DIVERSIFYING THE STEM FIELDS: FROM INDIVIDUAL TO STRUCTURAL APPROACHES

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DIVERSIFYING THE STEM FIELDS: FROM INDIVIDUAL TO STRUCTURAL APPROACHES

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Editorial: Diversifying the STEM fields: From individual to structural approaches

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Editorial on the Research Topic
Diversifying the STEM fields: From individual to structural approaches

The articles in this collection represent one snapshot of the work conducted under the auspices of the National Science Foundation (NSF). Many, though not all, contributions were presented at the NSF AGEP (Alliances for Graduate Education and the Professoriate) 2017 conference, which was held at the Clark Kerr campus of the University of California, Berkeley. The contributions represent a range of approaches–from theoretical to empirical to programmatic- to addressing equity and representation in graduate education. We firmly believe that each of these approaches richly contributes to the national conversation around broadening participation in STEM, as no one approach is going to give us a full picture of viable solutions and processes. Theoretical work may not translate well to applied settings, and real-world contingencies help elucidate and sharpen theoretical advances. Programmatic work impacts and benefits scholars in real-time, and often serves as a lifeline to underrepresented students navigating the road to the a doctoral degree. At the same time, programmatic work is conducted in settings with multiple factors simultaneously affecting outcomes, thus necessitating empirical work to help tease out and elucidate the processes that affect student success. Empirical work, however, is itself limited by its reductive and controlled nature; it requires both theoretical and programmatic work to remain relevant in the field. Together—theoretical, empirical, and programmatic approaches—help advance the field more than any single approach possibly could.

In this volume, we have also sought to represent a range of lenses through which to approach broadening participation in STEM. Broadening participation, almost by definition, means being open to different ideas and different ways of knowing, and of being critical and reflective about the very way we go about achieving our goals. Broadening participation means that not everybody who participates in a common endeavor will have the same worldviews, or the same understandings of what scholarship, mentorship, and even science might mean. Our efforts too easily become hegemonic

if we do not remain attuned to the assumptions and invisible norms that govern our practices. It is as important for us to remain open to critiques of how we do things, as it is for us to remain vigilant of the critiques we offer for other approaches. Broadening participation cannot be seen as a one-way entryway through which people walk through, fully conforming to the norms, traditions, and standards of the fields they are being invited to participate in. Rather, we must recognize that people are meant to change the field itself, to shape it, and to bring new questions and perspectives along with them. In doing so, our science grows more complex, more complete, and more collaborative.

History

Since 1998, the National Science Foundation (NSF) has invested more than $380 M in alliance-based approaches to increasing the diversity of the faculty in the sciences, technology, engineering, and mathematics fields (STEM).

Begun as the Minority Graduate Education (MGE) program, this initiative has supported universities in changing their institutional, departmental, and organizational cultures. The NSF, at the start, provided funding to higher educational institutions focused on designing and implementing practices that could result in significant increases in recruitment, retention, degree conferral and career (especially academic) entry in the number of African American, Hispanic, and Native American students receiving doctoral degrees in the sciences, mathematics and engineering. Eight universities were awarded nearly $2.5-million MGE grants each and the American Association for the Advancement of Science (AAAS) was charged with evaluating the effectiveness of this new program. This first group of MGE institutions to receive awards was: University of Puerto Rico; Howard University; University of Missouri-Columbia; University of Alabama-Birmingham; Georgia Institute of Technology; University of Michigan; Rice University; and University of Florida.

In 2002 the program was renamed the Alliances for Graduate Education and the Professoriate (AGEP). An additional 18 AGEP Alliances were awarded prior to 2008. The AAAS analysis, in 2010, documented a 21% increase in the average annual number of historically underrepresented minority (URM) PhD recipients in STEM at 19 of the 26 AGEP awardee institutions included in the sample. Further solicitations for NSF AGEP project proposals followed (National Science Foundation, 2012, 2014, 2016). While the long-term goal remained the same, namely, to increase the number of historically underrepresented minority STEM faculty, each call for proposals indicated a shift in expectations and requirements. For example, after the first two cycles, the NSF moved away from direct funding of designated graduate student fellowships for URMs and toward creating alliance-based strategies or "models" for change that might lend themselves to adoption at other institutions in higher education. From the 2012–2016 calls for proposals, more than 112 institutions of higher education partnered in one or more NSF AGEP alliance. Characteristics noted for funded institutions include the Basic Carnegie Classification of Institutions of Higher Education (Indiana University Center for Postsecondary Research, 2021) as well as designations for minority serving institutions (U.S. Department of Education, 2020). All institutions are located within the continental United States. Two-thirds of the partnering institutions have doctoral programs with high or very high research activity according to the Carnegie Basic Classification. The other third comprises schools focused on degrees at the associate's, baccalaureate, and master's program levels, tribal colleges, and a few professional doctoral programs. The number of partners in each alliance ranged from two or three to more than nine. Five institutions, The State University of New York at Stony Brook, Texas A&M University, Tuskegee University, the University of California, Berkeley, and the University of Maryland Baltimore County, lead consecutive or multiple NSF AGEP alliance projects. From 2012–2018, the NSF supported 27 alliances. Since 1998, NSF has funded more than 350 awards to 130 different institutions/organizations. AGEP has reached all 50 states and the Commonwealth of Puerto Rico, the District of Columbia and the Virgin Islands of the United States.

In 2012 a requirement to include social science and education research was added specifically to build the knowledge base about underlying issues, policies and practices that have an impact on the participation, transition, and advancement of URMs in the STEM fields.

By 2019, the funded AGEP projects, collectively, had generated a panoply of programmatic strategies and models, a range of approaches to evaluating their effectiveness, and a growing set of studies related to these efforts. The time was right to share the results among those working on AGEP projects, and beyond it to the community of social scientists interested in addressing the long-standing problems of underrepresentation of racial and ethnic historically minoritized groups in the professoriate. The University of California, Berkeley, hosted the first AGEP conference focused on sharing of social science research results in 2017, establishing a tradition with subsequent conferences held annually—including remotely during the pandemic years. Emerging from the normative context of the work to increase the number and representation of URM STEM faculty of the AGEP alliances, the social science research contributes rigorous documentation of the progress made by these projects, and data-informed suggestions about paths forward toward the long-term goals established by the NSF two and a half decades ago.

In 2021 the NSF issued a new AGEP solicitation, which continues the program's focus on increasing a racially and ethnically diverse STEM academic workforce. The new solicitation supports grants that address institutional changes

in the systemic and organizational policies, practices, culture and climate that support equity and inclusion, and mitigate inequities, in the academic profession and workplaces. AGEP does this through two funding tracks: AGEP Catalyst Alliances and AGEP Institutional Transformation Alliances. All tracks require collaborative university and college teams to use an intersectional lens to promote systemic change that considers the intersection of race, ethnicity, gender and other social identities. The AGEP Catalyst Alliances track supports the design and implementation of one or more organizational self-assessment(s) to collect and analyze data that will identify inequities affecting the AGEP populations; pilot equity strategies as appropriate; and develop a five-year equity strategic plan for the AGEP populations. The AGEP Institutional Transformation track is designed to support the development, implementation, and evaluation of innovative systemic and institutional change strategies that promote equity for AGEP populations, within similar institutions of higher education. ITAs create permanent policy and practice changes that advance AGEP populations, and the project work is expected to be sustained after NSF funding expires.

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Professorial Advancement Initiative: A Cross-Institutional Collaboration to Increase Faculty Diversity in STEM

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In this paper, we describe the model for faculty diversity developed as part of the Professorial Advancement Initiative (PAI) funded under the NSF AGEP program. The PAI, consisting of 12 of the 14 Big Ten Academic Alliance universities,[1] had the goal of doubling the rate at which the universities hired tenure-track minoritized faculty, defined by National Science Foundation as African Americans, Hispanic/Latinx, Native Americans, and Pacific Islanders. This paper reviews the key programmatic elements of the PAI and discusses lessons learned and the practices developed that helped the Alliance achieve its faculty diversity goal.

Keywords: postdoc fellow, mentoring, faculty diversity, systemic change, faculty hiring

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INTRODUCTION

The changing demographics in the United States provide compelling motivation to address the underrepresentation of faculty of color and ethnic minorities, especially in the science, technology, engineering, and math (STEM) fields. However, racial and ethnic inequalities and lack of faculty diversity in STEM fields at institutions of higher education persist as impediments (Yadav et al., 2020). A recent report by the Pew research center found that while 45% of the undergraduate students in the United States are racial or ethnic minorities, only 24% of the postsecondary faculty are nonwhite (Davis and Fry, 2019). Within STEM fields, these numbers are even more dire. As one study found, Black and Hispanic faculty representation in STEM fields range from 0.7 to 5.1% as compared to 4.2–15.1% in non-STEM fields (Li and Koedel, 2017). Even the latest data from the National Science Foundation (NSF) suggest that the number of African Americans, Latinx, Pacific Islanders, and Native Americans in STEM fields ranged from 0.5% (computer and information sciences) to 5.8% in (life sciences; National Science Foundation, 2019). A recent survey of over 7,000 professors at PhD granting institutions in the United States found that within STEM, social sciences, and the humanities median childhood income of those faculty is 23.7% higher than the general public and they are 25 times more likely to have a parent with a PhD. This has important implications for diversifying the professoriate and ensuring the need for institutions of higher education to examine how institutional structures perpetuate inequality, inhibit faculty diversity, and "sustain barriers that

[1]University of Illinois, Indiana University, University of Iowa, University of Michigan, Michigan State University, University of Minnesota, University of Nebraska-Lincoln, Northwestern University, The Ohio State University, Penn State University, Purdue University, and University of Wisconsin-Madison.

prevent minoritized individuals from gaining access to beneficial resources" (Griffin, 2020, p. 282).

Given that having teachers with a demographic similar to the students has been shown to have positive effects on students' sense of belonging and motivation (Egalite and Kisida, 2018), a diverse professoriate can also increase recruitment and retention of students of color in STEM fields. Over the years, many universities have focused on increasing the number of students of color graduating from doctoral programs. These efforts have had a marginal impact. According to the latest survey of earned doctorates, from 2010 to 2019, the proportion of doctorates earned by Hispanic and Latinx students grew from 6 to 8%, while the proportion of doctorates earned by African American students increased from 6 to 7% (National Science Foundation, 2019). The survey also reported that 46% of all doctoral students go on to a postdoctoral position, which while down from 55% in 2010, still represents a significant portion of the post-graduation employment (National Science Foundation, 2019) and a major source of future faculty. Ironically, relatively little attention has been paid to effectively supporting their academic career aspirations. The National Academy of Sciences (2014) pointed out that there is a lack of comprehensive understanding about experiences of postdocs, in general, and even less about postdocs of color.

A recent survey of 7,603 postdocs from 351 institutions found that the majority of the postdocs (57.7%) saw academic research as a long-term goal with industry research as the distant second career goal (17.8%; McConnell et al., 2018, p. 9). The authors found that postdocs' choice to pursue a research-focused academic career was positively correlated with postdocs' views about mentoring support as well as their feelings of career preparedness. The authors further argue that an increase in "mentor support and mentorship may be a particularly important tool for increasing female and under-represented postdocs' pursuit of research-intensive academic careers."

At the same time, prior research has found that postdocs of color face "micro-aggressions, challenges to their competence, different work expectations, expectations to be representatives of minorities in general, and different treatment" (Yadav et al., 2020, p. 176). As a result, postdocs of color often do not have a sense of belonging and feel isolated at their institutions, which is further exacerbated by lack of professional development (Yadav et al., 2020). Yadav et al. (2020) argued that we need to move away from the "one size fits all" model of professional development (PD) and develop support systems specifically for scholars of color. In this paper, we report on the model developed as part of the Big Ten Academic Alliance PAI program.

THE PAI MODEL

To increase the representation of faculty of color, the PAI took a multi-pronged approach, which involved: (a) creating within the alliance a pool of postdocs of color who subsequently were mentored to enter the academy as tenure-track faculty members; (b) fostering systemic change in the faculty hiring processes to increase the diversity of the applicant pool, reduce the negative impacts of implicit bias in the selection process, and mitigate practices that unfairly favor applicants of the majority demographic.

Postdoc and Faculty Mentor Professional Development

Our research identified a number of areas in which postdocs reported they needed mentoring to transition successfully to a tenure-track faculty role (Yadav and Seals, 2019). Most notably, postdocs reported that they needed support in developing their writing skills and ability to secure funding, which are important to be successful in a tenure-track position in our consortium of universities. In addition, postdocs reported a lack of sense of belongingness in their disciplines. In order to address these issues, we engaged postdocs and their faculty mentors in three primary activities: postdoc and faculty mentoring, cross-institutional webinars, and in-person workshops. These activities were informed by the needs of the postdocs that we identified by in-depth qualitative interviews conducted prior to the start of the workshops (see Yadav et al., 2020 about the postdoc needs) as well as suggestions from the postdocs as we did face-to-face and online workshops. Most importantly we discussed the role of mentors, sponsors, and coaches in career development.

The first step was the development of a postdoc mentoring guide for both postdocs and mentors that used the best practices from many sources including the National Postdoctoral Association, the National Institutes of Health, and the National Science Foundation. This guide was used by the mentee and mentor to formulate a customized Individual Development Plan for each postdoc in the PAI program. The purpose of the guide was to help facilitate conversations around PD needs and develop skills necessary for a faculty position. In addition to the mentoring guide, we also engaged both postdocs and mentors in PD activities.

The aim of the postdoc focused PD activities was to equip postdocs with important academic success skills, such as writing effective grant proposals, navigating the job application process, and creating a teaching and research plan. Results from our work suggested that the PD significantly improved postdocs' self-efficacy across the grantsmanship skills and job application process (Yadav and Seals, 2019). Specifically, our results indicate that postdocs were significantly more confident in their grant writing skills after the PD ($N = 41$, $M = 10.40$, $SD = 1.95$) than before ($N = 41$, $M = 6.37$, $SD = 2.30$) as well as applying for academic jobs after the PD ($N = 41$, $M = 20.00$, $SD = 3.58$) than before ($N = 41$, $M = 14.62$, $SD = 4.29$; see Yadav and Seals, 2019 for detailed information about the impact of the workshops). The following quote from a PAI postdoc participant further highlights our impact, "Since being in this program [PAI], I received great mentorship – all aspects of the faculty application process – including the interview as well as what happens once I become a faculty member."

While the function of these activities was to focus on specific skill building, an added value was the sense of community among the postdocs within their own universities as well as across the universities. In particular, the community building provided opportunities for minoritized postdocs to engage with other minoritized postdocs and share their experiences and perspectives as a person of color. For example, understanding

the unwritten rules at a predominantly white institution (PWI) could be entirely different for a person of color. Over 200 postdocs participated in the PD that covered a wide range of topics (see **Table 1** for a detailed description of the activities). In addition to these face-to-face PD activities, we also engaged postdocs in a series of webinars to support their transition into the academy. Examples of the webinars include how to publish in peer-reviewed journals, research-based strategies for overcoming imposter syndrome, and planning for a successful transition to a faculty position.

To further assist PAI postdocs in securing faculty positions, we created a directory that is designed to increase the visibility of our postdocs to faculty search committees. The searchable, online database is publicly accessible and includes relevant information about postdocs for search committees (e.g., education, research, and contact information). The Big Ten universities strongly encourage search committees to utilize this tool for recruitment with some even requiring search committees to actively recruit from the database. Since 2014, a total of 152 postdocs have opted into the directory with 62 transitioning to a faculty position and 22 into other positions within higher education.

Systemic Change in Hiring Faculty

Complementing the PAI's focus on postdoc mentoring and coaching was an effort to educate faculty about diversity and inclusion. An important part of this effort was engaging faculty members in an interactive workshop setting, where attendance by those serving on faculty search committees was required or strongly encouraged at each of the participating institutions. The general approach was borrowed from train-the-trainer workshops developed by the Women in Science and Engineering Leadership Institute at UW-Madison (WISELI),[2] University of Washington ADVANCE program,[3] and Purdue ADVANCE[4] – programs aimed at women in STEM fields. The workshops benefited tremendously from the willingness of these program leaders to share their innovations and materials, which in turn allowed the PAI to develop workshop materials aimed at hiring minoritized scholars.

The first part of the workshop was devoted to establishing the compelling need to diversify the campus community and highlighting the academic benefits of educating students in an inclusive academic environment. We highlighted the importance of those involved in faculty hiring to recognize that diversity is essential, that it provides a competitive advantage, and that inclusion of diverse scholars must be a priority for universities.

A section of the workshop was devoted to "active recruiting" where we discuss aggressive recruiting strategies and the inadequacy of simply placing an ad to attract minoritized applicants. We have heard faculty say *qualified minority candidates do not exist in my field or are few and far between* as justification for why their applicant pool is not diverse. In the workshops, we discussed how to find and attract talented minoritized candidates to apply for faculty positions. An important tool in this regard is the postdoc directory mentioned earlier, which is now a national database. As universities across the country increase the number of URM PhDs they graduate, we expect the PAI database and others like it to grow in proportion.

After a discussion of strategies to achieve a diverse applicant pool, we turned attention to the selection process and practices often employed that unfairly disadvantage minoritized applicants. In support of maximizing the faculty interaction during the workshops, we developed a series of 5 min videos depicting

[2]https://wiseli.wisc.edu

[3]https://advance.washington.edu

[4]https://www.purdue.edu/advance-purdue/

TABLE 1 | Listing of the variety of PD workshops.

Activity	Description
Grantsmanship workshops	These workshops focused on how to find grants and collaborators, write grants, as well as understand the review process. Insights to the university process and a review panel discussion were given. The various parts of a grant were described and examples of successful applications were examined. Postdocs were able to discuss the process for cross disciplinary teams as well as project management and team success.
Academic hiring and job search workshop	This workshop included providing postdocs with the institution's point of view for hiring faculty, how to prepare job application materials (e.g., cover letter, CV, teaching, research, and diversity statements), job interview process, and negotiating job offers.
Personal development and belongingness workshops	These workshops included discussion on how to navigate academic politics as a junior faculty member, especially at PWIs, and specifically designed to address the unique concerns of under-represented faculty members. The postdoc participants were engaged in the planning process by sending topics and themes they felt were important for their professional development. The speakers were intentional in expressing that we are giving them tools to help navigate a broken system that included hiring practices that the PAI project also worked to improve. Speakers were able to address the impact of being the "only one" in a department or team and how to navigate a culture that may have little knowledge of cross race mentoring.
Teaching workshop	This workshop focused on how to be an effective teacher, including developing competencies for teaching online. In addition, the activities also focused on what it means to teach as a faculty of color at a PWI.
Mentoring workshops	These workshops were specifically tailored to postdocs who are in the dual role of mentees to their PI and mentors-in-training as future faculty members. As such, the training provided a focus on both mentoring up and mentoring down. The mentoring workshops leveraged the work of Handelsman et al. (2005) to develop postdocs as effective mentors. Specifically, the workshops involved learning to communicate with mentees, setting goals and expectations, identifying and resolving challenges/issues, and developing aspects of good mentoring. We also addressed mentoring across cultures and finding mentors, sponsors, and coaches.

faculty search committee scenarios, each intended to set the stage for workshop discussion.

Three general sets of videos were produced. The first set includes three videos of a search committee just getting started. The second set consists of three videos depicting a search committee in the process of reviewing applications with the goal of narrowing the field to three finalists for campus interviews. The third set included four related videos of a committee in the final phase after campus interviews had occurred. The videos were designed to sharpen awareness among participants about practices and behaviors, particularly those that are subtle and unfairly disadvantage candidates from minoritized groups.

The workshops also included recommendations on communicating and interacting with candidates throughout the process and an overview of legal issues. Although the workshop is conservative from a legal perspective, we suggest that each university has its legal office review this part of the workshop content.

The efficacy of our model to increase diversity in the professoriate has been measured by the number of minoritized faculty hired during the program at the participating institutions as well as the number of minoritized postdocs who have successfully obtained faculty positions at other institutions. **Figure 1** below shows the breakdown of the number of minoritized faculty hired before the start of our project in 2013. Since the start of the program, 312 minoritized faculty have been hired at participating universities since 2013 with the highest increase 2 years after the program launched (2015–2016). Note that we did not get data from two institutions during the 2016–2017 academic year and data from one institution during 2018–2019 year. In addition, 178 minoritized postdocs have participated in the program since 2013 from which 62 obtained faculty positions and 100 work within a university context, including as research scientists or in their current positions.

DISCUSSION

Over the years of offering the PAI workshops, we have gained many insights through the extensive discussions and information sharing that occurred during these meetings. Several of the most significant recommended practices and observations are mentioned next.

First, when the PAI faculty hiring workshops were first introduced, the notion of unconscious bias was not familiar to many if not most of the attendees. Now virtually everyone who attends the workshops has had some exposure to this topic, and many (if not most) have been involved in multiple diversity and inclusion seminars and workshops within their departments. Therefore, it is important during each offering of the workshop that current obstacles to hiring minoritized scholars are identified (through the workshop discussions) and then addressed in subsequent offerings. Related to this point, the workshops should include facilitated discussion, where everyone can contribute and learn from the experiences of others.

Another practice that has worked well is to have a facilitator at each table, who receives a short briefing handout ahead of time and can facilitate the discussion after viewing a video or session presentation. This allows the participants to stay focused on the topic and ensure that all major points are addressed. We invite the facilitators several times during the year to serve in this role. As they participate, they learn the format and material and are able to lead as session presenters in subsequent workshops.

In order to increase diversity in faculty hiring, we have also come to recognize the importance of establishing policies that support diverse hiring. A notable example of which is the university's workshop attendance policy. When workshop attendance is on a voluntary basis, attendees who participate are typically those who are most informed about the issues. We have a greater impact when participation is strongly encouraged or mandated, particularly for search committee chairs.

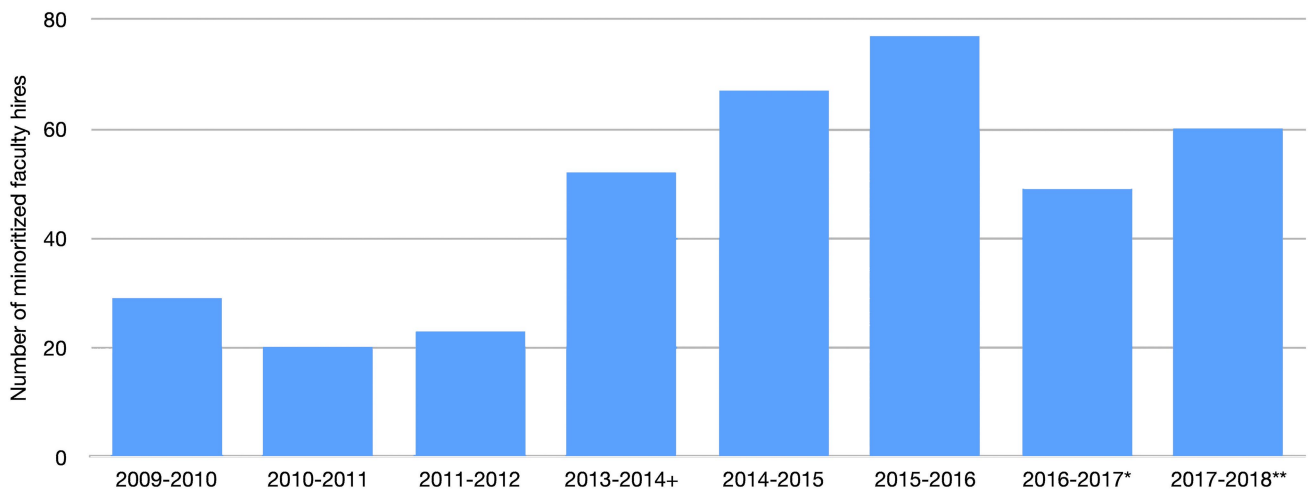

FIGURE 1 | Minoritized faculty hiring across participating institutions. +First year of the project. *Data not available from two participating institutions. **Data not available from one participating institutions.

The greatest benefit is achieved when all search committee members have attended. Another policy that has been effective is to have an oversight mechanism in place to monitor the diversity of the applicant pool for each faculty search. If the pool is not diverse, the overseer (which could be a committee, chair, or dean) would stop the search and require the committee to start over.

