly more *good* ($n = 17$) than *not good* ($n = 6$) ratings from students. However, the chi-square test on identifying and achieving career goals was not significant, $\chi^2(1, N = 23) = 1.09$, $p = 0.297$, indicating that students did not give statistically significantly more *good* ($n = 14$) than *not good* ($n = 9$) ratings to this type of faculty support.

Thus, although mean ratings did not differ significantly across the four types of faculty support, more granular analyzes indicated that students were somewhat equivocal about the quality of faculty support they received for pursuing their career goals. In contrast, students gave solidly good ratings to the other three types of faculty support. The outcomes about support toward career goals may partially be attributed to the Scholars not yet achieving their career goals or their faculty mentor being in a career pathway that does not align with the student's career interests. Future discussions are recommended to distinguish between mentoring to help them identify their career goals and asking Ph.D. graduates about the effectiveness of the mentoring provided in helping them achieve their career goals.

During the focus groups, a brainstorming session was held to identify the types of activities that faculty mentors should pursue in their mentorship of Ph.D. students. Figure 2 was adapted from several sources (Phillips and Pugh, 2010; Crumpton-Young et al., 2014; Gamble and Avery, 2014), and updated based on these brainstorming sessions with the Sloan scholars. To provide detailed guidance, the following 10 practices are recommended for faculty mentoring of doctoral students.

4.3.1. Communicate and agree upon mutual expectations

Communicating about mutual expectations can ease the transition of new students joining a research team. Shore (2014) provides a sample agreement that can be edited to fit the needs of any research group (see Table 6). The agreement summarizes key responsibilities of the advisor and of the student, as well as joint responsibilities to be agreed upon by both individuals.

4.3.2. Engage in short- and long-term planning

To facilitate progress in research and achieving departmental milestones, the Ph.D. student should engage in short-term and long-term planning with guidance from their mentor. Short-term planning should be conducted on a regular basis to set out daily and weekly goals that advance toward the student's research objectives and aims. During the beginning of the mentorship process, more guidance will likely be needed from the faculty mentor and the graduate student mentee. One of the goals of the mentorship experience is to help the graduate student gain confidence and independence (see Mentoring Practice #9). For long-term planning, an annual degree and career progress worksheet (e.g., Stanford University, 2019) can be used during annual check-ins with students to maintain progress over longer time horizons.

4.3.3. Provide a student-centered approach to mentoring

Understand that the student's need for support will change over time. The transitions that they experience throughout graduate school may be a very difficult time for them (see Figure 3A), and students will have varied degrees of preparation for each phase. Thus, a student-centered approach is needed to their mentorship. This may entail offering additional support in preparation for rigorous technical courses or the proposal defense, for example. Additionally, throughout graduate school students may experience major celebrations like weddings or the birth of a child, but students may also experience times of great hardship, such as when a parent or close relative

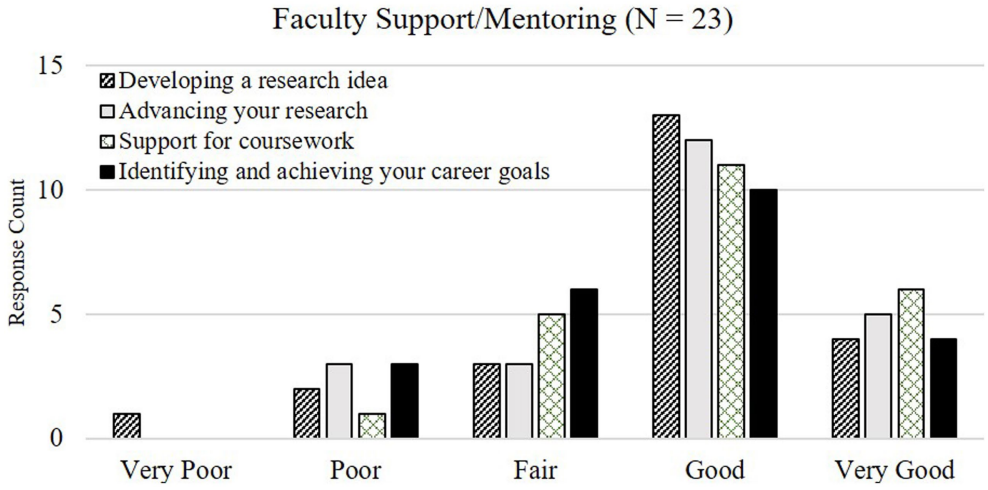

FIGURE 1
Survey results related to faculty support and mentoring.

FIGURE 2
Summary of the types of activities that mentors should be involved in. Adapted from Crumpton-Young et al. (2014), Gamble and Avery (2014), and Phillips and Pugh (2010).

becomes ill or when somebody that they care for passes away. During such times it is important for them to receive support from those around them, and understanding and empathy from their faculty mentors.