When we looked at departments that were not diverse, it appeared faculty demographics were not seen as an urgent problem. A good way to bring attention to department diversity is to make it a topic of reflection and assessment during the annual review of department chairs by deans, and the annual review of the deans by the provost. Similarly, it can be helpful to have "contributions to diversity" in the context of research, teaching, and service as an item for reflection and consideration in the annual review of faculty and as part of the promotion and tenure process.

In summary, our model's success indicates the importance of institutional commitment to increasing the number of faculty of color. One form of the commitment involves developing policies to change the hiring practices and educating faculty on how racial, ethnic, and gender biases can impact who gets interview opportunities for faculty positions and who eventually gets hired into those positions. At one of the participating institutions, policy change made it mandatory for those serving on search committees to attend faculty hiring workshops that discussed subtle bias using the videos discussed previously. In addition, the importance of this was highlighted by the fact that the Provost of the institution kicked off the workshops. Another aspect of the commitment involved each institution developing local capacity to deliver workshops and follow-up refresher courses. Our project team included trainers who visited each of the campuses and trained facilitators at each institution to deliver the faculty hiring workshops.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

AY, MS, CF, and LM contributed to conception of this paper. AY wrote the first draft of the manuscript. MS, CF, and LM wrote the sections of the manuscript. All authors contributed to the article and approved the submitted version.

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Faculty Time Allocation at Historically Black Universities and Its Relationship to Institutional Expectations

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University faculty divide their time into their main academic responsibilities, typically identified as teaching, research, service, and, at institutions with strong ties to their surrounding community, outreach. Most studies of time allocation have focused on faculty at Primarily White Institutions. The present study investigated how faculty at five Historically Black Universities (HBUs) allocate their time to their academic responsibilities. Data were analyzed based on their tenure status, gender, and representation in science, technology, engineering, and mathematics. Faculty estimated the percentage of time they currently allocate (*current*), the time they would ideally allocate (*ideal*), and the time they estimate their institution expects them to allocate (*expected*) to each academic responsibility. Across all demographics, there were discrepancies between current and ideal time allocation to research and teaching and, in some demographics, outreach. The greatest discrepancy between current and expected time allocation was observed in time allocated to research, with women and untenured faculty also showing a discrepancy in time allocated to teaching, and underrepresented faculty showing no discrepancies between current and expected time allocation. Women, untenured, and underrepresented faculty reported that their time allocation patterns were guided by external factors rather than personal preferences. The surveyed faculty also stated that the patterns of effort distribution expected to obtain tenure were not necessarily guided by the faculty handbooks at their institution. Although this study is limited by its relatively small sample size, it provides an insight into how faculty at HBUs divide their time and the reasons for them to do so.

Keywords: effort distribution, expectations for tenure, faculty time allocation, HBCU faculty, tenure at HBCUs

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INTRODUCTION

College and University faculty divide their time among three different academic responsibilities (Easterly and Pemberton, 2008). The first of these roles is *teaching*, which includes sharing of content knowledge with students, developing course materials, designing curriculum, and advising and mentoring students. A second academic responsibility is *research*, or the advancement of

knowledge in their area of expertise, which involves investigation, data analysis, and dissemination of disciplinary knowledge. Finally, *service*, or community-centered activities, includes participation in committees that assist with the effective functioning of their academic unit or institution and professional associations. In addition to these three traditional academic responsibilities, some institutions of higher education also develop close ties to their surrounding communities and, as a result, a fourth, *outreach* function has emerged, with the goal of extending educational and research programs to the community. In this paper, we provide a brief review of the literature on faculty time allocation, with the goal of discussing effort distribution among faculty in science, technology, engineering, and mathematics (STEM) at five Historically Black Universities (HBUs) in the southeastern United States.

Although the primary purpose of institutions of higher education is to promote knowledge through their teaching mission, failures in the educational role of these institutions came under question (e.g., Wingspread Group on Higher Education, 1993). Between 1972 and 1992, there was a significant change in professorial activities, with most faculty's efforts being focused on research and research productivity (Milem et al., 2000). The shift to a focus on research is at least partly determined by institutional pressure to secure external funding (grants and contracts; Anderson and Slade, 2016). The concerns about institutions of higher education failing to serve students' educational needs led to an increased interest in pedagogy and teaching effectiveness (e.g., setting student learning goals for each course), which forced faculty (especially at smaller institutions) to change how much time and effort they allocate to the activities that make up their professorial careers. For example, increased emphasis on out-of-classroom mentoring increases the time allocated to teaching activities (e.g., Bok, 1992). The redistribution of professorial responsibilities became a dividing factor among so-called Research 1 (R1) and Research 2 (R2) institutions (Carnegie Classification of Institutions of Higher Education, 2018), which are characterized by offering graduate programs and very high (R1) and high (R2) research activity, and smaller institutions which do not reach the research and funding amounts to place them into either category. R1 and R2 institutions tend to prioritize research above any other activity, whereas other institutions expect more effort to be allocated to teaching, service, and/or outreach. The framework created by R1 and R2 institutions has created institutions of higher education that strive for homogenization, resulting in an "institutional drift." That is, smaller institutions try to emulate this emphasis on research activities as they "strive to gain greater status and prestige by attempting to resemble more closely those institutions that have already established a 'legitimate' high ranking position in the institutional hierarchy" (Milem et al., 2000, p. 456). However, grants tend to go to larger institutions with state-of-the-art facilities, reducing the available resources for smaller institutions and new faculty (Murray et al., 2016).

College and University faculty are unique workers because their primary commitment is to their field of expertise rather than the institution itself; however, the expectations of each institution can strongly influence how faculty allocate their time to each of their academic responsibilities (Anderson and Slade, 2016). These institutional factors interact with individual characteristics, such as gender, tenure status, academic field, and personal preferences (Link et al., 2008). Untenured faculty are constantly pressured to navigate the expectations for attaining tenure and promotion, which in most post-baccalaureate granting institutions include evidence of successful grant proposal writing (Fairweather, 2002; Easterly and Pemberton, 2008). Link et al. (2008) observed that tenured, senior, faculty at research institutions allocate their time based primarily on personal preferences, gradually decreasing their emphasis on research and increasing their emphasis on teaching (associate professors) or service (full professors) as the pressure for tenure and promotion decreases (but see Betsey, 2007 and discussion below).

There are also well-documented gender differences in time allocation. For example, based on data from the National Study of Postsecondary Faculty of the National Center for Education Statistics, faculty report working 50–60 h/week, with female assistant professors working less time than male assistant professors (Jacobs and Winslow, 2004). Among this work time, females allocate less time than males to research, and more time than males to teaching and service, which may reflect personal preferences (Winslow, 2010) or a feeling of obligation to take on these responsibilities (Bellas and Toutkoushian, 1999; Link et al., 2008; Misra et al., 2012; Dahm et al., 2015; French et al., 2020). Female faculty are also more likely to have a working spouse/partner than male faculty, and they must divide their limited time among work and family responsibilities (French et al., 2020). Indeed, faculty (predominantly female) who provide care for children or other family members devote less time to research (self-imposed deadlines) than to teaching and service (externally imposed deadlines). In contrast, faculty (predominantly male) who have a partner to take caretaking responsibilities devote more time to research as opposed to teaching and service activities (Jacobs and Winslow, 2004; Misra et al., 2012). Indeed, married men tend to exhibit more research productivity (Bellas, 1992; Bellas and Toutkoushian, 1999) and occupy higher-level positions in academic institutions than unmarried men and both married and unmarried women (Bellas, 1992). Females are also more likely than males to be asked and allocate time to out-of-classroom activities, such as student advising of both academic and personal issues (El-Alayli et al., 2018), which are rarely taken into consideration for tenure and promotion decisions (Babcock et al., 2017).

Despite the wealth of information on gender disparities in time allocation, relatively few studies have included race as a factor when investigating time allocation to academic activities. Some of these studies have suggested that race is not a critical factor when looking at time allocation (e.g., Elmore and Blackburn, 1983; Russell et al., 1991). However, the usually small sample of individuals from racial and ethnic minorities underrepresented in academia (hereafter *underrepresented minorities* or *URMs*) may obscure differences between URM and nonURM individuals in their time allocation (see Bellas and Toutkoushian, 1999, for discussion). In a study analyzing the 1993 National Survey of Postsecondary Faculty (IPEDS;

National Center for Education Statistics, 1994), Bellas and Toutkoushian (1999) observed that Black faculty spent less time on teaching activities and more time in service activities than White faculty. The critical variable appeared to be the likelihood of doing "paid" vs. "unpaid" work, with women and URMs receiving more requests and being more willing to engage in unpaid activities. Furthermore, women and URMs may not be part of the networks that increase publication success (Exum, 1983); indeed, Black and female faculty tend to produce fewer publications than White male faculty (Betsey, 2007).

Although service is usually the least important criterion in promotion and tenure decisions (e.g., Blackburn and Lawrence, 1995; Washburn-Moses, 2018), it can be difficult for faculty to balance the activities that "matter" for tenure and promotion (i.e., research and teaching) and the service responsibilities that are essential for shared governance (Baez, 2000). Women are most likely to be asked to complete and engage in service activities, especially those internal to the institution (Guarino and Borden, 2017; O'Meara et al., 2017a,b). The increasing interest in diversity, equity, and inclusion may have had the unfortunate effect that URMs receive excessive requests for service, including participation in committees and student advisement. The direct consequence of this higher investment in service is that time resources cannot be allocated to research and teaching activities (i.e., these activities are mutually exclusive; Fairweather, 1993; Dey et al., 1997). However, due to the requirement to fulfill teaching duties, increased time allocation to service is usually associated with reduced time allocated to research (Bellas and Toutkoushian, 1999; Betsey, 2007). Some theorists have correctly argued that service provides URMs with status that empowers them as agents of change in their institution and should be weighed as equally important as service and research (Baez, 2000). However, the reality is that tenure and promotion decisions at most US universities (but not necessarily at primarily teaching colleges) continue to be based on research productivity and teaching effectiveness, with the former weighing more heavily on tenure and promotion decisions (Easterly and Pemberton, 2008). Furthermore, faculty at most universities are pressured to actively seek external funding (Kleinfelder et al., 2003), as exemplified by faculty search ads, which is difficult for primary caretakers who must make decisions as to whether to pursue external funding or allocate time to family responsibilities (Herbert et al., 2014).

Note that most studies on faculty time allocation have been conducted by surveying faculty at large, Primarily White institutions (PWIs; e.g., Misra et al., 2012; Dahm et al., 2015; O'Meara et al., 2017a,b), using national survey data but focusing on R1 institutions (e.g., Link et al., 2008; Anderson and Slade, 2016), or have collapsed Colleges and Universities in terms of whether they are 2- or 4-year institutions or whether they are PWIs or HBUs (Bellas and Toutkoushian, 1999; Perna, 2001; Jacobs and Winslow, 2004; Betsey, 2007; Winslow, 2010; BrckaLorenz et al., 2018; French et al., 2020). The present study focused on the specific context of Historically Black Colleges and Universities (HBCUs) and, specifically, HBUs. HBCUs surged in the US in the early 19th century to provide educational opportunities to Black and African-descent individuals who were not welcome at existing educational institutions. Starting with the founding of the African Institute (now Cheyney University) in 1827, and until 1964, HBCUs were established to serve students from Black and African descent, later extending this role to first-generation and low-income students (Thurgood Marshall College Fund, n.d.). Minority-serving institutions founded after 1964 are known as Primarily Black Institutions (PBIs). PBIs are institutions characterized by, "at least 40% African-American students, minimum of 1,000 undergraduates, have at least 50% low-income or first-generation degree seeking undergraduate students, and have a low per full-time undergraduate student expenditure in comparison with other institutions offering similar instruction" (Thurgood Marshall College Fund, n.d.). HBCUs have historically been student-centered (Fountaine, 2012) and community-oriented (Gasman, 2013). The value of HBCUs has been frequently questioned (Wilcox et al., 2014), with growing pressure to serve non-Black students (e.g., Outcalt and Skewes-Cox, 2002). However, they are still relevant as producers of Black leaders (Albritton, 2012), are among the leading institutions producing Black engineers (Boyington and Moody, 2021), and more than 30% of all Black science and engineering doctorates (UNCF, n.d.). Importantly, HBCUs are not homogeneous, ranging from 2-year institutions to doctoral and professional degree-awarding institutions, from elite schools with competitive admissions to open-admission institutions, as well as diverse levels of funding, student profiles, ranking, and Afro-centric curricula. Thus, analyses of HBCUs that "lump" all institutions into a single category fail to account for the diversity in their institutional missions (Arroyo and Gasman, 2014; Wilcox et al., 2014).

The rising costs of education have led many institutions of higher education to experience financial challenges (Betsey, 2007; Gasman and Commodore, 2014). Even with the signing of a Presidential Executive Order increasing federal funding to HBCUs (2017), the Congress HBCU PARTNERS bill (2021), and recent private donations in excess of $800 million to minority-serving institutions including several HBCUs, the financial gap between HBCUs and PWIs is still large. HBCUs tend to have small endowments, receive less state funding than larger PWIs, and depend heavily on fundraising, and these funding woes cannot be compensated with tuition increases that are incompatible with serving minority, first-generation, and low-income students (Gasman, 2013; Gasman and Commodore, 2014). Financial pressures have led to a reduction in tenure-track faculty hiring or hiring freezes, an increase in adjunct faculty, and reliance on online programs. Furthermore, financial struggles directly and indirectly affect faculty's time allocation, as the institutions try to maintain their educational and community service missions. HBCU faculty teach an average of four courses per semester, receive salaries that are significantly lower than peers at other institutions, and are expected to mentor and assist students, especially those from disadvantaged backgrounds (Gasman, 2013). These requests may decrease time otherwise allocated to research, considering that the number of research products from HBCU faculty is lower on average than from faculty at PWIs, although overall career

productivity is similar to faculty at PWIs (Betsey, 2007). Contrary to Link et al.'s observation of decreased research productivity as faculty advance in rank, Betsey (2007) observed that HBU faculty productivity increases as they advance in rank, probably due to increased teaching experience or reduced teaching loads. However, these observations do not take into consideration faculty attrition, given that individuals who fail to exhibit research productivity may not attain tenure and progress in the academic ranks.

The present study surveyed STEM faculty at five HBUs in the southeastern United States, asking them to estimate their current time allocation, their ideal time allocation, and their expected time allocation. The goal was to determine not only how their time is used, but also their perceived constraints to allocate their time in a way that is convenient for the progress of their careers, and whether they were well informed about the time distribution that was expected from their institutions. We will discuss faculty estimations of time allocations in light of the tenure and promotion guidelines published in the faculty handbooks at the HBUs that participated in this study. Each institution defined productivity in the areas of teaching, research, and service/outreach in accordance with their institutional values. Although all institutions describe research expectations (peer- and non-peer-reviewed publications and peer evaluations), only the larger institutions specifically mention grant proposals and attainment of external funding as essential to demonstrate research productivity. The smaller institutions appear to emphasize teaching excellence, including student advisement, curriculum/course development, and mentorship. Service to the University is also emphasized, with some institutions encouraging "unpaid" service activities, such as attending informal events on campus (e.g., athletic events).

Previous studies of faculty time allocation have analyzed faculty across disciplines, specifically the humanities and STEM, but despite observing some differences across fields, data have been interpreted in terms of another variable (e.g., gender, Winslow, 2010). Some studies highlighting research productivity have collapsed data from faculty across the arts and sciences, consistent with the organization of Colleges at many institutions (e.g., Bellas and Toutkoushian, 1999; French et al., 2020), or focused on STEM faculty (e.g., Misra et al., 2012; Anderson and Slade, 2016). Our study focused specifically on faculty in four STEM fields (biology, engineering, mathematics, and agricultural sciences), which represent different aspects of STEM, and which have expectations of research productivity for successful attainment of tenure and/or promotion. STEM faculty at HBUs are of particular interest because URMs make up approx. 30% of the US population but only about 9% of STEM faculty in the US (National Center for Science and Engineering Statistics, 2017) and a large proportion of these URM STEM faculty are housed at HBUs (Strauss, 2015; Gasman, 2021). Thus, as a whole HBUs have a more diverse professoriate than other institutions of higher education (Strothers, 2014) and are a unique environment in which URMs are *not* a minority. Because of these unique characteristics, it is possible that some of the constraints known to determine faculty effort distribution do not apply to faculty at HBUs. For example, it is possible that URM faculty do not experience the pressures related to tokenism they experience at PWIs or that untenured faculty allocate their effort in a manner consistent with the teaching mission of HBUs. However, the experiences of STEM faculty at HBUs have not been the focus of research on faculty time allocation, resulting in a void in our understanding of the reasons that foster or impede the success of HBU STEM faculty.

Time allocation has been viewed as a determinant of job satisfaction. In lieu of asking participants directly how satisfied they are with their job, we chose to ask them to estimate their *ideal* time allocation. This was intended to provide a measure of the deviation between what faculty expect their job to be and their actual work responsibilities, an indirect measure of professional satisfaction. External pressures are known to decrease teaching effectiveness (BrckaLorenz et al., 2018), change faculty behavior and reduce job satisfaction (e.g., Anderson and Slade, 2016), and increase turnover intentions (French et al., 2020). Finally, estimates of *expected* time allocation, faculty's view of what their institution expects them to do, provide an idea of what the faculty perceive they ought to do to meet the requirements of their position. Taken together, these measures can provide a rough picture of how well institutional expectations match the "ideal job" for HBU faculty, and the extent to which external pressures forces faculty to deviate from that ideal.

MATERIALS AND METHODS

Participants and Procedure

Participants were STEM faculty at five HBUs in the southeastern United States. They were invited to participate in the study *via* an email solicitation sent to all STEM faculty having a tenured or tenure-track position at their institutions. A total of 473 individuals were invited to participate in the study. Survey return rate was 18% ($n = 84$). Individuals electing to participate were provided with an informed consent, and only participants agreeing to the terms of this informed consent progressed to the study. Participation required completing an online survey, which included demographic questions, as well as questions about their effort distribution. Participation was incentivized *via* monetary compensation in the form of gift cards. All procedures described below were carried out with approval of the Oakland University Institutional Review Board (IRB) and were conducted in accordance with the guidelines of the 1964 Helsinki Declaration and its later amendments.

The participating institutions were all doctoral-granting institutions, with three of them labeled as "Doctoral Universities, higher research activity," and two of them labeled as "Masters colleges and universities, larger programs" according to the Carnegie Classification of Institutions of Higher Education (2018). All of the participating institutions offer post-baccalaureate degrees in four selected fields, which represent the four "hard" science areas of the Biglan (1973) model: hard-life-pure (biology/microbiology), hard-life-applied

(agronomy/agricultural sciences/agricultural economics), hard-nonlife-pure (mathematics/statistics), and hard-nonlife-applied (engineering/information sciences). Currently, 107 institutions are designated as HBCUs (three of these institutions were closed at the time this study was conducted), and 14 of those institutions offer all four of the disciplines selected for study; thus, the five participating institutions represent 5% of all HBCUs and 36% of HBUs offering all four of the selected disciplines. The participating HBUs were all located in neighboring states, providing similar social contexts for the institutions. The study consisted of a survey, which was administered in alternate semesters (Round 1, $n = 48$; Round 2, $n = 46$). In order to protect the anonymity of responses, participants were asked to create a survey ID, which was used to identify individuals who had participated in Round 1 in order to avoid duplication of data in Round 2. Ten individuals completed the survey in both Rounds 1 and 2, and for all questions that were repeated across surveys, only their most recent response was used for analyses. Thus, all data analyses reflect one response from each participating faculty member.

Measures

Current and Ideal Time Allocation

As part of a larger research project investigating other aspects of faculty experiences at HBUs, participants were asked to estimate the percentage of their time that is allocated to each of the required professorial activities: research, teaching, service, and outreach. The question was a "zero-sum" question, so that participants had to estimate all of their work time in a week (100%) how much (in percentage) was allocated to each activity; the sum of all time allocation had to add up to (but could not exceed) 100% (the total amount of time worked in a week). The prompt was as:

> *Estimate the number of hours per week that you devote to each of the following activities. Please read the descriptors carefully and select the answer that is most consistent with your actual experience in an average week.*
>
> *Research: time devoted to research, literature reviews, laboratory time, writing papers, writing grants, and completing administrative duties directly related to research.*
>
> *Teaching: time devoted to class preparation, classroom or online teaching, grading, office hours and advising, and administrative duties related to teaching.*
>
> *Service: time devoted to serving in committees or functions that serve your department or academic unit, college or school, university, professional organizations, and your profession in general.*
>
> *Outreach: time devoted to expanding the impact of your field and institution to benefit the community at large. If your institution categorizes outreach as a form of research, teaching, or service for the purposes of promotion and tenure and/or faculty evaluation, please include the time you devote to these activities under the category that is consistent with your institutional policies.*
>
> *What is your current time distribution, as represented by a proportion or percentage? Note that you will need to allocate time in such a way that it adds up to 100% across all categories. If one of the categories does not apply to your appointment, leave it as a zero (0).*

Note that asking about time allocation using a zero-sum format normalizes potential wide differences in the estimation of the number of hours worked in a week. Following the estimation of time allocated to each activity in a working week, participants were asked to provide an estimation of the percentage of time they would like to allocate to each activity (their "ideal" time distribution). The prompt for this estimation was as:

> *What would be your ideal time distribution, as represented by a proportion or percentage? Note that you will need to allocate time in such a way that it adds up to 100% across all categories. If one of the categories does not apply to your appointment, leave it as a zero (0).*

To better understand the pressures imposed on time allocation, participants were asked whether obtaining external funding to cover their research expenses was required by their academic unit in order to successfully attain tenure and promotion. Current and ideal time allocation questions, as well as the research requirement question, were included in Surveys 1 and 2.

Time Allocation in Preparation for Tenure and Promotion

A sub-sample of participants was asked what percentage of their time should be allocated to each activity in accordance to their institutional tenure and promotion policies. The question was added during the second round of surveying in order to better interpret the data obtained for the estimates of current and ideal time allocation. The sample participating in both rounds of surveys was roughly equivalent (50 and 47.8% untenured, 39.5 and 37.2% female, and 44.7 and 28.3% URM faculty for Rounds 1 and 2, respectively). They were asked to estimate the time those policies required that they allocate to each of their academic activities. The prompt was as:

> *Based on your department/academic unit's current promotion and tenure guidelines, what should be the time distribution of a faculty member in your department? Note that you will need to allocate time in such a way that it adds up to 100% across all categories. If one of the categories does not apply to your appointment, leave it as a zero (0).*

Untenured faculty were further asked whether their current time distribution was adequate to obtain tenure and promotion,

which they rated in a 4-point scale (definitely not, probably not, probably yes, and definitely yes). Further, all faculty were asked whether their academic unit's actual criteria for tenure and promotion were consistent with those specified in the faculty handbook, an informal convention that applied to their academic unit, or a guess they had because they were not sure about the actual requirements.

Statistical Analyses

Current and ideal time allocation data were analyzed using ANOVAs. Estimate (current vs. ideal) and activity (research vs. teaching vs. service vs. outreach) were entered into the ANOVA as within-subjects factors, whereas demographic variables (tenure status, gender, and representation in STEM) were entered into the ANOVA as between-subjects factors. The research questions led to expected interactions, and whenever an interaction was observed, the source of the interaction was assessed using univariate tests of significance. The large number of univariate tests that resulted from each analysis can increase the likelihood of a Type I error. This issue was addressed using a False Discovery Rates correction, in which the value of p for each comparison was adjusted using the Benjamini and Hochberg (1995) method. Briefly, this correction estimates that, if the level of significance is set at $\alpha = 0.05$, there is a 5% likelihood that a comparison reveals a "false positive" (Type I error). The method ranks the values of p for all comparisons based on their value and corrects the significance level (p_{adj}) using the formula:

$$p_{adj} = \left\{ \frac{total\ number\ of\ p\ values}{p\ value\ rank} \right\}$$

Comparisons between expected and current time allocation used Welch's t-test. Welch's t-test (rather than student's t-test) was used for analyses due to the difference in size and variance of the samples compared (Ruxton, 2006). Welch's t-test adjusts degrees of freedom by dividing each group's variability by the group's size (rather than using a pooled variability score).

Comparisons among frequencies were conducted using the chi-square (χ^2) statistic.

RESULTS

Descriptive statistics for demographic information are presented in **Table 1**. Data are not divided by institution or academic unit in order to ensure the anonymity of the participants' responses. Five participants did not provide information about their gender and were excluded from the gender analyses.

Current and Ideal Time Allocation

Time allocation responses were obtained from 84 participants. A 2(estimate: current vs. ideal) × 4(activity: research vs. teaching vs. service vs. outreach) ANOVA revealed a main effect of activity, $F(3, 249) = 95.09$, $p < 0.001$, and an Estimate × Activity interaction, $F(3, 249) = 42.31$, $p < 0.001$ (**Figure 1A**). The interaction was further analyzed with univariate tests, which revealed that participants rated the time currently allocated to teaching and service to be higher than they would like to allocate to those activities, $p_{adj} < 0.001$ and 0.05, respectively, and the time currently allocated to research and outreach to be lesser that they would like to allocate to those activities, both $p_{adj} < 0.001$.

Tenured vs. Untenured Faculty

A 2(estimate) × 4(activity) × 2(tenure status: tenured vs. untenured) ANOVA revealed a main effect of activity and an Estimate × Activity interaction, Fs(3, 246) = 95.43 and 49.50, ps < 0.001, respectively (**Figure 1B**). The main effect of tenure status and all interactions with this factor were not significant, all ps > 0.17. However, the ideal service allocation was higher for tenured than untenured faculty, $p_{adj} < 0.01$. When other activities were considered, both tenured and untenured faculty rated their current time allocation to research as lower than their ideal time allocation for research (both $p_{adj} < 0.01$), their current time allocation to teaching as higher than their ideal time allocation to teaching ($p_{adj} < 0.05$ and 0.005 for tenured and untenured faculty, respectively), and their current time allocation to outreach as lower than their ideal time allocation to outreach (both $p_{adj} < 0.05$). Thus, tenured and untenured faculty estimate their current time allocation to research and teaching similarly, and their ideal time allocation would increase research time and decrease teaching time in a similar manner. However, tenured faculty seem willing to allocate more of their time to service than untenured faculty.

NonURM vs. URM Faculty

A 2(estimate) × 4(activity) × 2(representation: URM vs. nonURM) ANOVA revealed a main effect of activity and an Estimate × Activity interaction, Fs(3, 246) = 82.99 and 34.11, ps < 0.001, respectively (**Figure 1C**). However, unlike the tenure analysis, there was a three-way, Estimate × Activity × Representation interaction, $F(3, 246) = 2.95$, $p < 0.05$. URMs estimate their current time allocating to outreach to be higher than nonURMs, and their ideal time allocation also includes more outreach than nonURMs, both $p_{adj} < 0.05$. Comparisons between current and ideal time allocation revealed that both URMs and nonURMs would desire to devote more time to research ($p_{adj} < 0.05$ and 0.001, respectively) less time to teaching ($p_{adj} < 0.05$ and 0.001, respectively), and more time to outreach (both $p_{adj} < 0.05$). Thus, although nonURMs and URMs have similar patterns in their current and ideal time allocations, URMs seem to be committing more time to outreach than nonURMs.

Male vs. Female Faculty

Five participants declined to provide their gender; thus, the gender analyses are based on 79 participants. A 2(estimate) × 4(activity) × 2(gender: male vs. female) ANOVA revealed a main effect of activity, $F(3, 231)$, $p < 0.001$, an Estimate × Activity interaction, $F(3, 231)$, $p < 0.001$, and an Activity × Gender interaction, $F(3, 231)$, $F(3, 231) = 2.85$, $p < 0.05$

TABLE 1 | Demographic information of the participant sample.

Gender	Representation	Tenured	Untenured	Total
Male	URM*	7	6	49
	nonURM**	17	19	
Female	URM	8	7	30
	nonURM	7	8	
Declined to provide gender	URM	2	0	5
	nonURM	2	1	
	Total	43	41	84

*URM: n = 30; **nonURM: n = 54.

(**Figure 1D**). There were no gender differences in current time allocation (all $p_{adj} > 0.37$). However, when ideal time allocation was compared, males wished to devote less time than females to teaching, $p_{adj} < 0.005$. Both males and females would like to allocate more time than they currently do to research ($p_{adj} < 0.001$ and 0.005, respectively), and less time to teaching ($p_{adj} < 0.001$ and 0.01, respectively). Males would also like to allocate more time than they currently do to outreach ($p_{adj} < 0.05$). Importantly, when the current time allocation to research and teaching was compared, both males and females reported allocating more time to teaching than research ($p_{adj} < 0.05$ and 0.005, respectively), whereas the ideal time allocation to teaching vs. research differed for males but not for females ($p_{adj} < 0.01$ and > 0.35, respectively). Thus, although males and females allocate about the same amount of time to their professorial activities and would like to allocate more time to research and less time to teaching than they currently do, males' ideal distribution of time includes allocating more time to research than teaching, whereas females' ideal distribution of time includes devoting equivalent time to teaching and research, and significantly more time to teaching than males.

Time Allocation and the Path to Tenure

Expected Time Allocation

A sub-sample of participants ($n = 41$) was asked to estimate their academic unit's expectations of time allocation in order to grant faculty tenure and promotion. There were no interactions between expected time allocation and tenure status, representation, or gender (all $ps > 0.18$), suggesting that faculty across all demographics have a consistent view of their institution's expectations for research, teaching, service, and outreach. Thus, data were collapsed across these factors. A one-way ANOVA revealed that expected time allocation to academic responsibilities was rated differently, $F(3, 132) = 70.90$, $p < 0.001$. Expected time allocations to teaching and research were higher than the expected time allocations to service and outreach, and expected time allocation to service was higher than to outreach, all $p_{adj} < 0.001$. However, expected time allocation to teaching and research did not differ, $p_{adj} > 0.37$. Thus, faculty estimated that they should allocate similar amounts of time to their teaching and research, and less time to their service and outreach, although outreach was viewed as the less valued activity.

Note that both tenured and untenured faculty were asked to answer this question and their responses entered into the analyses because this allowed for a rough determination of whether faculty on the tenure track (the faculty who are trying to meet expectations) had similar views of the institution's expectations as faculty who had already gone through tenure and promotion (the faculty who evaluate those expectations). The lack of differences in estimation of expected allocation between tenure-track and tenured faculty suggests a consistent view of institutional expectations to be met by faculty who successfully attain tenure and promotion.

Alignment of Current and Ideal Time Allocation to Expected Time Allocation

Current time allocations were compared to the expected time allocation using one-tailed Welch's *t*-tests (see **Figures 1A–D**). For the overall sample, time allocated to research was estimated to be lower than expected, $t(108) = 2.60$, $p < 0.01$, and time allocated to teaching was estimated to be higher than expected, $t(120) = 1.94$, $p < 0.05$. Tenured and untenured faculty estimated that they allocate less time to research than expected, $t(63) = 2.00$ and $t(46) = 1.84$, both $ps < 0.05$. However, only untenured faculty estimated the time allocated to teaching to be higher than expected, $t(56) = 1.69$, $p < 0.05$. NonURM faculty estimated that their time allocation to research was lower, $t(71) = 2.18$, and their time allocation to teaching was higher, $t(81) = 1.91$, than expected (both $ps < 0.05$). Surprisingly, URM faculty did not exhibit any discrepancies between their current time allocation and the time allocation expected by their institution, all $ps > 0.08$. Finally, both males and females estimated that their time allocation to research was lower than expected, $t(58) = 1.77$ and $t(39) = 2.26$, respectively, both $ps < 0.05$. However, only females estimated their time allocation to teaching to be higher than expected, $t(41) = 1.87$, $p < 0.05$. These results suggest that, although faculty overall consider that they should be allocating more time to research and less time to teaching, URMs consider that they are currently allocating the time that is expected to both of these activities. Across all levels of representation (URM and nonURM) females (but not males) and untenured faculty appear to estimate that the time allocated to their teaching (which in our survey included student advising and supervision) is not consistent with what they should be allocating to their professorial activities in order to attain tenure.

When ideal and expected time allocations were compared, the overall sample estimated their ideal time allocation to teaching to be lower than expected, $t(90) = 2.34$, $p < 0.05$, which

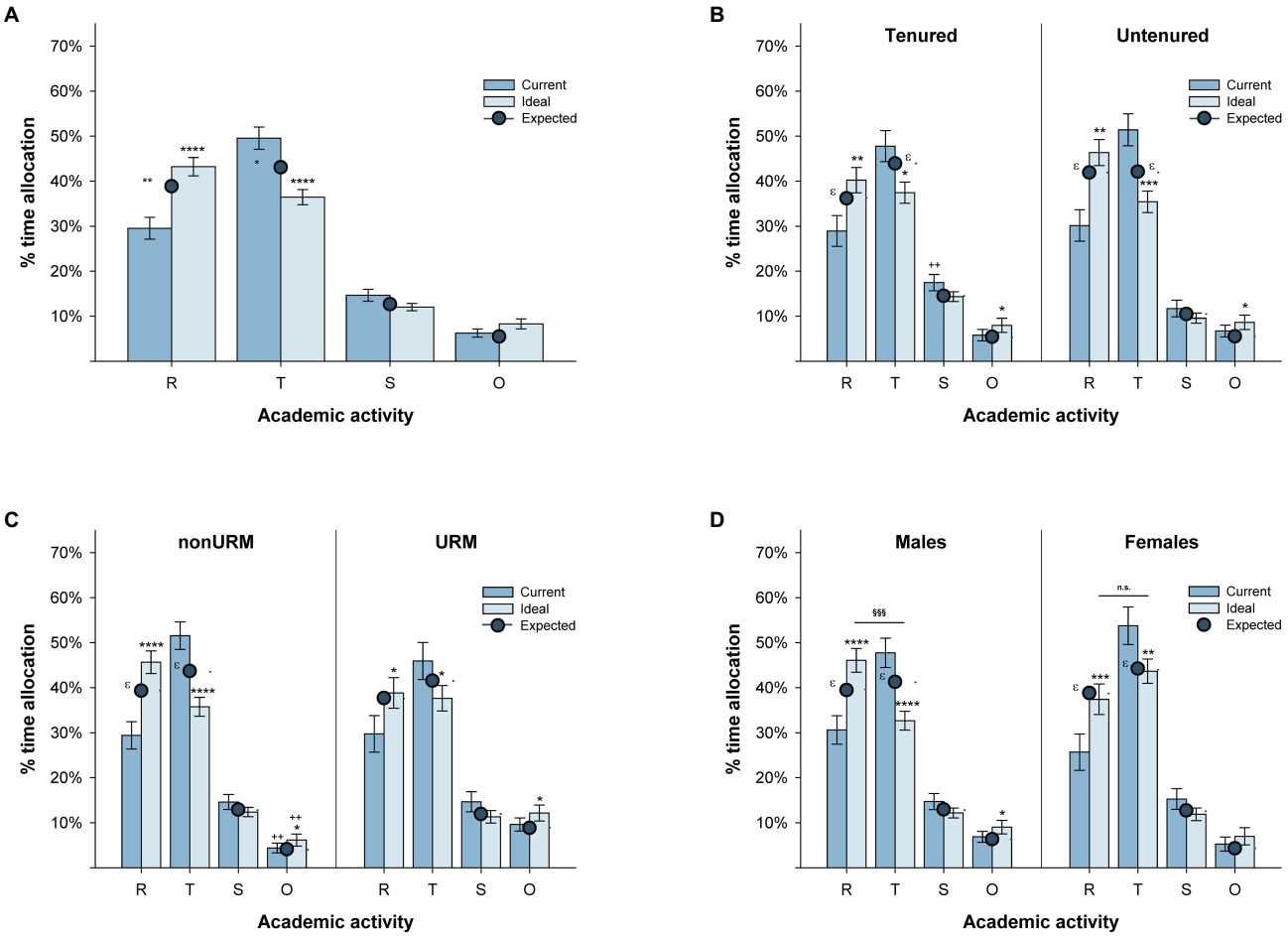

FIGURE 1 | Percent time allocation. Time allocation for all faculty **(A)**, faculty's tenure status **(B)**, representation **(C)**, and gender **(D)**. In the horizontal axis, R, research; T, teaching; S, service; and O, outreach. For comparisons between current and ideal time allocation, $^{*}p_{adj}<0.05$, $^{**}p_{adj}<0.01$, $^{***}p_{adj}<0.005$, and $^{****}p_{adj}<0.001$. For comparison between ideal time allocation to research and teaching, $^{§§§}p_{adj}<0.001$ and n.s, not significant. For comparisons between current and expected time allocation, $^{\varepsilon}p<0.05$. Brackets represent standard error of the mean. See text for further details.

was also the case for tenured, $t(45)=1.86$, and male faculty, $t(46)=2.34$, $ps<0.05$. The overall sample estimated their ideal time allocation to outreach to be higher than expected, $t(123)=1.93$, $p<0.05$, which was also the case for the nonURM faculty, $t(77)=1.73$, $p<0.05$. Notably, the demographics who viewed the time they currently allocate to teaching to be higher than expected (female and untenured faculty) would ideally adjust to those expectations, whereas the demographics who viewed their current allocation to teaching to be consistent with expectations (male and tenured faculty) would ideally allocate less time to teaching.

Information About Expected Time Allocation

The same sub-sample was asked whether the effort distribution that their academic unit expects from individuals seeking tenure and promotion is specified in the faculty handbook, based on informal expectations in their academic unit, or their best guess. Participants in the surveyed sample ($n=45$) were less likely to state that the handbook was the source of information for their estimates than informal expectations ($\chi^2=6.02$, $p<0.05$) and their best guess ($\chi^2=14.70$, $p<0.001$). Informal expectations did not differ as a source of information from their best guess ($\chi^2=2.22$, $p>0.13$). All comparison groups (tenure, representation, and gender) followed this same pattern. It is noteworthy that tenured faculty (who have a vote on tenure and promotion decisions) were also more likely to state that tenure and promotion decisions are more likely to be guided by evaluations of effort distribution based on informal expectations and their best guess than the faculty handbook (χ^2s $=7.11$ and 10.10, $ps<0.01$).

Expectation of Research Productivity

Participants were asked whether obtaining external funding was required to successfully attain tenure and promotion. Two participants did not answer this question; thus, the data below are based on 82 responses. Eighty nine percent of the surveyed faculty considered that obtaining external funding was required to obtain tenure and promotion. There were no differences in

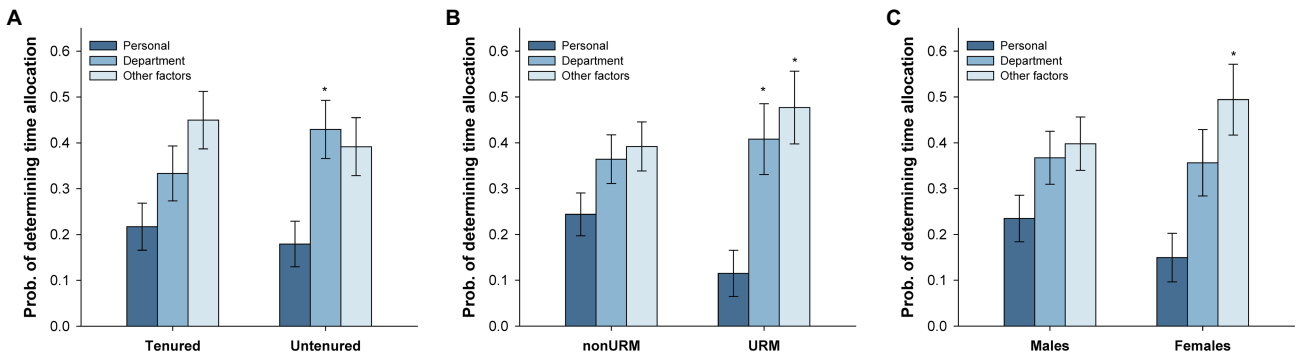

FIGURE 2 | Perceived reasons for current time allocation. Tenured vs. untenured **(A)**, nonURM vs. URM **(B)**, and male vs. female **(C)** faculty estimated the extent to which their current effort distribution was guided by personal preferences, departmental pressures, or other institutional factors (e.g., institutional policies and available resources). $^{*}p_{adj} < 0.05$ for comparisons between personal preferences, and departmental and institutional pressures. Brackets represent the standard error of the mean.

expectation of funding as a requirement for tenure and promotion among tenured and untenured faculty ($\chi^2 = 0.06$, $p > 0.83$), nonURM and URM faculty ($\chi^2 = 0.25$, $p > 0.62$), or male and female faculty ($\chi^2 = 1.49$, $p > 0.22$).

Reasons for Current Time Allocation

If obtaining external funding is required to obtain tenure and promotion, and faculty would like to devote more time to research than teaching, one may wonder why they allocate their time the way they do. Participants ($n = 82$) were asked whether their time allocation reflected their personal preference, the requirements of their academic unit, or other factors (e.g., institutional policies and availability of resources). Participants could select between one and three factors. Thus, their responses were weighed by the number of factors selected (e.g., if an individual selected all three factors, each factor received a weight of 0.33, whereas if they selected two factors, each factor received a weight of 0.5). A series of one-way ANOVAS were conducted to determine the impact of each of these motives for faculty time allocation. These ANOVAS revealed no differences among motives for effort distribution in tenured, nonURM, and male faculty, all $ps > 0.07$. In untenured faculty, $F(2, 78) = 3.46$, $p < 0.05$, the probability of personal preference was lower than the probability of department/academic unit pressures, Tukey's $p < 0.05$ (**Figure 2A**). In URM faculty, $F(2, 56) = 4.99$, $p < 0.05$, the probability of selecting personal preference was lower than the probability of selecting department/academic unit and other factors as determinants of their time allocation, Tukey's $ps < 0.05$ (**Figure 2B**). Finally, in females, $F(2, 56) = 4.28$, $p < 0.05$, personal preference was rated lower than other factors, Tukey's $p < 0.05$ (**Figure 2C**).

DISCUSSION

The present study asked faculty at HBUs to estimate the percentage of their work time that was allocated to each of their academic responsibilities: research, teaching, service, and outreach. There is a wealth of studies investigating how faculty distribute their time (e.g., Elmore and Blackburn, 1983; Russell et al., 1991; Bellas and Toutkoushian, 1999; Jacobs and Winslow, 2004; Betsey, 2007; Link et al., 2008; Winslow, 2010; Misra et al., 2012; Dahm et al., 2015; Anderson and Slade, 2016; O'Meara et al., 2017a,b; El-Alayli et al., 2018; French et al., 2020). However, these studies have rarely been performed by directly surveying HBU faculty; rather, studies providing information on time allocation at HBUs have typically used national data, such as the IPEDs (e.g., Bellas and Toutkoushian, 1999; Perna, 2001; Betsey, 2007). The present survey asked HBU faculty to estimate the percentage of their work week that is allocated to each of four academic responsibilities (these percentages added to 100% of their work time), the percentage of their work time that they would ideally allocate to each academic responsibility if they had no external pressures, and the percentage of effort toward each academic responsibility their academic unit/institution expected from faculty in order to obtain tenure and promotion. We observed that, although faculty were consistent in their perspective of the effort distribution that was expected from them, the way in which they *do* (current) and *would like to* (ideal) allocate their time is not necessarily consistent with these expectations. It is noteworthy that all faculty (regardless of tenure status, representation, or gender), considered the time they currently devote to research to be lower than the time they would like to allocate to this activity, and the time they allocate to teaching to be higher than the time they would like to allocate to this activity. Untenured faculty and female faculty (who reported the largest discrepancies between the time they currently devote to teaching and research activities) view their current time allocation to research and teaching activities to deviate from what is required to obtain tenure and promotion, whereas tenured and male faculty only reported such deviation in the time allocated to research. Surprisingly, URM faculty did not view their current time allocation to any of their academic responsibilities as diverging from the time allocation expected by their academic unit/institution (see below for discussion). Consistent with HBUs' tradition of extending education and

research to the surrounding community, all faculty's ideal allocation includes an increase from their current levels of outreach.

Historically Black Universities house a large proportion of the STEM URM professoriate in the US; however, little research has been devoted to understanding how faculty allocate their effort at these institutions. Despite HBU's tradition of student service, the long-term research productivity of HBU faculty seems to mirror that of faculty at PWIs, suggesting that HBU faculty allocate their effort in a way consistent with the expectations of large research institutions. BrckaLorenz et al. (2018) concluded that faculty fit one of five profiles based on how they allocate their time to research, teaching, and service: research-heavy (high research, moderate teaching, and low service), teaching-heavy (low research, high teaching, and low service), service-heavy (low research, moderate teaching, and high service), classic (moderate research, high teaching, and low service), or moderate load [low research, moderate teaching, and low service; a sixth, dual teaching-service profile was later suggested by French et al. (2020)]. In their sample, the number of hours of work reported by faculty varied between 25 and 53.5 h/week with the lowest number of hours reported by moderate load, followed by teaching-heavy, research-heavy, service-heavy, and classic faculty (in increasing order). The aggregated profile for our HBU faculty's current time allocation (**Figure 1A**) is most consistent with a teaching-heavy profile; however, in the sampled faculty's estimation, the profile expected by their institution is a classic profile (equivalent allocation of effort to teaching and research). Note that a difference between BrckaLorenz et al. and French et al.'s studies and the present study is that our participants were not asked to estimate a number of hours invested in each academic activity, but rather the proportion of time they allocated to each activity. However, the fact that a profile consistent with their defined profiles emerged suggests that the measures may be comparable.

One could view the similarities in current time allocation across faculty demographics as an equivalent effort to fit the profile expected by their institution and the observed differences as the result of uneven pressures on some of these demographics. Even though URM faculty are not a minority at HBUs, they may experience more pressures to mentor URM students than nonURM faculty, a pressure that may be increased in times of financial uncertainty (Gasman, 2013; Gasman and Commodore, 2014). Financial uncertainty may also lead to increased burdens on untenured faculty who may resort to taking extra service commitments to increase their profile at their institution. Race and gender are known to be associated to time allocated to out-of-classroom activities (Bellas and Toutkoushian, 1999), and the difficulties experienced by female faculty of color at PWIs are also experienced at HBUs (Blackshear and Hollis, 2021). Although the present study cannot yield conclusions regarding the reasons why race, gender, and their intersection yield differential time allocation profiles, we assume that the determinants of such time allocation in HBU and PWI faculty are mediated by the intersection of personal variables and the institutional context.

Another interesting observation derived from this study is that faculty did not view their institution's faculty handbook as the source of expectations for tenure and promotion decisions. Rather, they stated that tenure and promotion decisions were based mostly on informal expectations or their best guess of what those expectations were. This suggests that, without continuous feedback from their academic unit, faculty on the tenure-track may be distributing their time in a way that is inconsistent with established policies or, if adjusting their time allocation to established policies, their effort may not be consistent with the informal expectations of faculty productivity. The observation that tenured faculty (who make tenure and promotion decisions) also reported a lack of reliance on the faculty handbook suggests that there may not be clear guidelines for faculty seeking tenure. One reason for this lack of confidence in the faculty handbook may be related to the rotation of administrative personnel that is commonly observed in HBUs (e.g., Gasman, 2013). Another reason may be informal practices that have become established practices. For example, the faculty handbooks that we reviewed only mentioned submitting proposals or attaining external funding as expected from individuals seeking tenure at the larger institutions; nonetheless, faculty at all institutions reported that obtaining external funding was required to successfully obtain tenure and promotion.

Historically Black Colleges and Universities continue to be the institutions serving the students in greatest need of support and advisement, even in the face of the financial and administrative challenges with which they must contend (e.g., Gasman, 2013). However, their faculty are often evaluated (or *perceive* that they are evaluated) using a model developed for research-intensive institutions (*cf.* Jacobson, 1992; also see Fairweather, 2002). In this model, research is the most critical determinant of tenure and promotion decisions, whereas other activities, such as service, are viewed as less important (Baez, 2000). Not surprisingly, faculty in this study consistently viewed the time they would ideally allocate to research as significantly higher than what they currently allocate. Some demographics in the surveyed faculty also reported constraints in their time allocation, with untenured faculty, women, and URMs viewing factors other than their personal preferences as determining the way in which their time was allocated. Notably, the authors could not find any references to time allocation to outreach (to which the surveyed faculty would like to devote more time). The desire of HBU faculty to engage in outreach suggests that HBUs continue their historical function of service to the community and attract community-oriented individuals into its professoriate (Blake, 2018). This community service academic responsibility seems to be largely ignored in studies of faculty at PWIs, possibly grouping outreach activities into the research or service categories.