The mere act of offering a listening ear can help relieve some of the burden and anxiety that students may be experiencing. During the focus groups, students mentioned that some of the excellent mentors that came to mind were those that they felt they could be open with. Confidentiality is important to maintaining the trust of the student, and to continue having open conversations with them. Breaking that trust can put the mentoring relationship at risk. Mentors should be well-versed about the mental health resources that are available for students at their university, and be comfortable with providing a referral to mental health services when deemed appropriate. Accordingly, training that provides guidance for faculty mentors is needed from the institution to facilitate this process.

TABLE 6 A sample agreement with responsibilities for the research mentor and graduate student.

Mentor	Mentee
• Meet regularly with students and be contactable at other times • Arrange substitute advising during extended absences • Advise on course selection • Help prepare conference and journal presentations based on work with advisor assist with travel applications to attend professional meetings where students establish a "sense of belonging" in the discipline. • Assist in the preparation of comprehensive and oral exams • Help apply for funds to cover direct research costs and to provide stipends to full-time students. • Provide feedback within a mutually agreed time-frame on written work submitted for review.	• Regularly pursue work and keep the advisor informed on progress or problems. • Keep a backup copy of raw data, codes, and other pertinent products from your research. • Submit documents for review in Microsoft Word. • With appropriate guidance, prepare a draft version of the thesis or major report, normally within 3 months of its final presentation for master's degrees, or 6 months for doctoral degrees. • Take a professional role in one's discipline by undertaking at least one student or regular membership in an appropriate professional or academic organization. • Join in the preparation of conference presentations and publications on research and other activities done with faculty members. • Apply for travel grants and internal/external fellowships • Participate to a mutually agreed extent in teaching-related activities (e.g., serve as a Teaching Assistant for a course). • Report annually in writing on progress and contributions (department and university forms). • Regularly attend and participate in research group meetings. • To a mutually agreed upon degree, contribute to advancing team activities that further the common good of the research team (e.g., updating group mailing lists, convening meetings). These tasks will be equitably distributed. • Upon graduation, leave with the advisor a printed copy of the main research report, and an electronic copy that can be modified (e.g., not a PDF) of any data and the text of the thesis or project.
Joint responsibilities	
• Give full credit for the contributions of others and to research funding in all products. • Assign authorship according to the latest APA publication guidelines.	

Adapted from Shore (2014).

4.3.4. Create and promote an inclusive environment

Students may experience microaggressions from others (e.g., other students, faculty, staff) that may be related to their race, gender, gender presentation, sexual orientation, or religion. Such microaggressions can influence a student's mobility across science contexts, create pressure to prove ability and competence, instill a sense of social isolation, and undermine their psychological well-being (Walton and Cohen, 2007; Rainey et al., 2018; Anderson et al., 2020; Murphy et al., 2020). Moreover, students from underrepresented groups may feel a lack of belonging in courses, research groups, and departments where they are the minority (Rainey et al., 2018; Anderson et al., 2020). During the focus group sessions, examples arose where a negative impression was left on a student including: a resistance to upholding minority scholars and being too "sensitive" when voicing an opinion in a male-dominated environment; one student noted, "We're just trying to have an even playing field. Everybody has their own lived experience…You think of things differently." This lack of belonging can undermine motivation and retention among socially disadvantaged students (Walton and Cohen, 2007).

Research mentors should serve as an ally to their students. By offering personal experiences in their discussions with students, mentors can help mentees feel at ease to open up about more difficult conversations. Moreover, when mentees share personal anecdotes that normalize students' social or academic challenges, they can help underrepresented students realize that feelings of belonging uncertainty are both universal and temporary (Murphy et al., 2020). Additionally, it is of utmost importance for universities to establish a welcoming and nurturing campus climate that provides a sense of community and reinforces an equity-oriented culture in order to promote student success (NASEM, 2019). For example, in response to the unique challenges brought forth by the COVID-19 pandemic and to provide a venue for students to have open dialoge on issues of race, UCEM's College of Marine Science (CMS) program established Diversi-Teas on topics including: "How to stay motivated while working at home"; "Mental health and self-care during COVID"; "Systemic Racism: Real Talk: Educate yourself on the history of racism for Juneteenth"; and "Overcoming Imposter Syndrome."

Synergistically, we have closely followed published recommendations (Morehouse and Dawkins, 2006; Sowell et al., 2015) to foster "communal spaces" within graduate departments for underrepresented Ph.D. retention by hosting African American and Hispanic scientists (both internal and external to USF) for research talks, meetings with UCEM faculty champions, and informal conversations with scholars. The students spend private time with guest faculty and role models without USF faculty present to have unrestricted dialoge, build allyship, share personal stories of challenges, and seek professional guidance.

4.3.5. Provide timely and constructive feedback

Giving criticism is one of the main activities that supervisors of doctoral students have to undertake. It is not an easy task, and it should be done in a timely, constructive and supportive manner. Phillips and Pugh (2010) offer guidance to enable effective feedback including: reiterating that the purpose of feedback is to make progress and help the student expand their knowledge and skills; balancing the provision of appreciation and criticism; focusing on the current work

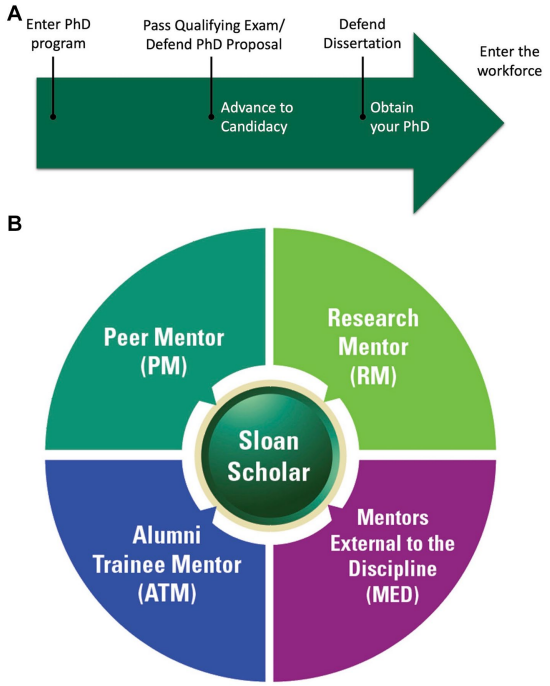

FIGURE 3
(A) Major transitions during graduate school; and **(B)** UCEM Multi-Dimensional Mentoring Model.

and not referring to similar mistakes in prior work; minimizing ambiguity in the critique; actively assessing how much criticism the student can usefully absorb in one sitting; and being clear about *what* needs to be done and why (e.g., if the work needs to be redone, advise the student about how the new and prior versions should differ; Phillips and Pugh, 2010). Accountability and support are needed to help the student advance in their research topic, and ultimately successfully defend their doctoral dissertation.

4.3.6. Understand your student's strengths and weaknesses

During the focus groups, it was noted that students were sometimes unclear about how they were performing from the perspective of their faculty advisor. The Individual Development Plan (IDP) is a tool that students can use to identify an individual's strengths and weaknesses from their role as a researcher (Fuhrmann et al., 2019). Moreover, it provides suggestions for possible career paths that match their strengths and interests. Tracking progress in the IDP and annual progress check-ins (see Mentoring Practice #2), can help faculty mentors guide their student about next steps for improving areas of weakness. The student can also ask their advisor to fill out the IDP for them to learn about their mentor's perception of their strengths and weaknesses.

Since some students experience Imposter Syndrome, having discussions about their strengths may improve their perception of their own abilities. The assessment process can be used as a means of "gaining a sense of belonging to academia, the institution and the discipline" (Chapman, 2017). Students can reduce feelings associated with the Imposter Syndrome with positive experiences; negative experiences, unfortunately, can serve to reinforce those doubts (Chapman, 2017).

4.3.7. Teach and guide your student through the PhD process

Areas where students would benefit from training include:

- How to write a conference paper, journal publication, dissertation, etc.
- How to conduct research
- How to create a poster for a conference
- How to give an oral presentation.

If the graduate student does not have experience in any or some of the areas above, training techniques to consider include: a presentation dedicated to each topic during research group meetings, organizing a writing seminar or a journal club within the research group or department, and recommending professional development activities for students to attend on these topics.

4.3.8. Help your students expand their network and allies

Considering that each faculty mentor has unique strengths, multiple mentors have been recommended for graduate students to help them "acquire interdisciplinary perspectives, develop broad professional competencies, explore career pathways, navigate graduate school, and support their well-being" (NASEM, 2018). Accordingly, a multi-dimensional mentoring (MDM) model has been developed and implemented for the UCEM as shown in Figure 3B. The MDM model consists of four components: (a) a Research Mentor to guide the Sloan Scholar in their research program; (b) a Mentor External to the Discipline (MED), which could be a faculty mentor from a different department or discipline to support the scholar's professional development and well-being; (c) a Peer Mentor (PM) that is an advanced graduate student within the same department or research area who can share "lessons learned" during critical transitional points for UCEM scholars (i.e., transitioning into the first year, preparing for candidacy, and transitioning into the dissertation stage); and (d) an Alumni Trainee Mentor (ATM) who is a USF Sloan alumni or another graduate in the workplace who can provide guidance on Ph.D. expectations, professional networking, and career development (Arellano et al., 2018).

4.3.9. Develop and implement a plan to help students gain independence

By the time a student graduates, they should be an independent researcher. Independence can be encouraged by initially setting very specific short-term goals. Over time, their goals can become more abstract and take longer to complete as the student develops experience and confidence (Phillips and Pugh, 2010).