Some of our findings are consistent with previous literature on faculty time allocation. For example, females were more likely to view teaching as a rewarding part of their appointment, as reflected in their desired allocation of equivalent amounts of time to teaching and research (Bellas and Toutkoushian, 1999; Link et al., 2008; Winslow, 2010; Misra et al., 2012;

Dahm et al., 2015; French et al., 2020). URMs in our sample reported equivalent proportion of time allocated to service activities as nonURM faculty, which is inconsistent with previous reports (e.g., Bellas and Toutkoushian, 1999). A possibility is that studies conducted at PWIs (or when a large number of institutions analyzed are PWIs) reflect "tokenism," or the fact that URMs are more likely to receive requests to participate in service activities. This tokenism may be less prevalent in HBUs, in which there is a larger representation of URM faculty (e.g., Gasman, 2013). Notably, URM faculty were the only demographic that reported no deviations from their current time allocation and the time allocation expected by their institution. This may reflect URMs' greater satisfaction with their role at the HBU than may be experienced by nonURM faculty. Indeed, Black faculty tend to report a better "fit" to professorial roles at HBUs than at PWIs (e.g., Mangan, 2015).

In summary, the present study should be considered a pilot investigation into the idiosyncrasies of faculty time allocation at HBUs. Considering the cultural and historical context of HBUs, the pressures for effort distribution imposed by the needs and function of the institution may lead to a better understanding of satisfaction, recruitment, and retention of faculty at HBUs.

LIMITATIONS AND PATHWAYS TO FURTHER RESEARCH

The largest limitation of the present study is that the sample size was large enough to analyze differences among faculty based on some demographic characteristics, but not large enough to conduct intersectional analyses. For example, URM female faculty may have challenges that are not shared by URM male faculty, and URM male faculty may encounter challenges that are not shared by nonURM male faculty (for a recent study investigating the unique challenges faced by Black women pursuing science and technology degrees, see Nguyen et al., 2021). Our sample was greatly skewed toward nonURM faculty in the tenure track (i.e., untenured), which may reflect a selection bias, since we could only analyze the data from those individuals who returned the surveys. However, this oversampling of nonURM faculty may reflect a gradual change in the composition of the professoriate at HBUs. For example, over the past 4 years, three of the participating institutions (which serve a total of approx. 22,000 students) collectively had less than 18 Black faculty in the tenure track, a number of which were not US Nationals. This is significant, as it may reflect HBUs' competition with PWIs for Black faculty, a growing problem over the last 20 years (e.g., Jackson, 2002; Mangan, 2015). Asking faculty to estimate how they allocate their time is also fraught with uncertainty and biases, and a more accurate approach would involve journaling of time investment in each academic responsibility (e.g., O'Meara et al., 2017b). Thus, the present data may reflect a subjective perception of investment, which may be exaggerated for laborious activities and minimized for preferred activities. Finally, a study including perceptions of leadership on faculty time allocation and tenure and promotion policies would allow for a better definition of institutional expectations of their faculty effort distribution.

CONCLUSION

Most research on faculty time allocation has been conducted in institutions other than HBUs. The present study revealed that, consistent with previous research on faculty time allocation, STEM HBU faculty allocate more time than they desire to teaching and less time than they desire to research. The way in which these faculties currently allocate their time and how they wish to allocate their time varies depending on certain demographic factors (based on tenure status, gender, and representation), despite the fact that all faculty groups analyzed have consistent views of what time allocation is expected by their institution. Current time allocation appears to be largely determined by external pressures rather than personal preferences, and the surveyed faculty reported a lack of clarity on the criteria used to make tenure and promotion decisions at their institution.

Although limited by its relatively small sample size, this study provides a preliminary view of STEM faculty time allocation at HBUs and highlights the fact that, although faculty can adjust to the context of their institution, there are still steps that could be taken to increase their success at the HBU. Furthermore, an understanding of how faculty allocate their effort as opposed to their preferred effort allocation could be used as the basis for designing policies aimed at recruiting and retaining quality STEM faculty at HBUs. The surveyed faculty fit the "teaching-heavy" profile for time allocation, but their ideal profile is consistent with the "classic" profile expected by their institutions. "Teaching-heavy" faculty tend to report the lowest levels of job satisfaction and the highest turnover intentions, whereas "classic" faculty report high levels of job satisfaction and low turnover intentions (French et al., 2020). Thus, increasing the clarity of tenure and promotion guidelines and ensuring that reviewing bodies adhere to those guidelines could be a first step that facilitates faculty's adjustment to the profile expected by the institution, as well as increase job satisfaction and faculty retention.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board (IRB), Oakland University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

ME and MQ are the PIs of the grants funding the research. ME contributed to the design of the study, reviewed the literature relevant to the development of the measures used in this study, wrote the initial draft of all sections of the manuscript, integrated feedback from co-authors through the editing process, and was responsible for the data analyses and discussion of the study. ZB assisted with literature review and data collection, and provided feedback on the manuscript. MQ contributed to the design of the study, reviewed and provided feedback on the manuscript, and participated in developing the discussion. CK assisted with literature review and data collection, and reviewed and provided feedback on the manuscript. FA assisted with statistical analyses and provided feedback on the manuscript. All authors contributed to the article and approved the submitted version.

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Instructional Set Moderates the Effect of GRE on Faculty Appraisals of Applicant Competence: A Vignette Study With Implications for Holistic Review

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While there is movement to create more equitable and holistic admission review processes, faculty continue to place strong emphasis on a single piece of information when making admissions decisions: standardized test scores. This study used an experimental design to test whether instructions provided to faculty prior to assessing doctoral applicants could support holistic review by reducing the weight of the general record examination (GRE) in faculty appraisals of competence and merit for graduate study. Tenured and/or tenure-track faculty ($N = 271$) were randomly assigned to one of three instructional conditions: Control (no instruction), "Diamond in the Rough," and "Weed Out." In addition, faculty participants were randomly assigned to read one of two vignettes of a prospective first-generation student who either received high or average GRE scores. Faculty then rated the applicant's competence using a three-item survey. As expected, faculty who read the vignette describing the candidate with the high GRE rated him as more competent than faculty who read the average GRE vignette. In addition, being instructed to seek out diamonds in the rough buffered the effect of the GRE score on competence. Faculty were also asked to indicate whether they would need additional information to make an admissions decision. They were more likely to ask about grades and research skills than about psychosocial factors that might contextualize the candidate's performance and perceived competence. The results of this study have implications for creating more equitable doctoral admissions processes that center equity, diversity, and inclusion in decision making.

Keywords: standardized tests, GRE, graduate admissions, holistic review, competence, heuristics and biases

INTRODUCTION

As gatekeepers, faculty decide who merits access not only to graduate programs but also to careers that require advanced degrees, including the professoriate. The Council of Graduate Schools (Kent and McCarthy, 2016) and funding agencies, such as the National Science Foundation, have recognized that a key to solving today's scientific and societal problems is to create more inclusive and equitable processes to diversify the workforce through holistic review processes. Holistic review includes a variety of practices aimed at contextualizing applicants' academic and professional experiences rather than focusing on single data points, such as standardized test scores. Yet, research has demonstrated that standardized tests, such as the general record examination (GRE), are heavily weighted in admissions decisions. Sometimes, these scores are used to make initial selections of candidates deserving of further review (Miller and Stassun, 2014; Posselt, 2014, 2016). Yet, other research has shown that test performance is highly correlated with race, gender, and first-generation college student status (Educational Testing Service, 2019) and that an overreliance on these scores may bar access to graduate school for deserving students from diverse backgrounds (Smith and Garrison, 2005; Vasquez and Jones, 2006; Miller and Stassun, 2014; Gómez et al., 2021). A purpose of the current study was to explore whether simple instructions could be used to mitigate the outsized influence that GRE scores continue to have on faculty's judgments of applicants for graduate study.

The current study extends the work of Cano et al. (2018), who conducted an experimental vignette study of faculty at a single institution. In a 2×2 design, faculty were randomly assigned to read a vignette about a doctoral applicant in which GRE scores and first-generation college student status were manipulated. Whereas faculty who reviewed the higher GRE vignettes were more likely to interview the candidate, faculty members' empathic orientation moderated this effect. Specifically, in the average GRE group, greater empathy in faculty was associated with a higher likelihood of interviewing, with interview rates appearing to be equivalent to vignettes with higher GRE scores. Faculty who were themselves first-generation college students were more likely to admit the applicant with average GRE scores and whose vignette included mention of their first-generation college student status. These findings are consistent with the empathy literature, which shows that empathy and shared life experience can influence altruistic and prosocial behavior toward others (Davis, 1980; Batson et al., 2007). Taking the perspective of applicants and empathizing with them may lead faculty to evaluate the experiences of marginalized candidates in a more favorable or generous light.

Are Faculty Judgments Malleable?

The research described above is one of many examples of how decision making is a process that is subject to our personal experiences. Decision making is also subject to biases and heuristics (Tversky and Kahneman, 1974). Faculty may use heuristics or cognitive shortcuts to simplify admissions decision making because of the need to review a great deal of information in a limited period of time. To make more efficient decisions, faculty may rely on their own personal experiences serving on search committees (e.g., availability heuristic), memories of successful or unsuccessful students (e.g., representative heuristic), and traditions, stories, and assumptions in their disciplines regarding adequate preparation for graduate study. At the same time, relying on these heuristics may replicate long-standing assumptions that deny educational opportunities to qualified candidates. It is possible to intervene and short-circuit these heuristics by encouraging deeper information processing (Kahneman, 2011). And indeed, there is growing interest in looking into ways to change how faculty members make admissions decisions.

In her study of the working of doctoral admissions committees, Posselt (2014, 2016) found that faculty members receive little guidance during the process. They often use unwritten norms and personal experience in selecting candidates, which often recreates or perpetuates patterns of admissions that favor continuing generation graduates from elite institutions and who received high test scores, which limits diversity in the graduate student pool. Posselt and others have called for department heads and graduate directors to reimagine doctoral admissions by creating rubrics that specify experiences and qualities that are valued by the program. Indeed, many programs have adopted holistic admissions and other methods that provide direction to faculty members (Mathur et al., 2019).

In the current study, we experimented with simple prompts that make explicit some of the ways in which faculty may approach the evaluation of doctoral applicants. We include a control condition that mimicked a "business as usual" approach to reviewing applications. Faculty members randomized to this condition were told to evaluate the candidate for admissions to their doctoral program. We also included two other conditions that primed faculty members to read the vignette of the doctoral applicant with particular goals. In one condition, faculty were instructed to look for the "Diamond in the Rough" candidate who could succeed in their program. In the other, faculty were instructed to look for the candidate that should be avoided because they will not succeed in their program (the "Weed Out" condition). The purpose of including these three instructional sets was to examine the extent to which instructional sets might mitigate the effect that GRE scores have on faculty members' perceptions of competence.

Current Study

The purpose of this study was to examine the effects of standardized test scores and instructional sets on faculty perceptions of the competence of a doctoral applicant. We focused on faculty members' ratings of competence rather than their likelihood of interviewing or admission because participants in Cano et al. shared that they would rarely make admissions decisions based on the limited information provided in the vignette. Thus, assessing perceived competence is more ecologically valid.

The Cano et al. vignettes for first-generation college students were used, which described a male candidate's skills and experiences along with his GPA and test scores. In both cases, the candidate had a first-year GPA that was less than a B and a final GPA that was approximately a B+. The only information that differed between the vignettes were GRE scores. This permitted a comparison of evaluations for high (75th percentile) and average (50th percentile) test performance. It is expected that faculty who were randomly assigned to the high GRE vignette would view the candidate as more competent.

Prior to reading the vignettes, faculty participants were randomly assigned to read one of three sets of instructions to test the extent to which the framing of the review process impacts judgments of competency. As noted above, the three conditions included no guidance (Control), seeking the Diamond in the Rough who can succeed, and Weeding Out the student who cannot succeed. It is expected that the instructional set would modify their ratings of competence based on whether the candidate had high or average GRE scores.

Finally, faculty members were asked if they needed additional information (e.g., specific grades and research skills) to interview or admit the hypothetical candidate. This item was included to provide insights into how participants' contextualize students' applications during their decision-making process. Along with instructional sets to committees, this information provides insights that can inform holistic review interventions.

MATERIALS AND METHODS

Procedure

This study was approved by the Institutional Review Board at Wayne State University. Faculty members at six urban Carnegie classified "Highest Research Activity" doctoral universities across the United States were recruited to participate in this study. Publicly available email addresses were collected by searching the public Web sites of these universities for tenure-track/tenured faculty in the science, technology, engineering, and mathematics (STEM) and social, behavioral, and economic sciences (SBE) disciplines. Emails that included the purpose of the study and a link to the online Qualtrics survey were then sent three times over the course of 3 weeks to potential participants. Potential participants were told that the purpose of this study was to better understand how faculty members make doctoral admissions decisions. Informed consent was obtained *via* an information sheet that opened upon clicking the survey link.

A total 2,756 faculties were emailed and 344 initiated (i.e., clicked on the survey link to begin the survey) the survey. Of those who initiated the survey, 344 completed at least one item. For the purposes of this study, we only include participants who completed the study, which resulted in a sample size of $N = 271$.

After reading the online information sheet, participants were randomly assigned to one of three instruction sets: Control, "Diamond in the Rough," and "Weed Out." In the Control condition, the instructions were as: "Your task is to evaluate applicants to your doctoral program. Please consider the information about the candidate that appears on the next page and then answer the questions that follow." Diamond in the Rough participants were instructed as: "Your task is to find "Diamond in the Rough" applicants who can succeed in your doctoral program. Please consider the information about the candidate that appears on the next page and then answer the questions that follow." Finally, Weed Out participants were told as: "Your task is to Weed Out applicants that will not succeed in your doctoral program. Please consider the information about the candidate that appears on the next page and then answer the questions that follow."

After reading the instructions, participants read a vignette about a male first-generation college student candidate who was applying to a doctoral program:

> Joe is an undergraduate in his senior year at a large public university and he has applied to your doctoral program. Joe indicated in his personal statement that he is pursuing graduate studies to prepare to be a professor and a researcher. Joe identified you as a potential advisor because he is interested in your program of study. It is clear from his personal statement that he has read several recent articles of yours and appears to understand the importance of the work presented in them.
>
> To prepare himself for this career, Joe has taken the necessary prerequisite coursework for the doctoral program. In college, Joe volunteered as a research assistant for a faculty member for 1 year. During this experience, he learned how to collect and enter data into Excel and SPSS, conducted descriptive analyses, and participated in weekly lab meetings with the professor, graduate students, and several other undergraduates. He noted that this experience was beneficial in helping him to recognize that he could pursue a career in scholarly research, especially given that he was the first in his family to attend college. Joe has also noted in his statement that he volunteered at a social service organization once per week. Joe wrote that his research and volunteer experienced helped him develop skills to work effectively on his own and in a team. Joe has also mentioned that he has learned good organizational and leadership skills by working a part-time job at a dining hall on campus during which he was able to work his way up the ranks from server to manager.

Respondents were randomly assigned to receive one of two sets of scores for Joe. Whereas both sets of scores included an overall GPA of 3.2/4.0 and a first-year GPA of 2.75, one group included higher GRE scores (GRE Verbal = 75th percentile, GRE Quantitative =80th percentile, and GRE Analytical = 60th percentile) than the other (GRE Verbal =55th percentile, GRE Quantitative = 40th percentile, and GRE Analytical = 50th percentile). These GRE ranges were selected based on two of the authors' experiences as search committee members (AC and LW) as well as to be sufficiently different from each

other but not so extremely high or low as to be unrealistic representations as to arouse suspicion from participants.

Measures

After reading the instructions and vignette, participants were then asked to rate Joe's competence for graduate study with a three-item scale developed by Moss-Racusin et al. (2012). Items included as: "Did the applicant strike you as competent?," "How likely is it that the applicant has the necessary skills for this job?," and "How qualified do you think the applicant is?" Participants responded using a 1 (not at all) to 7 (very much) scale. The inter-item reliability for competence rating was excellent (Cronbach's alpha = 0.94).

Participants were able to indicate if they wanted to review additional information about Joe to make admissions decisions: "What, if any, additional information would you like to know about Joe or his application to make a decision to *interview/admit* him?" Choices included as: No additional information needed, specific research skills, grades in courses, communication (oral and/or writing) skills, interpersonal skills, additional demographic information (e.g., race/ethnicity), volunteer or civic/community service or engagement, personal history or experiences including obstacles overcome, and other (fill in the text box).

Participants then responded to survey items to assess demographics (e.g., sex, degree year, and academic discipline).

TABLE 1 | Participants' demographic characteristics.

Participant Demographics*	
Variable	**% (n)**
Race/Ethnicity**	
White	85.24% (231)
African American/Black	2.58% (7)
Asian	8.49% (23)
Hispanic/Latina/o/x	7.83% (17)
First People/American Indian/Alaskan Native	0% (0)
Native Hawaiian or Pacific Islander	0.37% (1)
Other	1.85% (5)
Biological Sex	
Male	62.36% (169)
Female	36.16% (98)
Prefer Not to Say	1.48%(4)
Discipline	
STEM	58.67% (159)
SBE	39.48% (107)
Arts and Humanities	0.74% (2)
Other	1.11% (3)
Faculty Track (Tenure-Track or Tenured)	
Yes	97.79% (265)
No	1.48% (4)

*However, frequencies may not sum to 271 for each variable as participants were permitted to skip individual questions. *N = 271. **Participants were able to choose all identities that apply.*

RESULTS

Descriptive Statistics

The mean age of participants was 50.71 (SD = 12.39). Almost all of the participants had served on a graduate admissions committee (91.14%, $n = 247$) and had earned a Ph.D. (98.52%, $n = 267$). **Table 1** displays the other demographic information for the sample. Data were not available for all demographic characteristics as participants were permitted to skip items they did not want to disclose.

Interactions Between Instructional Set and Vignette

Data were analyzed using version 4.0.5 of the R statistical programming language (R Core Team, 2021), along with the car (version 3.0.10) and effects (version 4.2.0) packages by Fox and Weisberg (2019).

Mean competence scores were analyzed in a 2 × 3 factorial ANOVA, with vignette (high GRE vs. average GRE) and instructional set (Control, Diamond in the Rough, and Weed Out) as independent variables. This analysis was conducted to examine the extent to which vignette (high GRE vs. average GRE) and instructional set (Control, Diamond in the Rough, and Weed Out) interacted to predict faculty participants' perceptions of the applicant. The results of this analysis are shown in **Table 2**.

There was a significant main effect of vignette, demonstrating that participants rated Joe as more competent and qualified if they were assigned the high GRE vignette. In addition, there was a significant vignette x instructional set interaction.

As shown in **Figure 1**, the difference between the mean competence scores was greatest in the Control condition, was negligible in the Diamond in the Rough condition, and was intermediate in the Weed Out condition. These by-condition GRE effects are shown in **Figure 2**. They were explored further by means of *t*-tests.

In the Control condition, the mean competence score for the high GRE vignette was 3.34 greater than the mean competence score for the average GRE vignette. This difference was significant [$t(87) = 3.807$, $p = 0.0003$]. The analogous differences in the other two conditions were smaller, and neither was significant [for Diamond in the Rough, $t(104) = 0.433$, $p = 0.666$; for Weed Out, $t(74) = 1.605$, $p = 0.113$].

Additional Information Requested by Faculty

Participants were able to indicate if they wanted to review other information about the applicant. **Table 3** shows the frequency with which faculty participants desired additional information before making a decision to interview or admit the candidate into their graduate program. Faculty participants endorsed different types of information in similar proportions whether they were making an interview or admissions decision. Specifically, common pieces of information include grades in particular courses relevant to the field of study, more specificity about research skills, and examples of communication skills. Note, however, that the least requested information tended to be psychosocial information

TABLE 2 | Results of the 2 × 3 factorial ANOVA for mean competence scores.

Source	SS	df	MS	F	p	effect size eta^2
Vignette	177	1	177.000	12.837	0.0004	0.046
Instructional set	29	2	14.500	1.040	0.3550	0.008
Vignette x instructional set	113	2	56.500	4.103	0.0176	0.030
Error	3,659	265	13.808			

TABLE 3 | Desired information before making an admissions-related decision.

	Type of Admissions Decision	
Type of Information Desired	**Interview% (n)**	**Admit% (n)**
Grades in courses	19.3% (73)	16.1% (61)
Specific research skills	14.2% (54)	13.2% (50)
Communication (oral and/or written) skills	13.2% (50)	14.2% (54)
No additional information needed to make an admissions-related decision	10.3%(28)	2.6% (7)
Personal history or experiences including obstacles overcome	5.8% (22)	8.4% (22)
Interpersonal skills	5.5% (21)	5.5% (21)
Additional demographic information (e.g., race and class)	3.7% (14)	3.2% (12)
Volunteer, civic, community service, or engagement	0.5% (2)	0.8% (3)

(i.e., demographic information, interpersonal skills, and community engagement) that could be used to contextualize an applicant's portfolio, including obstacles or challenges the student overcame or strengths that may enhance graduate student success.

DISCUSSION

Based on the need to identify pragmatic solutions to support holistic review, the purpose of this study was to examine the extent to which instructional sets could affect faculty members' judgments of competence about graduate program applicants. More specifically, this study tested whether different types of instructions could modify the strong effect that standardized test scores often have in graduate admissions decision making. As expected and in line with research showing the weight that the standardized test scores have on judgments of merit (Croizet, 2008; Posselt, 2014, 2016), faculty who were randomly assigned to read the vignette with the high GRE rated the applicant as more competent and qualified than faculty who were assigned to the average GRE vignette. Recall that there were no other differences in the vignettes than the GRE scores. The results mean that, all things being equal, faculty use standardized test scores to make appraisals of competence. It is somewhat disturbing to see that one piece of data continues to outweigh so significantly other evidence, especially when the Educational Testing Service (2019) has argued that decisions should not be made on this single piece of evidence. At the same time, this result was not surprising given that people take mental shortcuts to make decisions in a more efficient manner (Tversky and Kahneman, 1974). Faculty have personal and collective professional experiences that may make them more susceptible to heuristics like the availability and representative heuristics when considering information like the standardized test scores.

Yet the current findings show that the outsized role of the GRE effect is not inevitable, which may be heartening for faculty and staff who are attempting to build holistic review processes. Faculty in the current study also provided different competency ratings to the applicant depending on the instructions they received. Specifically, faculty receiving the "Diamond in the Rough" instructions rated the candidate's competency similarly regardless of his GRE score. While not significantly different, high and average GRE candidate competence ratings were somewhat more disparate in the "Weed Out" condition. The largest difference was between the mean competence scores for faculty receiving no instruction (Control condition). On average, faculty receiving no instruction provided a competence rating that was more than 3 points higher for the high versus the average GRE candidate. The Control condition most closely approximates "business as usual" in graduate programs, where faculty are provided portfolios to review with no instruction as to how to review them. If this is the case, the typical approach to reviewing graduate applicants results in decisions in which one piece of information carries the weight in review.

Returning to the two experimental conditions, faculty who read the "Diamond in the Rough" instruction provided similar ratings of competency regardless of GRE score. Perhaps faculty who read this prompt reviewed the vignette more closely and noticed that the candidate was able to improve their GPA over time and had taken the initiative to get research experience, diminishing the weight of the GRE in their appraisals of competence. It is interesting that the GRE had little effect on competency scores when faculty were presented with the "Weed Out" instruction, although the difference fell in between the "Diamond in the Rough" and control conditions. Perhaps providing any instruction, even if it is to select the "worthy few," charges faculty with more deeply processing the information provided in the vignette. That is, paying attention to the details of a candidate's portfolio may reduce the impact of a single piece of data that might ordinarily carry great weight in snap decision making.