4.3.10. Aim for continuous improvement of your mentorship

Discuss with other faculty mentors their approach to areas in which you struggle. Also, consider taking a questionnaire on doctoral supervisory practices to identify areas for improvement (see Phillips and Pugh, 2010).

5. The success of the UCEM cohorts

The UCEM successes in mentoring, recruitment, and retention of African American and Hispanic Ph.D. students can be quantified and compared to the national average. USF outperforms the United States average in enrollment, time to degree, Ph.D. completion rates, and employment in STEM related fields (NASEM, 2019). These successes are not coincidental, but are due to the continued funding of the Alfred P. Sloan Foundation and institutional matches from USF.

5.1. Enrollment of African American and Hispanic Ph.D. students

Between Fall 2006 and Fall, 2020, the USF Sloan (Legacy and UCEM) recruited 136 students to its College of Engineering and College of Marine Science. From this group, 43% are African American, 56.2% Hispanic, and 0.8% Native American. With the start of the Sloan program at USF in 2005, historically underrepresented graduate student enrollment increased significantly and has been sustained for 15 years as shown in Figure 4. The ability to coordinate fellowship resources was transformational in reimagining the Ph.D. student population within the College of Engineering and College of Marine Science. From 2004 to 2012, African American Ph.D. enrollment in engineering increased from 5 to 20 (including a peak of 30 1 year earlier), a fourfold increase overall. In a similar vein, Hispanic enrollment within engineering increased from 11 to 45.

Despite recent challenges, our enrollment numbers offer compelling evidence that the USF UCEM has a compelling means for recruiting a critical mass of African American and Hispanic Ph.D. students in disciplines of high national need–engineering, computer science, and oceanography. UCEM Ph.D. enrollment has continued to outperform the national average. In, 2018, African American students accounted for 4.7 percent of USF Ph.D. enrollment in engineering compared to 1.7 percent nationally as shown in Figure 5A. In the same year, Hispanic students represented 5.6 percent of enrollment in USF engineering versus 3.4 percent nationally. Similarly, in oceanography, African American students accounted for 2.8 percent of total graduate enrollment (M.S. and Ph.D.) at USF compared to 1.4 percent nationally as shown in Figure 5B. The numbers were even more inspiring for Hispanic students at USF as they represented 9.7 percent of total graduate enrollment (M.S. and Ph.D.) compared to 7.1 percent nationally.

Fellowship resources from both USF and Sloan were foundational in building critical mass within the College of Engineering and College of Marine Science. With the change from the Sloan Legacy in 2012–2013, research advisors or departments must now provide full assistantships with the UCEM offering enhancement funding to support the scholar's personal well-being and professional development. As such, commitments must now be first obtained from faculty advisors and/or departments prior to extending five-year financial offers. This new need for increased "buy-in" has slowed our recruitment efforts relative to the Sloan Legacy years.

To address recent shortcomings, the goal of the new Sloan award (Years 7–9), is to support strategic planning of historically underrepresented graduate recruitment, mentoring/well-being, and professional development initiatives. Borrowing from the best practices of NSF Engineering Research Centers (National Academies of Sciences, Engineering, and Medicine, 2017), faculty champions have been empowered to lead the Center's recruitment thrust and drive institutional change (Kotter, 2012). In this context, they will have "increased ownership" (Thompson and Campbell, 2013) to identify Sloan applicants earlier in the recruitment cycle (September–December), while facilitating concurrent admissions/departmental