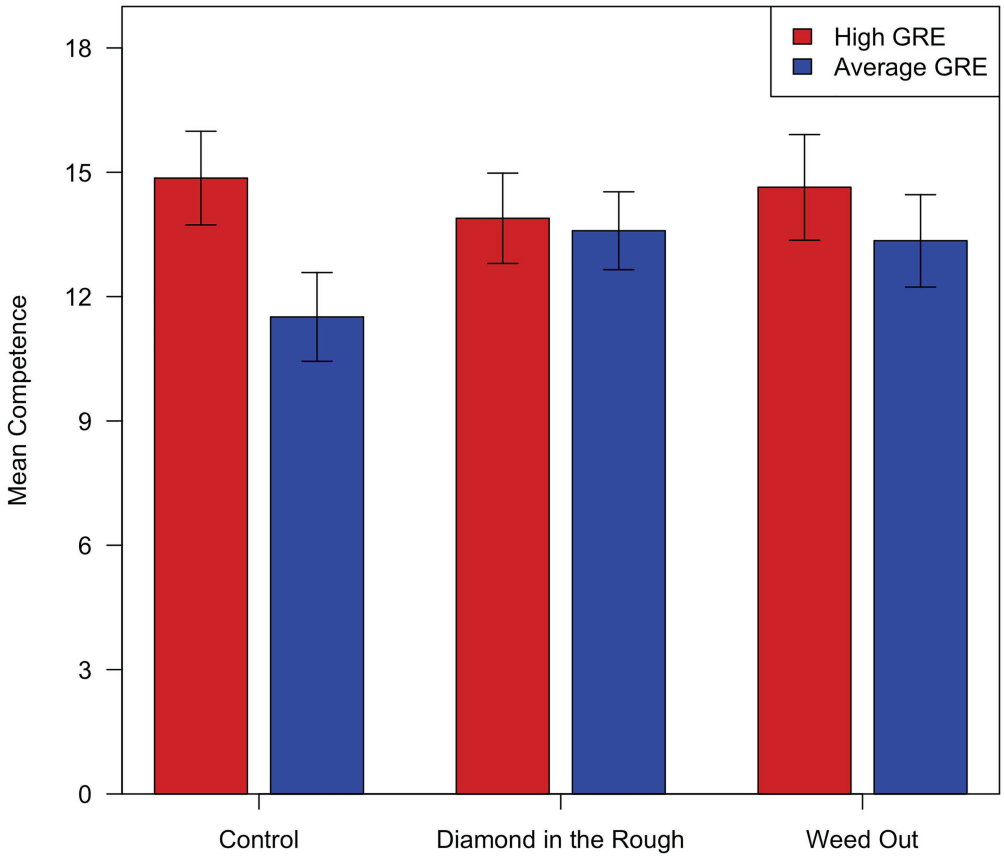

FIGURE 1 | Mean competence scores as a function of vignette and instructional set. Error bars show 95% confidence intervals.

To further understand how faculty use information to make admissions decisions, we also asked participants to indicate what additional information they would need to extend an invitation to interview and to admit the candidate. When they indicated they wanted to see additional information, faculty participants were most likely to request academic information, such as grades in specific courses relevant to the field of study, specific research skills, and examples of communication skills. Interestingly, psychosocial information, which could be used to further contextualize an applicant's experience, was requested less frequently: obstacles or challenges the student overcame, demographic information including race and gender, interpersonal skills, and community engagement activities. Information in these areas could be used to explain the candidate's low initial GPA and increases in GPA over time, especially as the candidate was a first-generation college student. In addition, this type of information could provide valuable information about the candidate's strengths in navigating environments characterized by systemic racism and working for justice in their communities. The fact that faculty asked for this information less frequently suggests that faculty may benefit from more guidance regarding how to contextualize applications and reduce implicit (or unconscious) biases that have been acted upon toward applicants from marginalized groups (Corrice, 2009; Milkman et al., 2015; Moss-Racusin et al., 2012).

The current findings must be interpreted in light of the study's limitations. The fact that faculty were not compensated for their time to complete the study may have contributed to our low response rate. Our response rate may also be a function of recruiting a bulk of participants in spring and summer. Nevertheless, the study includes faculty from a number of institutions. Researchers wishing to continue this work can build upon these findings by offering compensation and conducting focus group interviews or open-ended survey questions to gather more information about how faculty appraise applicant competence and attempt to make admissions decisions, especially in the context of holistic review. In addition, researchers are encouraged to examine how faculty-staff decision making across the academic training pathway (e.g., K-12 education and access to academic camps and enrichment, college admissions, college course, and lab experiences) results in many opportunities to grant access (or not) to qualified students even before they reach the doctoral admissions stage.

The current study demonstrates that although standardized test scores continue to dominate in appraisals of graduate applicant merit, simple instructional sets can diminish the outsized effect of standardized test scores

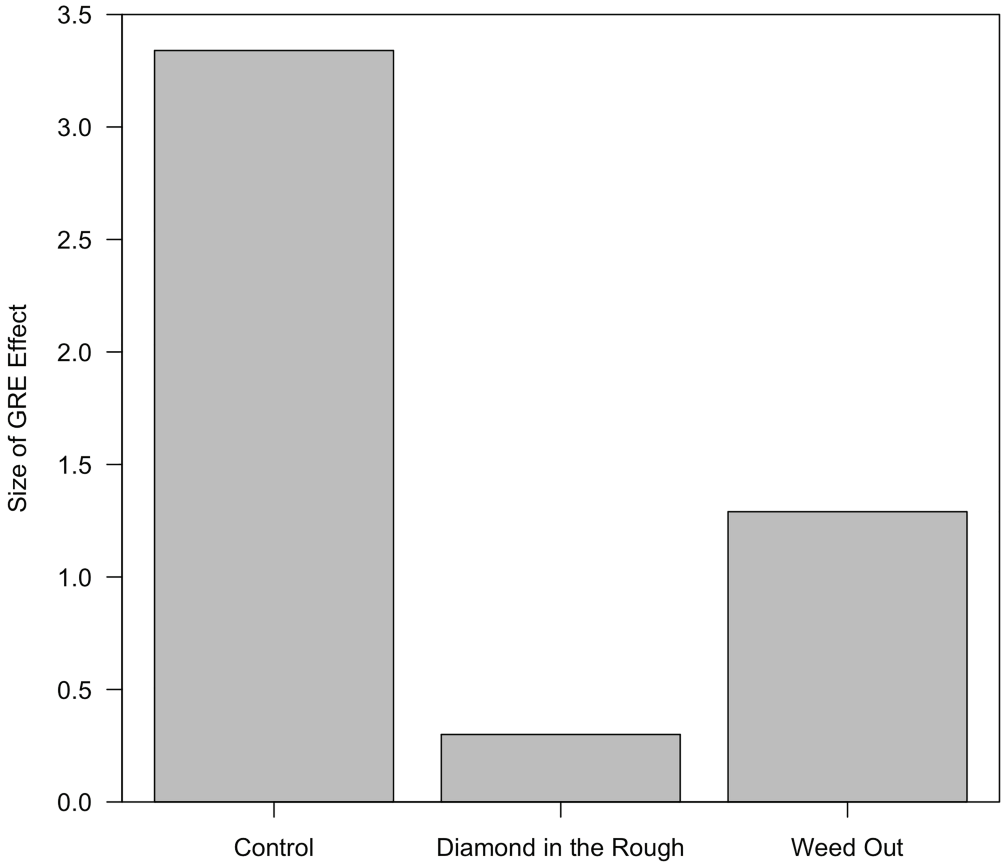

FIGURE 2 | The difference between the mean competence scores in the high GRE and average GRE vignettes as a function of instructional set.

in judging applicants' competence. In light of recent research demonstrating that the predictive validity of standardized tests is minimally meaningful and can hamper the goals of programs to create more just and diverse environments (e.g., Croizet, 2008; Pacheco et al., 2015; Petersen et al., 2018; Gómez et al., 2021), these findings have implications for the pursuit of Inclusive Excellence (Association of American Colleges and Universities, 2002). While a number of programs have eliminated a GRE requirement for doctoral admission (Langin, 2019), a number of programs still require or allow for optional submission of this information. For these programs, committees can consider the types of prompts they use to ensure their holistic admissions goals are met and they can be guided to request and evaluate information that can contextualize applicants' experiences and skills to select competent students who will thrive in their programs and beyond.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Wayne State University Institutional Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

IH-C, GS, and JN contributed to data collection, writing, and analysis. AC and LW conceived the original idea for this study and contributed to writing and statistical analysis. All authors contributed to the article and approved the submitted version.

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REVIEW
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A New Effort to Diversify Faculty: Postdoc-to-Tenure Track Conversion Models

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Calls to diversify the professoriate have been ongoing for decades. However, despite increasing numbers of scholars from underrepresented racial minority groups earning doctorates, actual progress in transitioning to faculty has been slow, particularly across STEM disciplines. In recent years, new efforts have emerged to recruit faculty members from underrepresented racial minority groups (i.e., African American/Black, Hispanic/Latinx, and/or Native American/Native Hawaiian/Indigenous) through highly competitive postdoctoral programs that allow fellows the opportunity to transition (or "convert") into tenure-track roles. These programs hybridize some conventional aspects of the faculty search process (e.g., structured interview processes that facilitate unit buy-in) along with novel evidence-based practices and structural supports (e.g., proactive recruitment, cohort communities, search waivers, professional development, enhanced mentorship, financial incentives). In this policy and practice review, we describe and synthesize key attributes of existing conversion programs at institutional, consortium, and system levels. We discuss commonalities and unique features across models (N = 38) and draw specific insights from postdoctoral conversion models developed within and across institutions in the University System of Maryland (USM). In particular, experience garnered from a 10-year-old postdoc conversion program at UMBC will be highlighted, as well as the development of an additional institutional model aimed at the life sciences, and a state-system model of faculty diversification with support from a NSF Alliances for Graduate Education and the Professoriate (AGEP) grant.

Keywords: postdoc, diversity, faculty diversity, higher education, AGEP

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INTRODUCTION

Despite recent demographic shifts in undergraduate college student enrollment and concerted federal, institutional, and foundation efforts, the percentage of faculty members who come from underrepresented racial minority groups[1] in tenured and tenure-track positions remains small, particularly in STEM fields (Griffin, 2020; Smith, 2020). Interventions in this area often focus on

[1]By underrepresented racial minority groups, we refer to the National Science Foundation [NSF], and National Center for Science and Engineering Statistics [NCSES], 2017 specification of the three U.S. borne ethno-racial groups – African American/Black, Hispanic/Latinx, and/or Native American/Native Alaskan – that are underrepresented in science and engineering.

increasing the number of underrepresented racial minority scholars interested in and prepared for faculty careers or providing institutional incentives ("target of opportunity" hiring programs) for the hiring of faculty from underrepresented minority groups (Griffin, 2020). Yet, structural barriers continue to play a significant role in the persistence of faculty racial gaps. Racial bias (Eaton et al., 2020; White-Lewis, 2020), hostile climate (Zambrana, 2018), narrow conceptions of scholarly excellence and quality (Hoppe et al., 2019; Settles et al., 2020), and workload inequities (Jimenez et al., 2019; Misra et al., 2021) cumulatively undercut diversity efforts focused on recruitment and hiring alone. Increasing the diversity of the faculty therefore requires strategic and systemic interventions, focusing on recruitment and retention but also organizational transformation and change (Griffin, 2020; Smith, 2020).

One emerging, yet understudied, intervention in this area are postdoctoral fellowship programs that seek to "convert" postdocs to faculty positions within the institution or systems in which they complete their fellowship. Such "grow your own" programs subvert norms of traditional postdoctoral programs, wherein postdocs typically work directly on the research of a single faculty member and then find a faculty position elsewhere (Griffin, 2020; Flaherty, 2021). Conversion programs have the potential to directly increase faculty diversity by (a) creating a talented pool of qualified fellows; (b) intentionally recruiting postdocs to departments/institutions with an interest in hiring them; and (c) creating internal commitments within departments and institutions to the professional success of scholars from underrepresented racial groups (Flaherty, 2021). Yet, because conversion programs are relatively new, the field lacks an understanding of the processes, practices, and policies that have been used to create, institutionalize, and sustain these new models.

The goal of this Practice and Policy Review is to fill that gap. We draw from an online, preliminary review of postdoctoral conversion programs aimed at increasing faculty diversity and our own experiences in designing, implementing, and evaluating postdoctoral conversion programs on our campuses in the University System of Maryland (USM). Based on these experiences and data, we suggest a five-stage model that institutions could consider in establishing their own postdoctoral conversion program(s) for faculty diversity. This model is intended to be the basis for future research, replication, and adaption.

This topic merits study and is timely for several reasons. For years, students have demanded that institutions hire, more faculty members from underrepresented racial minority groups, and these demands have intensified in the context of the protests for racial justice in 2020 and 2021 (Kezar and Fries-Britt, 2018; Ezarik, 2021). Postdoc conversion models therefore offer one way for institutions to fulfill their equity goals. As such, this study focuses on challenging institutions to think through the steps they can take to mitigate structural barriers to the professoriate for historically marginalized faculty through postdoc conversion models.

The structure of this review is as follows. First, we discuss the current ethno-racial demographics of academics in the United States and examine why interventions at the postdoctoral level are needed. Next, we describe our methods and how we arrived at our five-stage postdoctoral conversion model. Then, we discuss each stage of the model and make actionable recommendations, drawing examples from our own experiences and our program review. Finally, we discuss our findings and make suggestions for areas of future study.

Faculty Demographics in the United States

Table 1 shows the racial distribution of the U.S. population based on the most recent Census in 2020 compared to the racial distribution of graduate students, postdoctoral appointees, and faculty members in U.S. higher education institutions. When we compare the racial makeup of faculty in the last column, we see that White faculty members compose 73.15% of all faculty members, which closely represents their 76.3% share in the Census. However, the composition of faculty members from racially minoritized groups is not representative of their respective share of the population. For example, Asian faculty members make up 10.83% of all faculty, almost twice that of their makeup in the population (5.9%). Scholars who identify as Black/African American (5.84% vs. 13.4%), Hispanic/Latino (10.83% vs. 18.5%), or Native American (0.44% vs. 1.3%) are underrepresented in the faculty compared to their percentage share in the population.

Table 1 also illustrates that as levels of training increase, the percentage of underrepresented racial minority scholars decreases. Data from the 2019 National Science Foundation Survey of Graduate Students and Postdoctorates in Science and Engineering[2] indicates that among U.S. citizens and permanent residents, most pre-professoriate scholars are White. However, there is relatively greater diversity among underrepresented racial minority doctoral students and postdocs compared to faculty. This suggests that the postdoc to faculty transition is a critical juncture at which interventions should focus (Gibbs et al., 2015; Meyers et al., 2018).

Postdoctoral Faculty Diversity Programs

An emerging body of research shows that postdocs from underrepresented racial minority groups encounter numerous challenges as they navigate their fellowships. Factors such as racial bias and stereotypes, inadequate mentoring, poor job market prospects, and competitive and hostile cultures lead to waning interest in academic careers among underrepresented racial minority postdocs scholars (Gibbs et al., 2015; Jaeger and Dinin, 2017; Lambert et al., 2020). While such studies point to specific structures (e.g., mentoring) that need to be altered to enhance postdoc retention, relatively few studies examine integrated postdoc training models and how they might be linked to the successful transition of underrepresented minority postdocs into faculty careers within the institutions that host them. For example, a handful of studies indicate that access to multiple mentors and multi-institutional training (e.g., across

[2]Full-time faculty data retrieved from https://ncses.nsf.gov/pubs/nsf21318#data-tables

TABLE 1 | Percent distribution of graduate students, postdocs and faculty by race and ethnicity.

Ethnicity and race	US population	Doctoral students (all disciplines)*	Postdocs (science and engineering)[1]	Faculty (all disciplines)[2]
Hispanic/Latino	18.5%	8.07%	6.53%	5.29%
Non-Hispanic/Latino				
American Indian or Alaska Native	1.3%	0.34%	0.23%	0.44%
Asian	5.9%	9.70%	20.00%	10.83%
Black or African American	13.4%	7.12%	3.69%	5.84%
Native Hawaiian/Pacific Islander	0.2%	N/A%	0.18%	0.16%
White	76.3%	68.74%	57.63%	73.15%
Two or More Races	2.8%	3.18%	1.76%	1.07%
Unknown Ethnicity and Race	–	2.84%	9.97%	3.22%

**National Science Foundation Survey of Earned Doctorates, 2019, table 19: https://ncses.nsf.gov/pubs/nsf21308/data-tables.*
[1] National Science Foundation Survey of Graduate Students and Postdoctorates in Science and Engineering, Fall 2019, table 2-1: https://ncses.nsf.gov/pubs/nsf21318#data-tables.
[2] National Center for Education Statistics, 2018: https://nces.ed.gov/programs/digest/d19/tables/dt19_315.20.asp.

institutions with different missions) can be beneficial in preparing underrepresented racial minority postdocs for faculty careers (Holtzclaw et al., 2005; Faupel-Badger and Miklos, 2016; Eisen and Eaton, 2017). However, in most of these programs, the goal is that the postdoctoral fellow completes their fellowship and then takes a faculty position at another institution. That is, most diversity postdoc programs are not intended to directly increase faculty diversity at the institution at which the fellow is trained.

These models are based upon long-standing norms within postdoctoral training, but they can also present tensions. Institutions may devote significant resources to the creation of a diversity postdoc program that results in a short-term "boost" to diversity, but this boost is not sustained after the fellow completes their term. External grants (e.g., from the National Science Foundation or National Institutes of Health) have catalyzed many postdoc diversity programs, which then end upon the grant's completion. There may be a misalignment between the fellow's expectations about the prospect being hired into the department and the department's ability to hire, which can breed resentment and ill-will. These postdoc diversity initiatives, in isolation, may be insufficient to move the needle significantly (Meyers et al., 2018).

This is where our, the authors, experiences come into play. Six of the authors have been directly involved with the development and implementation of postdoctoral conversion programs that are responsive to individual postdocs needs and the structural barriers that can encumber successful transition to the tenure-track. We have all also been involved in national and disciplinary-based conferences on postdoctoral training and its potential to contribute to faculty diversity. As a collective, we have been involved with:

The University of Maryland, Baltimore County (UMBC) Postdoctoral Fellowship for Faculty Diversity, which is now in its tenth year. This program has hosted 20 scholars, and of those who have completed the program, has converted 11 of 20 underrepresented postdocs into tenure-track lines at UMBC (7 of 20 are tenure-track faculty nationally), one of whom has just received tenure. The UMBC College of Natural and Mathematical Sciences Pre-Professoriate Program (PFP), which has converted all of its participants to tenure-track positions at UMBC;

A modified President's Postdoctoral Fellowship Program at the University of Maryland, College Park (UMCP)[3]

An NSF-funded AGEP PROMISE Academy, a state system-wide postdoc conversion model to diversify biomedical faculty, under development via a consortium of five USM institutions (Salisbury University; Towson University; University of Maryland Baltimore; UMBC; UMCP). The AGEP PROMISE Academy state system model is fleshed out in a case report in this issue (Cresiski et al., submitted[4]).

With these experiences in view, we see the promise and potential limitations of postdoc conversion programs for enhancing faculty diversity. We thus undertook this review as a way to bring together our collective insights and data from the field to propose a conversion model.

POLICIES AND PRACTICES IN POSTDOCTORAL CONVERSION

We took an integrative approach to considering the postdoc conversion policies and practices. Specifically, we drew from a review of postdoctoral conversion programs (**Table 2**) as well as our own experience in creating, administering, and evaluating postdoctoral conversion programs on our own campuses and within our university system.

Methods

Our first step was to generate a list of postdoc diversity programs to include in our review. We focused on postdoc programs that:

[3]The President's Postdoctoral Fellowship Program is a national collaboration that originated with the University of California and affiliated national laboratories. The program includes UMCP, the University of Michigan, the University of Colorado, Stanford University, the California Institute of Technology, Carnegie Mellon University, the University of Minnesota, New York University, University of North Carolina at Charlotte, University of North Carolina at Chapel Hill, and Georgia Tech.

[4]Cresiski, R. H., Ghent, C., Rutledge, J., Carter-Veale, W., Aumiller, J., Bertot, J., et al. (submitted). Developing a state university system model to diversify faculty in the biomedical sciences.

TABLE 2 | Postdoc-to-tenure track conversion programs in United States.

Institution	Program name
(1) Binghamton University	Presidential Diversity Postdoctoral Fellowship
(2) Broad Institute of MIT and Harvard	Postdoctoral Research Opportunity Diversity Initiative
(3) Carleton College	Oden Postdoctoral Fellows
(4) Carnegie Mellon University[1]	President's Postdoctoral Fellowship Program
(5) Emory University School of Medicine	FIRST A Postdoctoral Fellowship Program at Emory
(6) Georgia Tech University[1]	President's Postdoc Program
(7) Harvard University	Mary Fieser Postdoctoral Program for Women and Minorities (2008–2013)
(8) Johns Hopkins University	Provost's Postdoctoral Fellowship Program
(9) Miami University	Instructor/Visiting Assistant Professor and Heanon Wilkins Fellow
(10) New York University[1]	Provost's Postdoctoral Fellowship Program
(11) Northeastern University	STEM Future Faculty Postdoctoral Fellowship Program
(12) Ohio State University	Dean's Diversity Postdoctoral Fellows
(13) Syracuse University	Chancellor's Faculty Fellowship
(14) University of California	President's Postdoctoral Fellowship
(15) University of California, Berkeley*	Chancellor's Postdoctoral Fellowship
(16) University of California, Davis*	Chancellor's Postdoctoral Fellowship Program
(17) University of California, Irvine*	Chancellor's ADVANCE Postdoctoral Fellowship
(18) University of California, Los Angeles*	Chancellor's Postdoctoral Fellowship Program
(19) University of California, Merced*	Chancellor's Postdoctoral Fellowship Program
(20) University of California, Riverside*	Chancellor's Postdoctoral Fellowship
(21) University of California, San Diego*	Chancellor's Postdoctoral Fellowship Program
(22) University of Chicago	Provost's Career Enhancement Postdoctoral Fellowship
(23) University of Illinois at Chicago	Bridge to the Faculty
(24) University of Colorado, Boulder[1]	Postdoctoral Fellowship Program for Academic Diversity
(25) University of Iowa	Provost's Postdoctoral Faculty Fellowship Program
(26) University of Maryland, Baltimore County	Pre-Professoriate Fellowship in Biological Sciences
(27) University of Maryland, Baltimore County	Postdoctoral Fellows Program for Faculty Diversity
(28) University of Maryland, College Park[1]	President's Postdoctoral Fellowship Program (part of FAMILE: Faculty Advancement at Maryland for Inclusive Learning and Excellence)
(29) University of Michigan[1]	President's Postdoctoral Fellowship Program
(30) University of Minnesota[1]	President's Postdoctoral Fellowship Program
(31) University of New Hampshire	Postdoctoral Diversity and Innovation Scholars program
(32) University of New Mexico	University of New Mexico's Inclusive Excellence Post-Doctoral and Visiting Scholars Program (IEPDVSP)
(33) University of North Carolina at Charlotte[1]	Multicultural Postdoctoral Fellowship Program
(34) University of North Carolina Chapel Hill[1]	The Carolina Postdoctoral Fellowship for Faculty Diversity
(35) University of Rhode Island	Multicultural Postdoctoral Fellowship
(36) University of Wisconsin – Madison	Anna Julia Cooper Postdoctoral Fellowship
(37) Vanderbilt University	Academic Pathways Program
(38) Wayne State University	Postdoctoral to Faculty Transition Fellowship Program

**Part of the University of California President's Postdoctoral Fellowship Program.*
[1]Part of the Partnership for Faculty Diversity at the University of California.

(a) explicitly focused on increasing faculty diversity (i.e., excluded programs that did not specify diversity as a goal); and
(b) specifically mentioned conversion or transition to the tenure-track at the host institution as a possibility or goal for postdocs that participated.