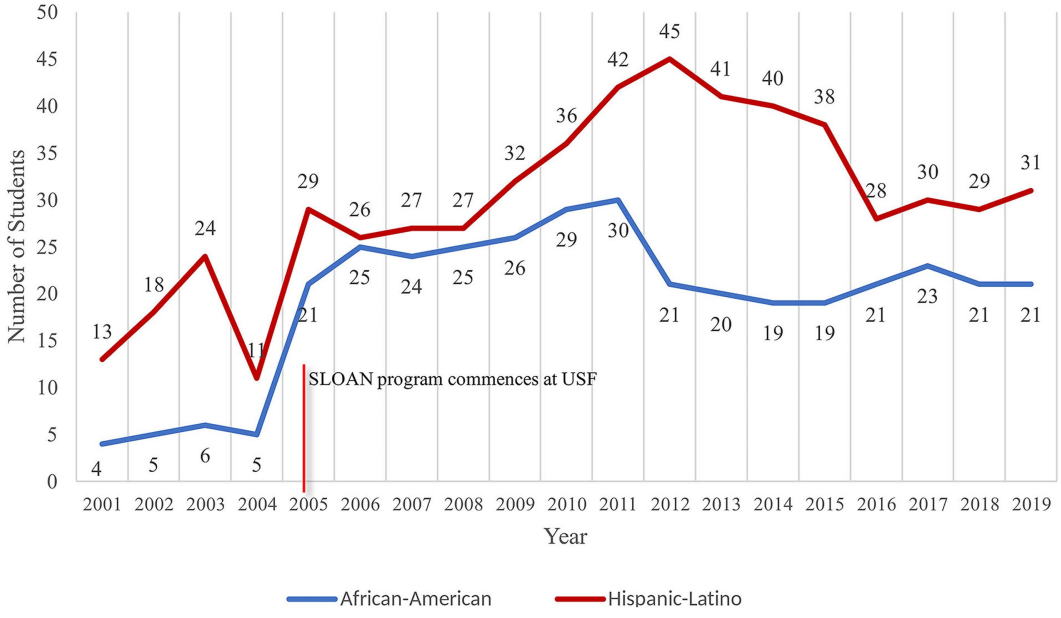

FIGURE 4
Total doctoral enrollment in the College of Engineering (COE) and the College of Marine Science (CMS) per year prior to and during the Sloan programs (Legacy and UCEM) at USF.

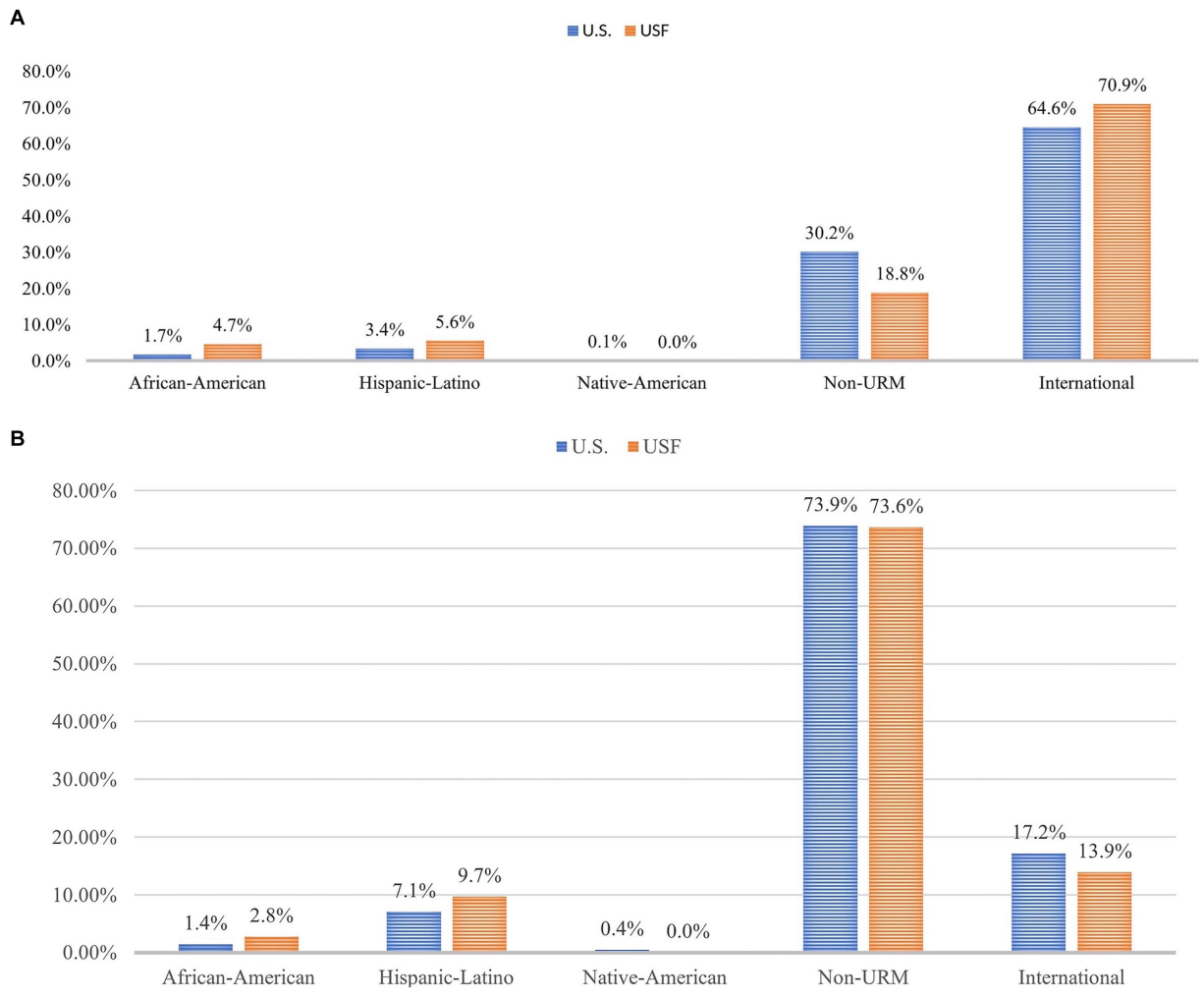

FIGURE 5
(A) Comparison by percentage between United States and USF graduate student enrollment in engineering in 2018 by race and citizenship status. United States. data obtained from Roy (2019); and **(B)** comparison between United States (M.S. and Ph.D.) and USF (Ph.D.) student enrollment in marine science in 2016 considering race and citizenship status. United States. data obtained from NSF NCSES (2019b).

assistantships (January–February), that can be enhanced with UCEM and extramural fellowships such as McKnight, GEM, NSF GRFP, and others, for five-year funding packages prior to the national acceptance deadline of April 15. This framework will maximize coordination of existing internal and external resources to support Ph.D. recruitment of historically underrepresented students in UCEM departments.

5.2. Retention in the Ph.D. program

The average time to degree at USF for all students starting the doctoral program between 2014 and, 2020 is lower than the national levels in, 2018 (see Figure 6A). The data is organized by race and field; note that the marine science program at USF has a relatively small sample size with an average total enrollment of 59 students per year. Additionally, the 10-year USF Sloan completion rate exceeded the national average for both engineering and marine sciences (see Figure 6B).

The success in time to degree and completion rate can be attributed to several factors including the availability of financial resources, peer support within the African American and Hispanic Ph.D. STEM community, program support and oversight, and access to multiple mentors, which are foundational for Ph.D. student success (Reichert, 2013; Sowell et al., 2015; Maton et al., 2016; Petersen et al., 2020). With respect to financial support, participation in USF's Sloan programs has enabled students to maintain an intentional focus on their research milestones and advance within their program in lieu of funding their studies through teaching assistantships.

USF Sloan (Legacy and UCEM) outperformed in nearly every discipline the national percentage of doctoral degrees awarded to historically underrepresented students (see Table 7). Only Hispanic-Latino in the disciplines of Computer Science and Engineering and Medical (Biomedical) Engineering were below the national average.

5.3. Employment

As previously mentioned in the introduction, there is a pressing urgency to increase the representation of historically underrepresented minorities in the STEM workforce, especially in academia due to the lack of diversity (Sowell et al., 2015; Henderson et al., 2020; American Society of Engineering Education, 2021). Most notably, USF Sloan has been successful in the placement of African American and Hispanic