To generate a list of programs to include, we first reviewed the diversity postdoctoral programs listed on minoritypostdocs.com, a website dedicated to career development and resources for scholars of color. We added to that initial list postdoc programs we were aware of based on our own networks and experiences (e.g., AGEP programs or institutions with programs not listed, which we generated from a Google search of "postdoc diversity programs"). Next, we reviewed the program websites of each program, determining which programs met the criteria above. Based on this, we narrowed the list to 38 postdoctoral conversion programs across the country (**Table 2**). For each program on this list, we noted the policies (e.g., search waivers) and practices (e.g., mentor training; annual reviews) specified on their websites that seemed to align with the goal of conversion.

Finally, we considered how these policies and practices mapped on to our own experiences in developing, implementing, and managing postdoctoral conversion programs on our own campuses and how policies and practices might best fit together or be sequenced to further the goals of increasing faculty diversity. For example, although some programs may not specify the process of conversion to the tenure-track, we recommended, based on our own experiences, that these expectations are made clear during recruitment. In this way, we identified discrete periods of time and activity based on how programs in our review sequenced various aspects of their models, as well as our own insights in what has worked (or needs to be improved).

We organized our findings into five stages: (1) Laying the Foundation; (2) Recruiting Fellows, Matching to a Mentor/Department and Pre-Arrival Preparation; (3) Fellowship Period; (4) Conversion to the Tenure-Track; and (5) Ongoing, Iterative Evaluation for Program Improvement. We consider these to be the five stages institutions, systems, or consortiums might follow to create a postdoc conversion program with the goal of increasing faculty diversity. We discuss policies and programs relevant to each stage and draw specific examples from

our review of national postdoc conversion programs as well as practical experience within the USM.

A discussion of limitations is warranted. Although we attempted to capture the breadth of postdoctoral conversion programs across the country, we did so based on a convenient sample of programs websites that could be accessed publicly. These data are incomplete in many ways, including the possibility that there may be postdoc conversion programs not included in this review; and that institutions may in reality use some of the practices (e.g., a search waiver) even if such information was not available on their website. For these reasons, we do not present evidence on the number of institutions that adopted certain practices (e.g., 10/38 had a mentoring program) because the data would not be conclusive. Moreover, as we have learned through our experiences, creating a sustainable postdoc conversion model is an iterative and non-linear process. Institutions may wish to alter the sequence of stages or place different policies or practices into different stages. While our goal is to offer common policies and practices for consideration and potential adaptation, we nevertheless acknowledge these as limitations to our approach. Ultimately, we hope that this discussion will spur additional scholarly literature and institutional transparency on this topic.

STAGE 1: Laying the Foundation

Stage 1 encompasses the foundational work required before beginning a program. This stage encourages institutions to honestly assess where they currently stand with the diversity of its faculty. It involves an institution critically examining pre-existing programs, identifying structural barriers, and looking to practices at other institutions (as we strive to accomplish in this report). Stakeholders must also decide how a postdoc conversion program will be funded and build and secure financial and operational commitments at multiple levels, including the department, college, and executive leadership of the institution. And perhaps most importantly, institutions must determine who will execute and lead the program.

Assessing Existing Faculty Diversity Efforts

One of the most critical elements in establishing a postdoc conversion program is for the institution to place it within the context of existing faculty diversity efforts and extant practices. For example, after years of insufficient progress with the recruitment and retention of faculty from underrepresented racial minority groups, in 2010, UMBC established the Executive Committee on the Recruitment, Retention, and Advancement of Underrepresented Faculty (henceforth called "Executive Committee"), a group of tenured faculty members of color, co-chaired by the provost and one of the committee members, to lead UMBC's faculty diversity efforts. This group did an analysis of existing initiatives and efforts on campus, including the UMBC's NSF-ADVANCE Program and existing AGEP programs focused on graduate education, as well as an analysis of faculty diversity programs at other institutions across the country. The Executive Committee determined that previous diversity hiring practices such as incentive hiring and target-of-opportunity hiring were unsuccessful because they failed to address the underlying issues of inhospitable departmental climates, bias, and institutional racism. This group then identified UNC Chapel Hill's Postdoctoral Fellowship for Faculty Diversity program and the University of California System (UC System) President's Postdoctoral Fellowship Program as relevant and successful models to emulate. There is some limited evidence that other postdoc conversion programs have likewise dovetailed on existing faculty diversity efforts. For instance, the Northeastern Future Faculty Fellowship Program and Syracuse University's Chancellor's Faculty Fellowship explicitly state that their programs emerged in relation to ADVANCE programs.

Understanding relevant local, state, and national employment regulations is also critical at this point. For instance, as UMBC program leaders designed the Fellowship for Faculty Diversity program, some prominent faculty questioned the constitutional and statutory legality of the program, more specifically the focus on scholars from underrepresented racial minority groups. Program leaders were able to cite the existence of National Science Foundation programs and models like UNC Chapel Hill's Postdoctoral Fellowship for Faculty Diversity and the UC System's President's Postdoctoral Fellowship Program to legitimize the program goals, therefore mitigating some resistance.

Establishing Structure and Co-leadership

Another critical piece is for institutions to establish program and leadership or co-leadership structure. Many of the postdoctoral programs reviewed seem to be managed and facilitated centrally by the provost's office or faculty affairs office. For example, postdoc conversion programs at John Hopkins University and Northeastern University are centrally managed by faculty affairs offices within academic affairs. The UMBC Fellowship for Faculty Diversity Program uses a co-leadership model: unlike many other programs, UMBC's Executive Committee is the main advisory body for the program, putting genuine authority in the hands of faculty of color, though the fellows are funded (and the application process is managed) by faculty affairs. Similarly, UMCP's program is funded by faculty affairs, reviewed by a diverse committee of university faculty, and the application process is managed by the office of postdoc affairs. To operate a system-wide program, the UC System's President's Postdoctoral Fellowship Program has central administrators who are employed by the system. Similarly, the USM AGEP PROMISE Academy is administered by a leadership team composed of graduate deans, faculty affairs administrators and postdoctoral affairs staff from across the five-institution alliance. While a part-time director ensures continuity and accountability, the co-leadership from participating institutions creates meaningful buy-in that supersedes silos and potential power dynamics.

There are also examples of conversion models housed within academic colleges, including UMBC's Pre-Professoriate Program, which is located within the College of Natural and Mathematical Sciences, and The Ohio State University's (OSU) Dean's Diversity Postdoctoral Fellows in the College of Education and Human Ecology. In the case of the Pre-Professoriate Program, the decision to have a college-level program was a strategic one. Given the expectations and resources needed to prepare scholars for tenure-track roles in the life sciences (including laboratory

space and startup funds), program designers created a program parallel yet distinct from the centrally managed Fellowship for Faculty Diversity Program. The dean's office manages the Pre-Professoriate Program, and it has its own requirements and expectations.

Creating Application Processes, Procedures, and Cost-Sharing

Based on our review, most postdoc conversion programs outline a competitive process, wherein candidates apply centrally, departments put forward candidate application packages they determine to be a good match, and a central academic administrator or committee (e.g., provost's office; a committee; a dean) determines which departments/units will be granted a postdoc position. The mechanisms by which applications are generated and put forward vary substantially. For example, in the UMBC Fellowship for Faculty Diversity, departments review applicants and submit their own requests to their dean. The dean then makes recommendations to the Executive Committee, who selects finalists for interview. After interviews with the departments and a variety of stakeholder offices, the Executive Committee decides which candidates to offer to the positions. These assessments are based on factors such as candidate qualifications, availability of appropriate mentors, and departmental readiness to retain and support the advancement of underrepresented scholars (see Stage 2). Similar competitive processes are in place at institutions like the University of Illinois at Chicago, UNC Chapel Hill, and Northeastern University, or in place at the unit level such as in UMBC's Pre-Professoriate Program or OSU's Dean's Diversity Postdoctoral Fellows Program. To maximize departmental faculty buy-in, the Pre-Professoriate program adopted a standard faculty search process to hire each Pre-Professoriate fellow. Institutions participating in the President's and Chancellor's Postdoctoral Fellowship Programs (including UMCP) use a centralized application system (i.e., fellows could apply centrally to be postdocs at more than one institution). However, even with a centralized application mechanism, there are institutional processes that must be determined (for example, a department may write letters of support for selected candidates and forward applications to the dean or the faculty review committee, which reviews the materials and makes recommendations to the provost, etc.).

In terms of funding the initial postdoc period, we found significant variability. Several programs (e.g., UMCP), specified a cost-sharing structure where the initial postdoc salary/stipend is shared between central academic affairs and the host department. Other institutions, such as Johns Hopkins University, Northeastern University, and the University of Chicago Illinois, appear to offer full central funding (e.g., from academic affairs) during the fellowship period, with varying levels of central salary subsidy after the postdoc converts (see Stage 4). Likewise, there is variation in how postdoc resources (e.g., professional development, research funds) are funded. We see benefits in either approach. One on hand, cost-sharing strategies may enhance departmental buy-in and ensure that departments recruit only those candidates that they think will be successful. On the other hand, fully subsidized postdoc salaries may incentivize departments with fewer resources to participate. In the AGEP PROMISE Academy Alliance, the five institutions within the alliance must determine mechanisms to fund the fellows, but professional development, travel, and some research funds are covered by the NSF grant.

Classification of Postdocs and Joint Titling

Early-on, it is imperative that institutions engage with Human Resources to determine how the postdocs will be classified. Postdoctoral positions are not uniformly standardized at or across institutions in the U.S., a fact that has made research about this population notoriously difficult (McConnell et al., 2018). Titles and classifications directly impact a fellow's access to institutional and departmental resources, how they are perceived by colleagues, and the hiring or conversion process itself. For conversion, it is important to distinguish whether postdocs are university faculty members or trainees. This difference in employment status may mean that some postdocs receive a salary while others receive stipends, which requires different tax treatments. Although all postdocs have access to health and dental insurance through the university, payment and withholding arrangements differ.

One option employed by some institutions is joint titling, offering a faculty position/title concurrently to the postdoctoral one. The University of Chicago's Provost's Career Enhancement Postdoctoral Fellowship appoints fellows under a classification of "Instructors on the tenure track" with the intent that they will be promoted to Assistant Professor at the end of the fellowship period. UMBC's Pre-Professoriate program hires fellows into Research Assistant Professor roles, a non-tenure track faculty rank, that gives scholars all the benefits of being classified as faculty and acknowledges the mutual intentions of the fellow and the department to have the fellow become a tenure-track faculty member.

STAGE 2: Recruiting Fellows, Matching Fellows to a Mentor/Department and Pre-arrival Preparation

Stage 2 focuses on recruiting fellows, identifying faculty mentors and host departments, establishing and communicating expectations, hiring fellows, and preparing for their arrival. Programs that seek to garner a large pool of applicants should begin their recruitment process by creating an active recruitment plan as well as actively engage departments in recruitment. Steps should also be taken to ensure postdocs, proposed faculty mentors, and departments understand the intent, structure, and their responsibilities within the program.

Recruiting Fellows

In creating a recruitment plan, programs should generally engage in assessing policies and procedures for recruiting and hiring fellows to make sure a robust, evidence-based plan can be created. For example, prior to beginning recruitment for all UMBC's Fellowship for Faculty Diversity fellows (and indeed for all faculty positions), the Executive Committee requires each department to develop a comprehensive 'faculty diversity hiring and recruitment plan' that includes a discussion of

search committee composition, an active recruitment strategy, inclusive draft job advertisement, and initial evaluation and interview strategy. The Dean's Office and Provost Office review these plans before searches are authorized. Additionally, UMBC implemented *Interfolio: Faculty Search*, an online software, which increased the transparency of the faculty search committee's candidate review and provided a tool to track the diversity of the applicant pools. A webpage for the program was also created to provide information to potential applicants. In addition, leaders can also look at the national pipeline of doctoral degrees by discipline based on the annual Survey of Earned Doctorates (SED) and compare this to faculty applicant pools, finalist pools, and hires within departments across the institution. This data assessment provides an opportunity for discussion to move beyond anecdotal evidence[5].

After institutions put internal procedures into place, they must engage in well-documented recruitment approaches to increase the pool of underrepresented applicants (Peek et al., 2013; Bhalla, 2019). The primary method is centered on utilizing existing networks, through national associations, and through regional and national conferences. Regional and national conferences that focus on retainment of minoritized communities such as, the Southern Regional Education Board (SREB), the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), the National Society for Black Engineers (NSBE) are common avenues for postdoctoral program recruitment. In the case of UMBC's Fellowship for Faculty Diversity, the Executive Committee also relied on "The Committee on Strategies and Tactics to Recruit to Improve Diversity and Excellence" (STRIDE), a program in which respected faculty members support the efforts of search committees, departments/programs, and colleges to recruit, retain, and promote diverse faculty and foster more inclusive and equitable academic spaces for faculty peers. Likewise, the AGEP PROMISE Academy developed a Guidance Document for the Recruitment of AGEP PROMISE Academy Fellows[6] to ensure semi-standardized practices that leverage evidence-based approaches in the recruitment of fellows across the alliance institutions. This document includes sample job advertisement language, appendices of minority graduate and postdoctoral directories, email addresses of top minority Ph.D. producing programs in the biomedical sciences, and sample rubrics for the evaluation of candidates. The overall goal of such practices is to give departments tools for being more proactive in recruiting potential postdocs.

Creating a Mentor/Departmental Match Process

Faculty diversity programs around the country emphasize the fundamental role of effective mentorship during the fellowship period. In a departure from the traditional model of fellows supporting their mentors' research, successful postdoctoral conversion programs aim to support fellows' independent research and teaching. This component is clearly outlined by such programs such as those in the UC System, the University of Michigan, and the UNC Chapel Hill, and programs in USM. Across these programs, we observed relative consensus that appropriate mentors would be those who had an established track record of mentoring and were tenured faculty members, although a handful of programs indicated that untenured faculty may be "involved" as mentors (though not the primary mentor).

The process by which mentors and corresponding departments are identified varies. In some models, such as UMBC's Fellowship for Faculty Diversity, fellows apply to the program centrally at the institution or college level. Once departments receive a candidate's application and determine the criteria by which the postdoc will be evaluated, they internally identify willing and appropriate mentors. This approach ensures that a fellow's application is assessed based on the strength of their skills and alignment with department needs, rather than putting the onus on the fellow to identify departments and mentors in which there may be a fit. If departments are interested in supporting a postdoc, they then submit a detailed mentoring plan as part of the overall application process. In fact, a few programs including UMBC's Fellowship for Faculty Diversity program and the University of Rhode Island's Multicultural Postdoctoral Fellowship in the Biological Sciences, require departments to identify a primary faculty mentor and a secondary mentor outside of the fellow's program as part of their application process.

Other programs require the applicant to identify a proposed mentor and department in their application. For example, most of the Presidential and Chancellor Postdoctoral Fellows Programs, including UMCP's, require applicants to solicit and subsequently submit a letter from the proposed mentor, department chair, and sometimes the dean, that indicates their support for the postdoc. This method ensures that the pool of potential postdocs is composed of candidates who already have faculty and department support.

One aspect that was unclear from our review was when, if, and how candidates were interviewed and by whom. Traditional postdocs are often interviewed only by the hiring faculty member if interviewed at all. But postdocs that are going to be considered potential faculty colleagues require a different degree of vetting by a broader set of stakeholders. For UMBC's two conversion programs, extensive interviewing is done with the potential hiring department, department chair, and deans among others, similar to that of a traditional, national faculty search. For the AGEP PROMISE Academy fellowship, leadership aims to set up research talks and networking events with fellows and institutions of interest as informal interviews to assist fellows in connecting with departments that are potential hiring departments within the university system. An interesting pilot program, the Cottrell Emerging Scholars Program[7], facilitates underrepresented postdoctoral candidates (from programs which

[5]Many institutions have adopted the practice of using data to give context to applicant pools in faculty hiring. For instance, see the University of Wisconsin–Madison's search and selection guidebook: https://wiseli.wisc.edu/wp-content/uploads/sites/662/2018/11/SearchBook_Wisc.pdf

[6]https://drive.google.com/file/d/1arLAq_Ok8HX3Jiyoi6BYCHleQq4N3yvk/view

[7]https://rescorp.org/news/2020/12/diversity-program-helps-postdocs-prepare-for-interviews

do not include conversion, like Vanderbilt's Academic Pathways[8] program) to visit other campuses within a consortium for an intensive mock faculty job interview. This clearly serves as an opportunity for professional development for the postdoc, but it also has become a recruitment mechanism for the departments hosting the mock interviews and has directly led to placement of fellows in tenure track positions. While this is not yet a full-fledged postdoc conversion model, aspects of this program may be worthy of replication especially for those considering consortia or system approaches.

One emerging practice we found at a few institutions was the creation of mentor development programs. For example, at UMCP, faculty members who are the mentors of President's Postdoctoral Fellows are required to participate in mentoring training that uses the Entering Mentoring framework[9]. We are also aware of mentoring trainings that occur in the Big 10 Academic Alliance as part of their AGEP programs[10]. While all programs in our review specified a mentoring component, professional development/training for mentors was not universally required.

Assessing Readiness

As discussed, many postdoc conversion programs are competitive processes, wherein departments submit applications and a central hiring authority (e.g., dean, provost, committee) decides which units will be granted funds to host a postdoc. Our review uncovered several criteria by which these determinations are made, including readiness assessments and future hiring needs.

An emerging practice in this area is an assessment of "departmental readiness" to welcome, support, retain, and help advance scholars of color. Some institutions, like UMBC, have put in place mechanisms to examine if departments applying to have a postdoc have environments that are inclusive, welcoming, and are places where a scholar is likely to be retained. Determination about a department's readiness is made based on evaluating the quality of the mentoring or retention plans the department submits with the application package; examining the department's history of recruiting, retaining, and mentoring faculty from underrepresented racial minority groups; and/or participation in relevant diversity-related assessments or trainings. Other institutions, such as UMCP, mention the evaluation of a retention plan, though the details of the plan are not specified. Similarly, other institutions mention mentoring plans as required, but it is not clear if plans are reviewed/assessed as part of the postdoc award process.

Another criterion by which readiness might be evaluated is the extent to which the department will be able to hire when the postdoc's fellowship is complete. For instance, in Johns Hopkins University's process, department chairs or deans can submit an optional letter indicating the possibility for the postdoc to be hired either within the department or within another institutional department at the end of their postdoc term. Although this letter is not a guaranteed promise of a faculty position, it strengthens the potential that the department will be approved for the postdoc position. A similar policy exists at University of Colorado Boulder and Syracuse University. At UNC Chapel Hill, departments craft postdoc job descriptions with future hiring needs in mind (EAB Global, 2017). Likewise, in UMBC's Fellowship for Faculty Diversity, the dean evaluates whether departments will be able to hire a postdoc and forwards those applications to the Executive Committee. Alternatively, some programs are only open to departments that will have upcoming faculty positions and make clear which departments are taking postdoc applications each year, such as OSU's Dean's Diversity Postdoctoral Fellows and the University of Missouri's Faculty Diversity Postdoctoral Program. The overall goal of such efforts is to create scenarios wherein the postdoc is being hired into departments that will have the ability to hire in the future and give priority to those departments.

Negotiating Expectations and Terms

From the outset, postdoctoral conversion programs should provide transparency around the conversion process for the benefit of all relevant parties, particularly for the fellows, mentors, and departments in which fellows are appointed. In UMBC's Fellowship for Faculty Diversity program, the fellow's appointment letter outlines for the fellow and host department the requirements of the position, as well as salary, funding for moving expenses, travel, office space, and research[11]. Many programs, such as University of Colorado Boulder, Northeastern University, and UMCP, likewise specify that fellows must be given office space, specific minimum start-up, or professional development funds.

The extent to which conversion is discussed and formally stated during the negotiation process is nebulous. Some of the postdoc programs reviewed specifically state what the process for conversion will be on their websites (e.g., the UC System, OSU) or as part of the hiring process (UMBC's conversion programs) and will be discussed in Stage 4, though these seemed to be the exceptions rather than the rule. Other programs, like the AGEP PROMISE Academy, acknowledge multiple pathways to conversion, one predetermined (where the fellow is intended to be hired into the tenure track at their postdoctoral institution) and one flexible (where the fellow will be assisted in finding possible future placement within the university system). The language about the possible conversion must signal to the applicant that the tenure-track position is not guaranteed and is based on performance, while still assuring fellows that conversion is intended. We recommend that both the job advertisement and offer letter use language such as "opportunity" and "intention" (instead of a "guarantee") to transition to a tenure-track faculty position.

Formal duties of postdocs differ from program and program. As most postdoc conversion programs are located within

[8]https://www.vanderbilt.edu/inclusive-excellence/academic-pathways-an-initiative-for-academic-diversity/

[9]https://www.hhmi.org/sites/default/files/Educational%20Materials/Lab%20Management/entering_mentoring.pdf

[10]https://www.btaa.org/leadership/pai/postdocs

[11]In UMBC's Pre-Professoriate program, the start-up funding for the expected tenure-track conversion is negotiated prior to the fellowship. For both programs, the funding for the salary of a tenure track position and all associated funds (including start up, travel) are encumbered at the faculty rate starting at the beginning of the fellowship.

research-intensive institutions, the postdoc's primary duty is to develop their independent research agenda (which contrasts with typical postdoc models wherein a postdoc works on their faculty mentor's research). For example, in UMBC's Fellowship for Faculty Diversity, Pre-Professoriate Program, and in the AGEP PROMISE Academy, postdocs are expected to develop and further their independent research agenda to prepare them for a tenure-track position within the institution or university system, respectively. The extent to which postdocs participate in teaching varies widely. In Carleton College's Oden Fellowship program, teaching occupies half of the fellow's time (two courses in the first year, three in the second year). UMBC's fellows are required to teach one course per year (though not in the first semester of the fellowship to ensure adequate time for adjusting to a new institution and getting research off the ground). Other conversion programs leave teaching duties to the discretion of the postdoc or specifically state that teaching is not expected (e.g., UMCP's President's Postdoctoral Fellowship Program, Northeastern University's STEM Future Faculty Postdoctoral Fellowship Program). No formal expectations pertaining to service, including mentoring/advising, were described within conversion programs, though it seems logical that if postdocs are in classroom roles, they may be asked to informally advise and mentor students.

STAGE 3: Fellowship Period

Stage 3 focuses on the postdoc fellowship period and covers activities of the fellow, their faculty mentor(s), and the department into which they were hired. This stage includes onboarding, professional development, community building, and evaluation. Most postdoc conversion programs (including those located at institutions within USM) specify a two-year fellowship period, with conversion to a tenure track position taking place prior to the third year, although nationally there are some exceptions (e.g., the Heanon Wilkens Fellowship at Miami University is only one year). During this period, the fellow is onboarded, mentored, and assessed.

Onboarding the Fellow

The onboarding process is critical to ensure postdocs feel welcome and can successfully teach and launch their research. Hiring and onboarding a new postdoc in a conversion program is generally the purview of the department and varies considerably. To ensure quality onboarding, some more centralized programs have developed standardized onboarding experiences and/or documented expectations for departments onboarding fellows. The UMBC Fellowship for Faculty Diversity program has developed several specific onboarding practices that program leadership communicates to departments and fellows prior to the start date. These practices include written guidelines that outline the responsibilities of mentors, chairs, and fellows, and checklists that spell out the expectations from the department and the provost's office staff (including professional development resources, office space, and pay and insurance information)[12]. Onboarding should also include a substantive review of the conversion process and criteria that was hopefully discussed prior to hire. UMBC ensures the fellow, department chair, department administrative staff, primary faculty mentor, provost office administrative staff, business office, and human resources staff all review the conversion documents in a meeting together so there are no questions left unanswered. These meetings are recorded and accessible to stakeholders at any time in the future.

Onboarding also involves creating connections between fellows and department members. UMBC's Pre-Professoriate program in the natural sciences hires fellows on the standard academic job cycle intentionally to facilitate fellows' ability to participate in all campus new faculty activities (orientations, socials, open houses, etc.), thereby integrating them into the department, college, and institution. UMCP's President's Postdoctoral Fellowship program expects fellows to participate in a program orientation and a program reception. They also provide expectations for host departments to "welcome the fellow into the department and make every effort to ensure that the fellow is included in communications about departmental colloquia, seminars and social events." The postdoc conversion program at University of Colorado Boulder likewise specifies that departments should take action to ensure the fellow is included as a faculty member in the department. All these practices serve to establish scholars as a colleague/potential colleague and not an "inferior" trainee.