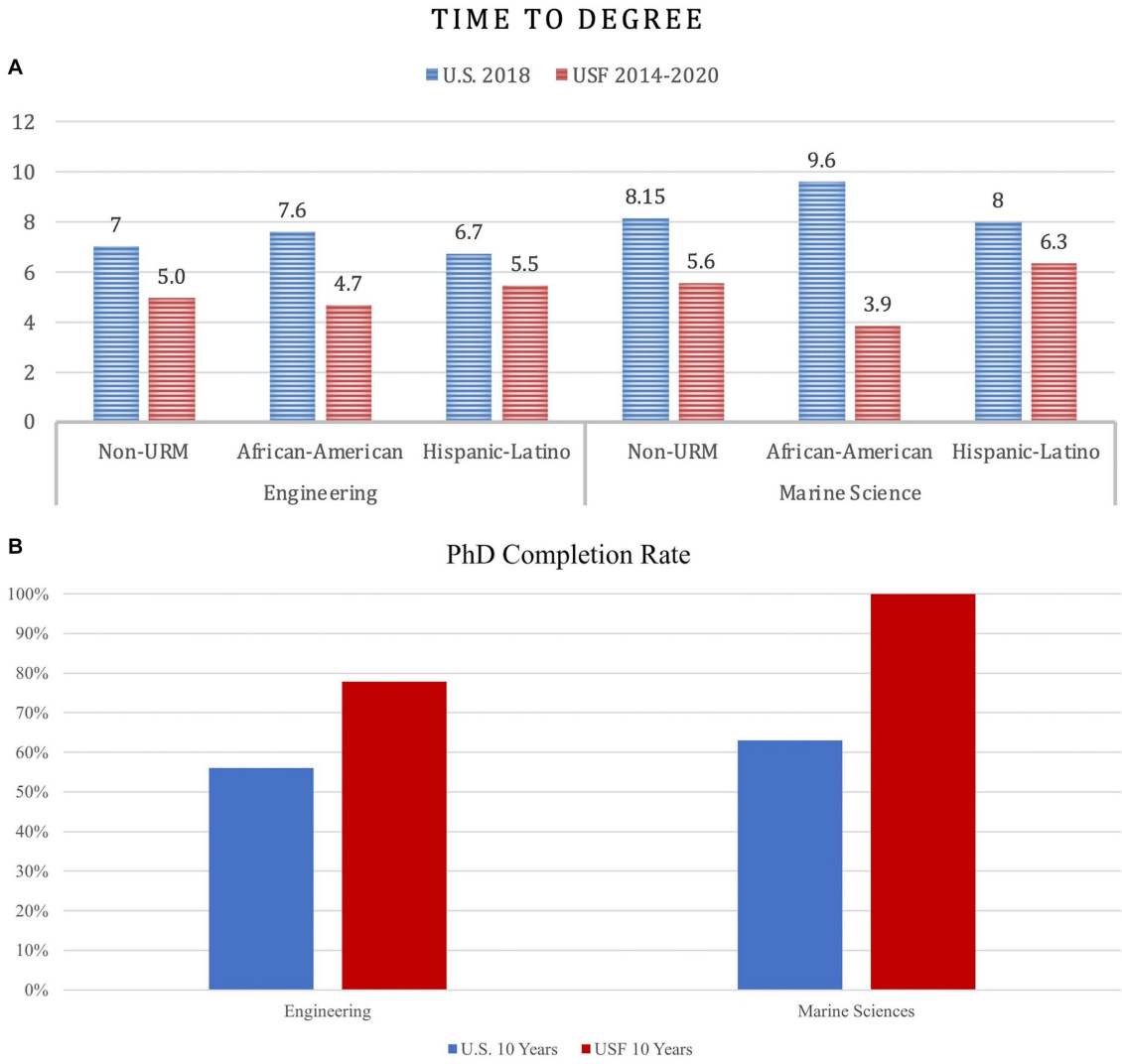

FIGURE 6
(A) Time to completion of the Ph.D. degree for the United States (median) and USF (average) considering race and field (NCSES, 2019a); and **(B)** 10-year completion rates for historically underrepresented students in Engineering and Marine Science (Sowell et al., 2015). Note that Life Science data is used for the time to degree data for the United States 2018 Marine Science representation and for the Ph.D. completion rate data for the United States Marine Sciences representation.

graduates in the academy as faculty or post-docs. In fact, their employment in academia is more than double the national average (see Figure 7; Table 8). USF Sloan Ph.D. engineering graduates also obtain careers in government (federal, state, and local) at nearly twice the national average. Taken together, this led to fewer USF Sloan graduates in industry or non-profit organizations.

6. Conclusion

Closing the gap in graduate school attainment of students from historically underrepresented groups in science and engineering is vital for maintaining the nation's competitiveness in technology and research innovation, but also advancing the economic mobility and societal well-being of future generations as the demographics of our nation becomes increasingly diverse. Toward this goal, this article has presented the USF UCEM's approach for recruiting and mentoring African American and Hispanic graduate students in STEM. Beyond relying on quantitative measures (GPA, GRE), inclusive admissions strategies with an intentional focus on identifying and nurturing students with "unrecognized potential" for graduate school achievement via partnerships with minority-serving institutions/feeder programs along with the establishment of M.S.-to-Ph.D. bridge programs to provide paid research training, academic socialization, cohort programming and community have been at the root of USF Sloan's successes. Lastly, institutional resources to sustain critical mass coupled with incentivizing faculty for strong advocacy to university leadership and external stakeholders have been indispensable.

These practices have been developed over nearly two decades while recalibrating over the years as new insight has been gleaned from Sloan scholars, graduates, and institutional champions. By doing so, USF has established a transdisciplinary community of practice that has prepared Sloan scholars for post-graduate careers through an individualized and personalized mentoring model. Similarly, USF's efforts to build inclusive excellence and foster social justice in graduate education for African American and Hispanic doctoral students in

TABLE 7 Percentage of PhDs awarded in USF and in United States institutions to United States citizens categorized by field of study and race (NSF NCSES, 2019a).

Discipline	USF (2006–2020)			United States (2018)			
	Majority Domestic	USF SLOAN (Legacy and UCEM)		Majority domestic	Minorities		
	Non-URM	African American	Hispanic	Non-URM	African American	Hispanic	Native-American
Marine science	82.8%	6.0%	11.2%	92.5%[a]	2.4%[a]	4.7%[a]	0.5%[a]
Chemical and biomedical engineering (included BME PhD until 2017–2018)	65.0%	20.0%	15.0%	90.0%	1.6%	8.0%	0.5%
Civil and environmental engineering	73.3%	9.3%	17.4%	83.7%	6.3%	9.5%	0.5%
Computer science and engineering	84.8%	6.5%	8.7%	86.3%	2.9%	10.8%	0.0%
Electrical engineering	70.1%	16.4%	13.4%	91.4%	4.1%	4.5%	0.0%
Industrial engineering	57.9%	5.3%	36.8%	88.3%	1.7%	10.0%	0.0%
Mechanical engineering	70.0%	10.0%	20.0%	90.5%	3.0%	6.2%	0.4%
Medical engineering[b]	83.3%	16.7%	0.0%	88.4%	4.6%	6.9%	0.1%
Overall engineering	71.7%	12.4%	15.9%	88.5%	4.2%	7.1%	0.2%

[a]USF Marine Science and national data for Ocean Science (NCSES, 2019a, NSF 19-304, Tables 4–7). USF degree is "Marine Science" and national data (NCSES, 2019a) references Ocean Science.
[b]New USF department began awarding the BME PhD in the 2017-2018 academic year.

STEM is one that can be modeled and adapted by other institutions to align with their institutional culture and values.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, with the exception of data presented in section 4.3 and Figure 1 to protect the anonymity of the participants.

Ethics statement

Ethical review and approval was not required for the program review in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required in accordance with the national legislation and the institutional requirements.

Author contributions

ND-E co-designed the methods, conducted and analyzed the surveys, focus groups and faculty interviews, and contributed to writing the original draft, reviewing, and editing the article. JA acquired and analyzed data for student success, facilitated survey data collection, and contributed to writing the original draft, reviewing, and editing the article. MH acquired and analyzed data for student success, and revised the article. WI facilitated the survey preparation and focus groups, and acquired and analyzed data for student success. DC and JB supported the manuscript preparation and revision. TP and PR supported project management, data collection and analysis, and contributed to the editing and review of the original draft and revisions. BB led conceptualization of the USF UCEM program, collected and analyzed data for student outcomes, and contributed to the original draft and revisions of this manuscript. JLZ-C PI of the UCEM at USF, co-led conceptualization of the USF UCEM program, co-designed the quantitative and qualitative approaches, analyzed data for student outcomes, and contributed to the original draft and revisions. All authors contributed to the article and approved the submitted version.

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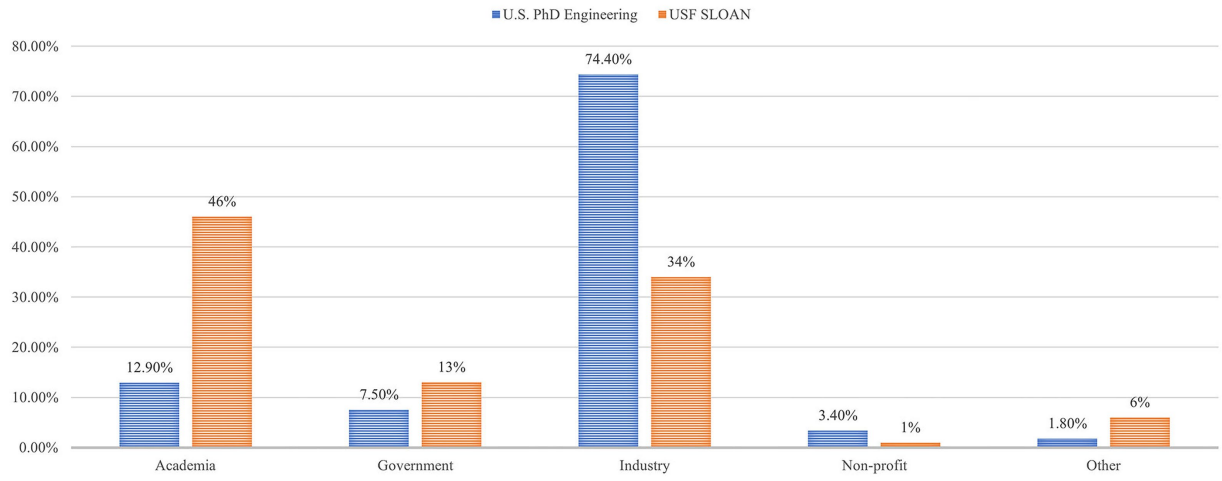

FIGURE 7
Career placement by employment sector for USF Sloan Scholars and United States Ph.D. engineering graduates by field (NSF NCSES, 2019a).

TABLE 8 Employment sectors for historically underrepresented students at USF, historically underrepresented students in all fields (NSF NCSES, 2019a), and engineering students from United States institutions (NSF NCSES, 2019a).

Employment sector	Academia	Government	Industry	Non-profit	Total
USF Sloan (2006–2020)*	34.44%	16.67%	44.44%	1.11%	90
USF sloan engineering*	27.54%	11.59%	55.07%	1.45%	69
USF sloan marine science*	57.14%	33.33%	9.52%	0%	21
NSF URM STEM and humanities (2018)	49.02%	11.25%	19.26%	7.69%	
United States overall engineering (2018)	12.9%	7.5%	74.4%	3.4%	

*Does not include students that left with a M.S. degree or were transferred to departments outside of the College of Engineering or the College of Marine Science (e.g., Geo-Science).

also like to acknowledge Ryan Wakefield from USF's College of Engineering for the preparation of Figure 4.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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