Fellow Professional Development

Nearly all the conversion models in our review mentioned that fellows would be invited or expected to participate in professional or career development. At the same time, there was wide variation in the extent to which these expectations were formalized and the kinds of activities in which fellows participated.

An existing best practice is the use of individual development plans (IDPs) or individual mentoring plans. IDPs serve many goals, including establishing long and short-term career goals, identifying specific activities in which the fellow will partake, marking progress over time, and structuring informal/formal evaluation of postdocs by their mentors and departments. The goal of IDPs in conversion programs should be to lay a specific professional development path that will ready the postdoc for the successful and smooth transition to a tenure-track faculty role in the department. Several USM institutions use individual development or mentoring plans in their postdoc conversion models, including the programs at UMBC, UMCP, and the AGEP PROMISE Academy. In UMBC's Fellowship for Faculty Diversity, for instance, departments who host a postdoc create and submit "Faculty Development Plans," which detail the research, teaching, and professional development goals for the upcoming semester. At the end of each semester, mentors and fellows submit an assessment report that reviews their progress and addresses any challenges. The AGEP PROMISE Academy has developed a standardized self-assessment tool to assist fellows and mentors identifying areas of growth and opportunity to increase chances of success

[12]Sample materials from the UMBC Fellows for Faculty Diversity Program can be found here: https://drive.google.com/drive/folders/10Zkgx25gyIbhoib00XiYsngyk4O6B04g?usp=sharing

securing (and being successful with) a tenure-track position[13]. Conversion programs at the University of New Hampshire and UNC Chapel Hill likewise require postdocs to create IDPs with their mentor and revisit them periodically to assess progress.

In conjunction with IDPs, most conversion programs offer or require fellows to participate in ongoing professional and career development. Professional development activities include workshops on teaching, grant-making, mentoring, or other skills development topics. Other activities might include discussions of work-life integration or maintaining productivity. The extent to which such professional development activities are offered centrally or by each postdoctoral fellows' department varies substantially. For example, in UMBC's Fellowship for Faculty Diversity program, professional development is largely the responsibility of the department, whereas at UMCP, the office of postdoctoral affairs offers central professional development workshops and training (in addition to any activities or workshops at the department level). In contrast, the AGEP PROMISE Academy employs a consortia model where professional development is offered to fellows across institutions, leveraging the strengths of institutions with different missions (e.g., pedagogical workshops from the teaching-centered institutions, grant writing from the medical school).

Another issue relates to the quantity and quality of professional development provided. UMBC Fellowship for Faculty Diversity program leaders noted that the kinds of activities in which postdocs participate varies widely, with some completing many and others relatively fewer. In contrast, the UMBC Pre-Professoriate program specifies at least three, institution-level professional activities fellows are expected to complete at minimum (a 4-day entrepreneurship training program, a STEM teaching series that leads to an internally recognized certificate, and an inter-department mentoring program). In the latter case, the Pre-Professoriate program integrated existing campus and unit-level faculty development activities into the requirements for fellows.

There are benefits and limitations of any approach. Department-level professional development potentially provides postdocs with local and discipline-specific knowledge that the postdoc can then leverage as a faculty member. Institutional and cross-institutional programs provide opportunities for networking and community building and potentially reduce program duplication but may also require more centralized coordination. The takeaways here are that program leaders might wish to establish baseline professional development expectations while still allowing for flexibility based on relevant disciplinary, institutional, and individual contexts. Moreover, leveraging existing professional development resources, at either the campus or consortia level, may be useful in areas more universal to the faculty experience (e.g., work-life integration) but less so at the disciplinary or institutional level.

[13]https://thepromiseacademy.files.wordpress.com/2021/02/apaa-clo-skills-assessment-revised.pdf

Cohort Models

Many of the postdoc conversion programs we reviewed seemed to establish postdoc cohorts or recruit multiple fellows to begin their fellowship at the same time. For instance, the University of Illinois at Chicago's Bridge to the Faculty (B2F) uses a cohort model to provide a community to its fellows where they participate in group meetings and workshops that build skills toward tenure track roles together. The University of Rhode Island's Distinguished Multicultural Postdoctoral Fellows program aims to "cluster-hire" three fellows in distinct disciplines around a theme this coming year, providing offices in the same building to facilitate connection. Using a cohort model benefits the institution in that the processes of recruitment, hiring, and onboarding occur synchronously - this is especially true for programs that run in alternate years (e.g., UMBC's Fellowship for Faculty Diversity, Carleton College's Oden Postdoctoral Fellowship). Relatively few conversion programs reviewed distinctly named cohort building as a goal, representing a potentially untapped opportunity.

Fellow Evaluation, Reporting and Accountability

Many conversion programs include annual review processes. Annual reviews take two forms, though each is typically tied to the postdoc's individual development or mentoring plans and department/mentor expectations guidelines. First, some postdoc conversion programs like UMBC's Pre-Professoriate program and the UMCP President's Postdoctoral Fellowship Program require that each fellow receive a formal annual review, wherein the postdoc receives feedback on their research and teaching as applicable. Likewise, postdoc programs at the University of New Hampshire and OSU specify that scholars receive an annual written performance review. These types of reviews are akin to faculty annual review processes and thus prepare them for the tenure track. Ideally, annual reviews (like IDPs) provide fellows feedback about their progress toward conversion within the department in which they are working (as opposed to more general feedback on research).

Another kind of annual review takes place at the institutional level, wherein departments, mentors, and postdocs complete assessments and submit them to central administrators. For instance, in the UMBC's Fellowship for Faculty Diversity, program leaders established templates for annual reporting and required the postdoc and their mentor to complete the report each semester. Such reporting allows program leadership to monitor for potential issues and anticipate which departments would be hiring in the coming academic year. Reporting also held departments, mentors, and postdocs accountable for completing the activities laid out in mentoring or professional development plans, and allowed the Executive Committee to suggest and support interventions that may be deemed necessary for the fellow's professional development.

STAGE 4: Conversion to the Tenure Track

Conversion describes the formal transition of a postdoctoral fellow into a tenure-track faculty position, including the process and procedures for how to evaluate the fellow. As most campuses have very detailed procedures outlined in policy about faculty

hiring, it is imperative that those establishing programs work with their shared governance process to determine a conversion pathway that is supported by the faculty within the department and the institution at large. For some campuses and programs, this is circumvented by having rigorous search processes for the postdoctoral fellow, aligned with typical national faculty searches, and search waiver policies that facilitate dean and/or provost hire. Although the details of the conversion process are likely of great interest to postdoctoral fellows and institutional leaders hoping to replicate these models, the processes remain obscure: of the 38 institutions reviewed, very few fully describe their conversion process on their websites. Actual procedures, criteria, and policies are frequently absent. Below we describe what we were able to garner regarding evaluation criteria, financial incentives, and search waiver policies enabling the conversion process.

Evaluation Criteria and Procedure

The criteria for tenure-track conversion eligibility varies across programs and detailed criteria were not easy to obtain online for most programs. Typically, programs allude to components of the evaluation process or hitting "benchmarks" that are not defined. For example, Wayne State University's (WSU) Postdoctoral to Faculty Transition Fellowship program states that fellows who obtain external grants during their postdocs will be considered for tenure-track appointments at WSU with competitive compensation and startup packages. The program adds that "upon completion of a set of rigorous program milestones, fellows will be eligible for consideration for tenure-track faculty positions at Wayne State." Likewise, University of Colorado Boulder notes that department chairs "should consider the fellow for faculty appointments and provide fellows with timely information regarding a future faculty appointment," but does not specify how conversion will take place. Similarly, Carnegie Mellon University indicates that the fellowship offers "the possibility" of succeeding to a faculty position, but nothing further is specified on the website.

There are exceptions. OSU's Dean's Diversity Postdoctoral Fellowship program has a detailed program handbook[14] that clearly outlines the annual expectations of fellows, the evaluation timeline, and recommendations for hire into a tenure track role. For UMBC's Fellows for Faculty Diversity, the evaluation process is clearly outlined in the offer letter to the newly hired fellow and reiterated during onboarding meetings for the fellow, mentors, and departmental and institutional staff. In particular, the materials[15] spell out that as early as the completion of the first semester in the role, the departmental faculty can vote to begin the process of conversion to tenure track. The evaluation of the fellow's progress during the fellowship includes six components: (1) a presentation of research (and teaching, if appropriate), (2) a meeting with the department faculty, (3) a meeting with the department chair, (4) a meeting with the Dean, (5) a meeting with the Vice Provost for Faculty Affairs, and (6) at the conclusion of these conversion "interviews," the department conducts a vote to recommend to the dean and provost the conversion to a tenure-track assistant professor. For UMBC's Pre-Professoriate Fellows, the fellow prepares a dossier that is evaluated by the department faculty, who make a recommendation to the chair and dean about conversion to a tenure-track position. This process was intentionally designed to simulate the promotion and tenure process, to enhance the legitimacy of the fellow, increase department buy-in, and set fellows up to successfully move onto the tenure-track.

For state-wide systems who might want to jumpstart the process of conversion, implementation of these new faculty hiring pathways involves anticipation of critical roadblocks that might derail the conversion process. Challenges identified by the AGEP PROMISE Academy Alliance include establishing institutional commitments across participating institutions to the postdoctoral fellow after the fellowship; identifying search waiver processes that could facilitate conversion into a tenure-track roles at institutions across the university system; and developing hiring, onboarding and matchmaking processes for the fellow that increase their opportunities to build relationships with departments as a potential future faculty member.

As was mentioned in Stage 2, we recognize that in most conversion programs (institutional or system-wide), a tenure-track position is not a guarantee for the postdoctoral fellow. At the same time, establishing and providing as much detail as possible about the processes and/or criteria by which a tenure-track position may be offered would benefit applicants and likely strengthen the competition for these programs.

Financial Incentives

One way that institutions reduce the financial barrier of postdoc conversion programs is by linking the program to existing or new targets of opportunity hiring programs. For instance, at UNC Chapel Hill, the Office of the Executive Vice Chancellor and Provost provide a salary incentive for up to four years for faculty members who further the diversity goals of the department, which can be used to hire postdocs who participated in the President's Postdoctoral Program. Likewise, UMCP recently made efforts to align the Presidential Postdoc Program with the newly re-established target of opportunity incentives for assistant and associate positions. Departments that host President's Postdoctoral Fellowship postdocs can also apply for target of opportunity funds if they convert the postdoc to a tenure-track position (though this process is not automatic).

Another way institutions support the conversion of postdocs into faculty roles is by providing financial incentives. The UC System offers a centralized, institutional subsidy for universities that hire their President's Postdoctoral Fellowship postdocs or Chancellor's Postdoctoral Fellows into internal faculty roles at any of the system's campuses[16]. Campuses receive a $85,000 faculty salary subsidy per year for 5 years. Based on our review, the UC model appears to be the only one financially centralized at a system level (the AGEP PROMISE Academy, while a system

[14]https://ehe.osu.edu/sites/ehe.osu.edu/files/postdoctoral-fellowship-handbook.pdf

[15]Sample materials from the UMBC Fellows for Faculty Diversity Program can be found here: https://drive.google.com/drive/folders/10Zkgx25gyIbhoib00XiYsngyk4O6B04g?usp=sharing

[16]https://ppfp.ucop.edu/info/fellowship-recipients/hiring-incentive.html

model, does not have centralized funding for the postdoctoral positions nor hiring incentives).

Financial incentives can also serve as an accountability mechanism to ensure that the department fulfills its obligation to provide professional development and support to *sustain* the converted fellow. For instance, UMBC's Fellowship for Faculty Diversity specifies that faculty lines do not continue in the department if the converted fellow is not retained. If the fellow leaves the department even after conversion, the line cannot be filled by the department through a national search – the position returns to the control of the provost's office, potentially to be used for a new Fellow for Faculty Diversity in an upcoming cycle. Such structures can incentivize departments to create a climate where scholars choose to stay and are supported in their advancement.

Search Waivers

Much like the processes put in place for partner hires or senior hires, institutions can put in place search waiver policies that departments can utilize or apply for when converting a postdoc into a faculty position. There are a few ways in which these search waivers apply to postdoc-faculty conversion. For example, departments applying for a postdoc as part of the UNC Chapel Hill Postdoctoral Fellowship for Faculty Diversity at UNC "pair" their postdoctoral line with incentive funding the completion of the fellowship term (EAB Global, 2017). Similar search waiver provisions exist at University of Colorado Boulder and UMCP. Search waivers are typically, though not exclusively, used in tandem with the financial incentives discussed previously. That is, if a department identifies a candidate that furthers the diversity goals of the unit, they will apply for both a search waiver and target of opportunity funding, effectively removing process-related barriers tied to an open search as well financial barriers related to funding a new faculty line. In some institutions, the conversion process is made easier if the fellow is considered an employee (rather than a trainee) because employees are given higher priority. For example, at University of Colorado Boulder, departments can access a search waiver if the candidate is already considered an employee.

For system-wide approaches, such as the UC System's incentive model or USM's AGEP PROMISE Academy, search waivers are a critical piece of how postdoctoral fellows can be pulled into tenure-track lines at institutions outside of where they completed their postdoctoral fellowship. The UC System has a system-wide policy explicitly outlining and encouraging hires from their diversity programs, while USM does not. Instead, USM relies on institutional policies of search waivers and target of opportunity hires for this process, though system wide language is being explored.

STAGE 5: Ongoing, Iterative Evaluation for Program Improvement

Stage 5 emphasizes the importance of self-study. Achieving successful results requires an iterative evaluation process that is ongoing and involves both process and summative evaluations. This iterative practice allows the stakeholders to be reflective about the program and adjust rather than just give up without truly understanding where things went wrong.

Structured Program Evaluation and Documentation

It is imperative that the program have a plan for assessment at designated times for appropriate self-study. Program leadership should establish how data will be collected both quantitatively (e.g., number of hires, percent converting to the tenure track, percent retained and achieving tenure) and qualitatively (e.g., focus groups, meetings between program staff and mentors or departmental faculty). We found that relatively few postdoc conversion programs make public their evaluations, and those that do offer a more quantitative approach. For instance, the UC system reported in 2017 that over 90% of fellows were still in the UC system[17] and UMBC reported that over 50% of fellows that participated in the Fellowship for Faculty Diversity have been retained. On the other hand, such data were rarely available, and we lack evidence about the experience of fellows and departments within these programs.

Evaluation should track successes, but also understand barriers and failures. It is important to consider why postdocs do not convert, for example. For each cohort of the Fellowship for Faculty Diversity, UMBC's Executive Committee evaluated what worked and what did not and the lessons they learned. After each cohort is hired, program leaders administer a survey to stakeholders (e.g., department chairs, deans, fellows) about their experience. The Executive Committee also conducts exit interviews with any departing fellows (and indeed all departing faculty members) to understand why they were not retained and to understand aspects of department cultures that were unwelcoming and/or identify how resources could be deployed more strategically to ensure the fellow's success. Program leaders keep detailed electronic notes to ensure lessons learned are not lost over time. In other words, UMBC has benefited from ongoing evaluation and has built in structured times to evaluate the ongoing successes and struggles of the program.

Postdoc conversion programs have the potential to also have impacts beyond the scholars who participate. For instance, the programs at UMBC have led to departments and programs rethinking their entire recruitment process, including crafting inclusive job advertisements, engaging in active recruitment and networking, creating shared evaluation metrics and application review procedures, and implementing welcoming interviewing processes and protocols. Additionally, the mentoring expectations and reports that are required have led many departments to develop more intentional and inclusive mentoring practices to support not only the fellows but also all pre-tenured faculty.

Continuous Program Improvement

As UMBC's President Freeman A. Hrabowski often says, "success is never final." Our five-stage process might be viewed as a mostly "finished product" but is the result of continuous organizational learning based on things that went wrong or turned out differently than originally planned. Many of the templates for offer letters, mentoring plans, individual development plans, and departmental readiness assessments discussed previously were generated in response to program failures. For instance,

[17] https://ppfp.ucop.edu/info/documents/provost-letter-august-2018.pdf

the UMBC Fellowship for Faculty Diversity developed a mechanism for ascertaining departmental commitment and readiness (through a submitted mentoring plan) as a response to early challenges with conversion of postdocs into faculty roles. The AGEP Promise Academy developed recruitment resources in response to challenges institutions faced in identifying postdocs; and we have recommended policies and practices to enhance clarity and transparency in the conversion process as the result of hiccups experienced in postdoc programs across the USM. Although our review of national postdoc conversion programs did not reveal similar program modifications in response to evaluation efforts, we suspect our experiences are not unique.

Actionable Recommendations

In the previous section, we suggested a five-stage process for how institutions, systems, and multi-institution consortiums might develop, implement, and evaluate a postdoctoral conversion program aimed at enhancing faculty diversity. Based on these experiences, we have four recommendations that institutions, systems, and consortiums should consider before launching a postdoctoral conversion program.

Assess Existing Faculty Diversity and Development Programs

When it comes to organizational diversity initiatives, there can be a tendency to "add" programs rather than assessing and utilizing models already in place (Chronicle of Higher Education [CHE], 2021). The success of the UMBC's Fellowship for Faculty Diversity led to the construction of the parallel but unique Pre-Professoriate program in the life sciences, and subsequently the state-system AGEP PROMISE Academy approach, demonstrating how programs can build off each other and from the success of existing faculty diversity initiatives (e.g., UMBC's ADVANCE Program). Program leaders engaged in iterative program improvement and learned from mistakes. Academic leaders considering such programs may likewise want to take stock of the existing diversity program landscape before launching a new postdoctoral conversion program.

Cultivate Multi-Level Commitment of Financial and Human Resources

Financial support should be cost-shared, with support from central administration (i.e., provosts and/or deans for institutional models, state university systems for consortia approaches) as well as support from the department. Buy-in from department members can be generated through trainings that break down myths about the lack of diversity in doctorates, combat implicit racial bias as well as subfield/disciplinary bias, and engage department members in proactive faculty recruitment.

Commit to Comprehensive Evaluation and Problem Solving After Failures

Program administrators should consider the systems that can be put in place to determine if departments are "ready" to recruit, onboard, support, mentor, and learn from postdocs from racially minoritized groups and hold them accountable for when they fail to live up to their obligations. There should be mechanisms in place to ensure that the department cannot make another bid for a postdoc until the department demonstrates growth and change in abilities to support and retain additional scholars. At the same time, departments that fail to retain postdocs may also be more invested in change and should be given opportunities to learn from their failures.

Establish Fellows as Members of the Faculty From the Outset

Significant work must be done to establish incoming fellows as members of the faculty (or soon-to-be members of the faculty). This must be a multi-pronged approach, and should include joint classification or titling, access and invitation to faculty development centers/listservs, faculty onboarding and orientation events, ongoing professional development, and inclusion in faculty department meetings and decision-making. Several postdoc conversion models in our review mentioned their fellows be assigned a faculty office, for example, a gesture that has significant psychological impacts on the fellow and departmental faculty.

DISCUSSION

This paper drew from a review of 38 postdoctoral conversion programs as well as our own experiences as administrators, evaluators, and researchers of such programs. Across programs reviewed, we make the following observations. First, many (though not all) of the programs in our review are located at highly-ranked and research-intensive doctoral institutions. They are also mostly single-institution programs, not consortium-based approaches. This is perhaps unsurprising, given it is easier to implement programs within an institution rather than across them, research universities often have greater resources, and prestigious institutions often adopt similar tactics for addressing organizational problems. Faculty diversity is also a more critical challenge at some research-intensive institutions (Smith et al., 2012). However, we believe that multi-institutional collaborations are necessary for advancing faculty diversity (Griffin, 2020) and offer much promise for creating meaningful professional development and training opportunities and enhancing long-term collaborations between institutions with a variety of missions and resource levels.

On the other hand, creating a cross-institutional organizational change program requires significant effort, including creating new and sustainable leadership and communication channels; generating buy-in from system heads, administrators, department chairs, and individual faculty members; navigating disciplinary, departmental, and institutional silos; and understanding state and federal employment law (Tierney and Sallee, 2008; Thomas, 2018). This is not a process that should be undertaken without strategic calculation of readiness, resources, sustainability, and capabilities, human and financial.

A second observation is that all of the programs in this review reiterated the importance of faculty mentors, as signaled by the requirement that postdocs have an "assigned mentor." However, research emphasizes the need for multiple mentors, including those within their department/discipline and from outside of it; and from mentors who share aspects of the identity (e.g., race) and those who do not (Griffin et al., 2020; Hsieh and Nguyen, 2020; Davis et al., 2021). We are also aware of the literature that shows that senior faculty of color tend to do the lion's share of mentoring for early career faculty of color, because they are sought out, assigned, and/or prefer to assume those roles, representing a form of cultural taxation that may increase stress and burnout and lower retention (Zambrana, 2018). Thus, institutions and administrators should consider how postdocs can be plugged into mentoring networks. They should also take steps to ensure that senior faculty of color do not become the *de facto* mentors for all postdocs participating in such programs (e.g., by cultivating inclusive mentoring cultures and enhancing the ability of White faculty to mentor faculty of color).

One of the areas that is less represented in our findings is the critical importance of developing a sense of community and belonging for postdocs. Decades of research show that faculty of color often experience isolation, marginalization, and hostile climate in predominantly white institutions (Turner et al., 2008; Kelly and Winkle-Wagner, 2017). In addition to mentors, departments should encourage opportunities for fellows to share their scholarship, generate collaborative relationships within and outside of the department, connect to relevant affinity groups, and establish relationships with other faculty members at similar career stages (Fries-Britt and Snider, 2015; Martinez et al., 2017). Cohort approaches may in part meet some of these needs, but program designers should consider multi-pronged approaches at building community.

Finally, although our results suggest a general model by which postdoc conversion might occur, we also recognize that institutional type, culture, rankings, as well as departmental cultures and disciplinary norms (Kezar and Eckel, 2002) will no doubt shape the implementation and outcomes of a postdoc conversion program. For example, in some STEM fields, postdoctoral positions are a necessary step to the professoriate. There are therefore prevailing norms and expectations about the kinds of research a postdoctoral fellow should do and if they should be retained after completing their fellowship. On the other hand, in disciplines where postdoctoral fellows are less common, departments may need more support in terms of identifying good faculty mentors and orienting postdocs to the institution. In any of these contingencies, establishing thoughtful and comprehensive processes, from recruitment to conversion, and generating faculty buy-in is critical at the outset.

Ultimately, our results suggest that the creation of a postdoctoral conversion program aimed at increasing faculty diversity is an organizational change process (Kezar, 2001), not just a hiring initiative. There are several critical junctures at which the implementation of a postdoc conversion program requires a dramatic shift in policy and practice but also in culture, norms, and expectations. For instance, similar to the recommendations of those who have studied equity-minded change in higher education (Bensimon et al., 2016), many of the policies and practices outlined in this review require whole departments and colleges to take responsibility for the success of postdocs. Departments and their members are therefore engaged in, and accountable for, increasing diversity in their local context. We also note that aligning postdoc recruitment with tenure-track hiring may address some of the long-standing concerns about reliance on postdocs as sources of cheap and temporary labor (Jaeger and Dinin, 2017), in that conversion requires a long-term commitment from the hiring department. In all, the successful implementation and sustainability of a postdoctoral conversion program is incumbent upon changing processes and procedures, as well as pre-existing mindsets and behaviors that undercut diversity and change.

Our review suggests many areas for future examination. First and importantly, we know relatively little about the experiences of postdocs within these programs, including the factors that lead to successful (and unsuccessful) transition. Researchers may wish to understand the implementation of postdoc conversion programs using organizational change theories (e.g., Kezar, 2001) and better understand the mechanisms (e.g., search waivers) by which postdocs convert to faculty roles. Qualitative case studies that include interviews with postdocs and program administrators and examination of documents from the programs included in this review would contribute greatly in this area.

Second, relatively few programs make public the percentage of postdocs who successfully convert to tenure-track positions, which makes it difficult to ascertain the extent to which conversion programs serve their intended purpose of increasing faculty diversity, and what aspects of the programs (e.g., mentor professional development) seemed to be linked to success. We encourage researchers to consider multiple methods of studying the impact of such programs, for instance, using large historical databases (e.g., IPEDS) comparing institutions that have adopted such programs to those that have not and different kinds of implementation strategies (O'Meara et al., 2020).

Finally, researchers may also want to further examine how multi-institutional approaches to faculty diversity are influenced by system governance procedures, legal regulations, and differences in institutional policies, procedures, and cultures; as well as examine the potential benefits of localized (e.g., college or departmental) postdoc programs and/or drawbacks to centralized and/or multi-institutional approaches (e.g., duplication of professional development opportunities or conflicting mentoring guidance).

CONCLUSION

At first glance, postdoctoral diversity programs with the goal of conversion may seem like yet another initiative focused solely on recruitment of underrepresented racial minorty scholars who managed to survive the rigors of graduate school. Instead, this research focuses on understanding *and changing* the institutional and systemic structures that lead to the loss of talent from minority backgrounds. Our national review of conversion programs and

our own experiences at universities within the University System of Maryland suggest that to be successful, conversion models need to align recruitment practices with assessing readiness, cultivate academic leaders who are allies, develop mentors, put in place career development resources, and fundamentally shift institutional policies and practices. Deployed strategically and in a context-specific way, we see much potential in postdoctoral conversion programs for spurring institutional change and increasing the diversity of the faculty.

AUTHOR CONTRIBUTIONS

All authors contributed intellectually to the design of the manuscript through regular meetings and provided editing and commentary. DC conducted the research to identify diversity postdoctoral programs in the United States, performed the data analysis, did the literature review, authored the introduction and discussion and significant portions of the policies and practices section. AR authored and provided many of the examples from the UMBC Fellowship for Faculty Diversity (including specific policy examples and documents), provided historical context of program development both for the UMBC Fellowship and the AGEP PROMISE Academy. BE collected data, performed the analysis, found/organized references, and authored portions of the policies and practices section. WC-V helped with data collection, performed the data analysis, constructed the tables, and authored portions of the policies and practices section. WL and PM provided the institutional context and history about UMBC programs and authored examples from those programs. RC project managed the publication effort, collected the data, performed the analysis, and authored portions of the policies and practices section, particularly from the AGEP PROMISE Academy. All the authors have read and approved the final version of the manuscript.

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The Mental Health Consequences of Work-Life and Life-Work Conflicts for STEM Postdoctoral Trainees

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Research has shown that work-life conflicts exist among all kinds of workers, including academics, and these conflicts are a key contributor to workers' reports of poor well-being. Very little research has been done on work-life conflict among post-baccalaureate PhD trainees (e.g., graduate students and postdoctoral trainees) who reside in an important liminal stage in the professoriate pipeline. In this study, we examine the degree to which postdocs believe they suffer from conflicts between their work responsibilities and their home responsibility and the relationship between those conflicts and postdoc's mental health. We argue that, like other workers, postdocs suffer (in numerical terms and its relationship to health) more from the work-to-life imbalances than from life-to-work imbalances; life matters more than work, ultimately. Our results, based on a survey of 215 STEM postdoctoral trainees, reveal that a majority of postdocs say they have work-life conflicts and these work-life conflicts are associated with negative mental health outcomes. We discuss the potential impact of these findings on attempts to broaden participation in STEM careers and diversify the professoriate.

Keywords: work-life imbalances, postdoctoral trainees, academic workers, mental health, anxiety, attrition, persistence

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INTRODUCTION

Work-life conflict occurs when work responsibilities and life (usually household) responsibilities interfere with each other (Greenhaus and Beutell, 1985; Frone, 2000; Amstad et al., 2011).[1] For example, workers have less time to spare for work or life (Netemeyer et al., 1996; Carlson and Perrewe, 1999; Edwards and Rothbard, 2000; Buonocore and Russo, 2013), stressors in one sector often impact performance in the other (Byron, 2005), and the different roles in the two arenas may not be easy to separate from one another (Olson-Buchanan and Boswell, 2006). These conflicts are key contributors to reports of poor well-being among workers (Burke, 1988; Frone, 2000; Grant-Vallone and Donaldson, 2001; Grzywacz and Bass, 2003; Denson et al., 2018) as well as low productivity and turnover in jobs (Poulose and Sudarsan, 2014; Badri, 2019).

[1]Research in this area often refers to these conflicts as conflicts between work and "family" even though many of them, necessarily, analyze the impact of "family" conflicts with work responsibilities experienced by unmarried or uncoupled workers without children. We use a broader term – *work-life* – to capture various ways one's (home) life might impact or be impacted by their work.

Moreover, studies detailing the impact of work-life conflicts on well-being among all kinds of workers have led researchers to take an interest in the work habits of college and university faculty given the nature of their jobs and research suggesting faculty work anywhere from 50 to 60 h each week (Jacobs and Winslow, 2004; Misra et al., 2012). These investigations have revealed that, despite the autonomy and flexibility of work that characterizes this occupation, faculty too (particularly those in STEM fields) report suffering from work-life imbalances. Ironically, those two amenities of academic work – autonomy and flexibility – lead to overworking and overlaps between work roles/responsibilities and those responsibilities faculty may have in their households (Williams, 2000; Fox et al., 2011; Culpepper et al., 2020). Research on the work-life balance experienced by faculty has revealed that work-life balance is crucial to their well-being as well (Damaske et al., 2014; Ren and Caudle, 2016). This research has proven valuable and enlightening, igniting important conversations on university campuses about ways to ameliorate what is often seen as an intractable problem in academic environments.

Like the research on faculty, most research on work-life conflict has focused on employed laborers, that is, workers in the part-time or full-time paid workforce. Virtually, no attention has been paid to work-life conflict of trainees in the pipeline to some of these positions, especially when those trainees have considerable time commitments as working apprentices.[2] Specific to this paper, few studies have tested the relationship between work-life balance and well-being among postdoctoral trainees (going forward, "postdocs") who sit in the liminal stage between graduate school and being faculty (Moors et al., 2014; Ysseldyk et al., 2019). It is important to understand the lives of postdocs because their experiences, like those of graduate students, are often critical to the decision to pursue academic careers. If postdocs are experiencing work-life conflicts and the concomitant impacts of those conflicts on their mental health, we might expect them to be less productive in their postdoc appointments (and thereby, less competitive for jobs) and/or more likely to want to leave the academic pipeline, another version of professional turnover. It is, therefore, important to know more about the experience of work-life conflict among postdoctoral trainees.

We will fill this gap in the literature by scrutinizing the relationship between work-life conflict and mental health among the postdocs by using a survey of 215 STEM postdoctoral trainees. We look into both work-to-life conflict (i.e., the demands of work interfere with home/family life) and life-to-work conflict (i.e., the demands of family or spouse/partner interfere with job-related activities). We seek to answer two related questions: a) whether work-life conflicts exist (in both directions) for postdocs and b) whether those conflicts predict higher levels of anxiety while controlling for the postdocs' background, health status, and their experience in their postdoc appointment.

[2]An exception to this is the amount of attention given to work-life conflicts encountered by medical residents, house staff, and surgical fellows (Schwartz et al., 1990; Dorsey et al., 2003; Tambyraja et al., 2008; Glynn and Kerin, 2010).

In the following pages, we first outline the literature on work-to-life conflict and its impact on mental health. Next, we describe our data and methods and present correlations between our variables. We then report our regression results that shows that work-life conflicts significantly impact postdocs' mental health. Finally, we discuss our research's findings and implications for postdoctoral trainees' transition to academic jobs.

BACKGROUND

Work-Life Conflicts and Imbalances

Both family and work have gone through significant transformations in the past two centuries, along with shifts in the demographics of those making up the labor force. These resulted in increases in the time people spend working and "changes in the pace and intensity of work" (Kossek et al., 1999; Helmle et al., 2014). Furthermore, the number of households with dual incomes increased, more women are in the workforce, and the proportion of older people in the population is higher (Hammer et al., 2005). In addition to these major social changes, researchers have been interested in studying how workers manage their work and life because it can provide valuable information concerning workers' mental health and life satisfaction, which ultimately affects their productivity at work and job satisfaction (Poulose and Sudarsan, 2014).

Work-life balance refers to the harmony one achieves when their work does not interfere with the activities and roles they have outside of work. Work indicates a job someone does to pay for their livelihood. The non-work (i.e., "life")-related activities they do could range from taking care of their children and spending time with their partner to enjoying leisure and avocational activities. Work-life balance consists of a person's perception of the amount of time that is available to them for both their work and life outside of work (Gröpel and Kuhl, 2009). When there is an imbalance caused by one sector, it is likely to negatively affect the other sector (Poulose and Sudarsan, 2014). A work-life imbalance – or conflict – means that one's work duties inhibit their ability to fulfill their life duties and/or one's life duties affect their work duties (Greenhaus and Beutell, 1985; Frone, 2000; Amstad et al., 2011).

Greenhaus and Beutell (1985) outline three reasons why people have work-life imbalances. The first reason is the time-based conflict which states that one's time commitment to and demands of one role leaves little room for completing the other role (Netemeyer et al., 1996; Carlson and Perrewe, 1999; Edwards and Rothbard, 2000; Buonocore and Russo, 2013). Three examples of this type of conflict would involve an excessive amount of time spent working a week, having a work schedule that is not flexible, and "role overload" (Keith and Schafer, 1980; Pleck et al., 1980; Burke, 1988). The second reason is the strain-based conflict which states that the resulting strain (i.e., tension or anxiety) from one role complicates the ability to fully perform another role (Netemeyer et al., 1996; Edwards and Rothbard, 2000; Byron, 2005; Buonocore and Russo, 2013). Lastly, the third reason is the behavior-based conflict which claims that the specific behaviors required of

one role are not compatible with another role (Edwards and Rothbard, 2000; Buonocore and Russo, 2013).

Researchers study work-life balance because it affects workers' overall well-being. Work-life conflicts a strong positive relationship with psychiatric disorders, such as anxiety, mood, and substance addictions (Burke, 1988; Frone, 2000; Grant-Vallone and Donaldson, 2001; Grzywacz and Bass, 2003; Bellavia, 2005; Amstad et al., 2011). For instance, Frone's (2000) study of the work-life conflict of employees demonstrated that those with this type of conflict had an increase of 1.99 to 29.66 times the likelihood to have a mental illness than those without this type of conflict. This has implications for the person's ability to fully show up for the various roles in their life, let al. one sustain a healthy lifestyle. Conversely, more work-life balance is associated with good mental health and lower rates of turnover (Badri, 2019). By studying the nuances of the work-life balance, research has uncovered how workers' roles on an individual and organizational level influence their mental health (Hammer et al., 2005; Badri, 2019).

Faculty and Work-Life Conflict

Research shows that college and university faculty, particularly STEM faculty, tend to work longer hours than people in other professions, leaving them with less time to spend on their non-work life (Jacobs, 2004). In line with this, people often go into the faculty pipeline with the understanding that at some point, they may be confronted with high expectations on the number of hours they need to work. The work faculty do is closely linked to their identity, which has implications for the amount of time they dedicate to their work (Fox et al., 2011; Lester, 2013). With an academic culture that rewards faculty who work overtime and constantly perform at high levels, there is no surprise that many find themselves stretched for time to do things outside of work (Fox et al., 2011). However, although academia may require long work hours, it is also one of the most flexible fields to work in (Damaske et al., 2014; Fontinha et al., 2019). As such, faculty should still be able to adjust their schedules to fit the needs of their non-work life. These characteristics make the study of the work-life balance of academics extremely valuable for researchers in higher education. Like other workers, when faculty have work-life imbalance, they experience various psychological and emotional illnesses. Faculty with work-life conflicts are more likely to report mental health problems, low satisfaction with their work, and a higher propensity for burnout and decisions to leave their positions (Aazami et al., 2015; Kazley et al., 2016; Denson et al., 2018; Badri, 2019). Given the correlation between work-life balance and mental health among faculty, it is possible that others in academia, especially those in the pipeline to be faculty, may have similar difficulties managing their work/life conflicts and suffer negative mental health outcomes as well.

Postdoctoral Trainees, Work-Life Conflict, and Mental Health

Most, if not all, of the literature on work-life imbalances and health focuses on full-time workers, including faculty. Very little attention has been paid to the potential for work-life conflict encountered by trainees for faculty careers (e.g., graduate students and postdoctoral associates) who also work part- or full-time schedules as part of their training regimen. While some research (Schwartz et al., 1990; Dorsey et al., 2003; Tambyraja et al., 2008) has documented the problems, medical residents have achieved a balance between work and family/personal time – problems leading to declines in interest in some medical specialties (e.g., surgery) – virtually, no research has examined work-life conflicts among STEM postdocs, who likely experience similar difficulties. The little research that has been done suggests that postdocs, like medical residents and faculty, find it difficult to attain work-life balance, and this likely leads to negative mental health outcomes (Ysseldyk et al., 2019).

As taking on a postdoctoral appointment is becoming almost normative in STEM disciplines, particularly in the biological and biomedical sciences, understanding the behaviors, motivations, and experiences in this liminal – and for many, pivotal – stage in the STEM professoriate pipeline is important for building a more complete picture of what causes attrition from and persistence in that pipeline, particularly for future faculty of color and women.

As the stage in a potential faculty member's training that most closely approximates what it might be like to *be* faculty, we suspect the difficulty faculty have maintaining balance between work demands and the demands/desires associated with their non-work life will be found among postdoctoral trainees as well. The association between these work-life conflicts and mental health is well-documented. Therefore, we make the following hypotheses:

H1: A majority of STEM postdoctoral associates and fellows experience conflicts between their work demands and the home/life responsibilities. This takes three forms:

H1a: A majority of postdocs – regardless of family status – will report that the demands of their job interfere with their home and/or family life (work-to-life conflict).

H1b: Among postdocs with families (i.e., spouse/partner, children), a majority will report that their home life interferes with their job-related activities and responsibilities (life-to-work conflict).

H1c: Among postdocs without families, few will report that their home life interferes with their job-related activities and responsibilities (life-to work conflict).

H2: Work-life conflicts are a predictor of poor mental health. This relationship exists for both work-to-life conflicts and life-to-work conflicts.

H2a: The greater one's experience of work-to-life conflicts, the higher the levels of mental health disorder they will report.

H2b: The greater one's experience of life-to-work conflicts, the higher the levels of mental health disorder they will report.

DATA AND METHODS

We used a web-based survey as the principal tool to gather information from 215 STEM postdoctoral appointees. In 2017, staff members in the Offices of Postdoctoral Affairs (OPA) at 30 research-intensive doctoral universities forwarded our invitation to participate in the research to their cohort of postdoctoral trainees.[3] The invitation described the parameters for involvement in the research, specifically, that potential respondents be US citizens or permanent residents in the first, second, or third year of their first postdoctoral appointment in one of five broad STEM categories: agriculture and conservation resources, biological and biomedical sciences, STEM education, engineering and computer science, or the physical sciences and math.[4] First-time postdocs were chosen because we were interested in the pathway from receipt of doctorate through the first postdoc position to faculty, other postdoc positions, or non-academic jobs. The OPA staff were informed that we were particularly interested in understanding the experiences of women; as a result, this population was oversampled.

While an accurate accounting of how many potential respondents were exposed to the recruitment materials was unavailable to us, more than 750 postdocs responded positively to the invitation. Most of those potential respondents were ineligible to participate because they did not meet the base requirements for inclusion in the study. Ultimately, we ended with a sample of 215 postdoctoral trainees. Of these respondents, 65% are women. We weighted our analyses to account for the oversampling that created this conflict. We used the proportion of STEM postdoctoral recipients (35%; National Center for Science and Engineering Statistics, 2017a) who are women as a target population for this weighting. The racial balance – 77% White, 23% non-White – more closely approximates the percentages of White/non-White US citizens and permanent residents with STEM doctorates in the disciplines we analyze (National Center for Science and Engineering Statistics, 2017b).[5] More than half (51%) of our respondents were in their of the postdoc. Representation among the disciplines was as follows: agriculture (6.5%), biological and biomedical sciences (56.3%), STEM education (3.3%), engineering (14.4%), and physical sciences (19.5%); these percentages differ from the national postdoc population by less than 10% (National Center for Science and Engineering Statistics, 2017a).

[3]In all cases, the offices were not allowed to give us names and other details of their postdoctoral population. As a result, we could not constrain the list of invitees to only those postdocs who met our study parameters.

[4]As this project is part of a larger study aimed at broadening participation in STEM training and diversifying the STEM professoriate, we follow the lead of the National-Academy-of-Sciences (2011) in focusing our attention on the physical sciences, the life sciences, engineering, and mathematics only. We, therefore, exclude the social sciences (e.g., sociology, psychology, and history) and social science focused agriculture/conservation postdocs.

[5]The focus of the larger study (i.e., on diversifying the STEM professoriate) led us to exclude foreign postdocs, whose career motivations, pathways to postdocs, and ability to "diversify the professoriate" have been shown to be significantly different from non-foreign STEM doctorate recipients, particularly non-Whites (Amuedo-Dorantes and Furtado, Stephan and Ma, 2005, Zeithammer and Kellogg, 2013).

In addition to the survey data on which this analysis is based, we conducted interviews ($n = 75$) with survey respondents about their first-year experiences of their postdoctoral appointments. The majority (77%) of these interviews involved some discussion of either the work-life conflicts postdocs were experiencing themselves or their assumptions about work-life conflicts awaiting them if they pursue careers in the academy. These responses were most commonly a response to the question, "What is your current experience like in laboratories and with faculty advisors." While not used in the primary analysis reported here, selected quotes from these interviews will be used in the discussion to contextualize recommendations to ameliorate these conflicts.

Key Independent Variables: Work-Life/ Life-Work Conflicts

We were interested in examining the relationship between mental health outcomes and conflicts between our respondents' work responsibilities and their home/family life. Therefore, we used two series of four questions developed by Netemeyer et al. (1996) that measure conflicts between one's work and home life responsibilities. These scales reliably capture the various ways work might impact or be impacted by ones' responsibilities at home, be they family-related (e.g., partners, children, and elder care.) or not.

The first independent variable is work-to-life conflict. On a 4-point scale ranging from 1 (strongly disagree) to 4 (strongly agree), respondents indicated the extent of their agreement with the following four statements: "The demands of my job interfere with my home and family life," "The amount of time my job takes up makes it difficult to fulfill my family responsibilities," "Things I want to do at home do not get done because of the demands my job puts on me," and "Due to job-related activities, I have to make changes to my plans for family activities." These items were combined in a scale ranging from 4 (complete strong disagreement) to 16 (complete strong agreement). This scale has a mean value of 10.24 and is treated as a single factor: work-life conflict ($\alpha = 0.86$).

The second independent variable is life-to-work conflict. On a 4-point scale ranging from 1 (strongly disagree) to 4 (strongly agree), respondents indicated the extent of their agreement with the following four statements: "The demands of my family or spouse/partner interfere with my job-related activities," "I have to put off doing things at my job because of demands on my time at home," "Things I want to do at my job do not get done because of the demands of my family or spouse/partner," and "My home life interferes with my responsibilities at my job such as getting to work on time, accomplishing daily tasks, and working overtime." These items were also combined in a scale ranging from 4 (complete strong disagreement) to 16 (complete strong agreement). This scale has a mean value of 8.04 and is treated as a single factor: life-work conflict ($\alpha = 0.87$).

Key Dependent Variables: Generalized Anxiety Disorder

We use generalized anxiety disorder as our measure of mental health disorder. Generalized anxiety disorder is measured using

7-item Generalized Anxiety Disorder scale (GAD-7; Spitzer et al., 2006). The GAD-7 only estimates symptoms of anxiety. On a 7-point scale ranging from 0 days to 7 days, trainees indicated the number of days in the past week that they felt such experiences as "worried too much about little things" and "felt so restless that it is hard to sit still." These items were combined in a scale ranging from 11 to 40 ($\bar{x} = 21.75$) and treated as a single factor: anxiety ($\alpha = 0.82$). If we divide the scale by the number of statements (7) and identify which respondents experience the set of seven symptoms more than 3 days a week, we determine that 34% of our respondents experience the amount of anxiety deemed problematic.

Demographic Controls and Other Likely Covariates

We control for seventeen factors that may covary with these mental health outcomes. These factors are added into the models in three sections: health covariates, common demographic covariates, and variables related to respondents' STEM training and experience.

Self-reported overall health was measured using one-item: "Thinking back over the past month, how would you say your general health has been?" Trainees could choose poor, fair, good, very good, and excellent. This seemingly simple self-rating of general health has been shown to be more reliable than even physicians' ratings of health (Idler and Benyamini, 1997). We recoded this variable to a dummy variable such that "1″ represents "very good" and "excellent" health ($\bar{x} = 0.52$). We also include two other personality variables that are associated with mental health: dispositional optimism (i.e., an inclination to have favorable expectations for one's future regardless of the odds) and mastery (i.e., sense of control over one's life). We use Scheir and Carver's (1985) 12-item Life Orientation Test for dispositional optimism: Respondents indicate degree of agreement with statements, such as "I'm a believer in the idea that every cloud has a silver lining" (range = 10–32, $\bar{x} = 21.81$, $\alpha = 0.83$). We use the 7-item Pearlin and Schooler (1978) Mastery scale for mastery: Respondents indicate degree of agreement with statements, such as "I have little control over the things that happen to me." (range = 11–28, $\bar{x} = 20.60$, $\alpha = 0.80$).

The second group of possible covariates includes demographic characteristics commonly associated with academic/occupational identity and/or mental health among postdoc populations: gender (female = 1; $\bar{x} = 0.35$), race (non-White = 1; $\bar{x}$=0.21), age (continuous variable; $\bar{x} = 31.82$), high levels of educational debt (debt over \$40 k = 1; $\bar{x} = 0.13$), and high household income (income over \$100 k = 1; $\bar{x}$=0.30). Two demographic covariates – relationship status (coupled = 1; $\bar{x} = 0.75$)[6] and parenthood (parent = 1; $\bar{x} = 0.18$)—are analyzed separately to answer hypotheses 1a–1c. They are also used in the regressions as controls.

We then control for six variables reflecting experiences gained in the pursuit of their training in science. Our respondents represent a range of one to three years in their postdoc; we control for year one ($\bar{x} = 0.54$). Using a set of questions commonly used to determine positive appraisals (e.g., "my colleagues view me as a scientist," "my supervisor(s) view me as a scientist"), we created a scale (range = 10–36, $\bar{x} = 25.78$, $\alpha = 0.90$) indicating the degree to which respondents agree various communities recognize them as a scientist; we refer to this as "science appraisals." We also include a science efficacy scale (range = 26–48, $\bar{x} = 41.31$, $\alpha = 0.84$) from a set of questions asking respondents to indicate their level of confidence in their ability to perform twelve science tasks (e.g., use technical instruments and techniques and report research results in a written paper). Perceived unfair treatment was measured using the Everyday Discrimination Scale (EDS; Williams and Mohammed, 2009) with a 7-item scale (range = 7–32, $\bar{x} = 13.07$, $\alpha = 0.83$) where respondents indicated how often (never to almost every day) they had experienced some form of treatment they perceived as unfair or unwarranted in their workplace (e.g., "You have been treated with less respect than expected at work," "Individuals at your institution acted as if they think you are not smart").[7] Success in publishing and presenting research should support positive mental health outcomes for academic trainees. If respondents have published solo authored papers, presented solo authored papers, or have won awards, we coded them "1"; "0" if they do not report these successes ($\bar{x} = 0.62$). The models also included a dummy variable where "1" represents if they have a faculty mentor ($\bar{x} = 0.79$).

Analytical Strategy

We used ordinary least squares regression modeling in order to determine the relationship between our independent variables (work-life/life-work conflict) and generalized anxiety.

RESULTS

If we divide both work-life/life-work conflict scales by the number of statements (4) and identify which respondents have an average response greater than 2.5 (agree and strongly agree), we determine that nearly 62% of our respondents experience work-life conflict. About 15 percent of our respondents experience a high (1 standard deviation above the mean) level of work-life conflict. Surprisingly, there is no significant difference between singles and coupled respondents in the degree to which they report work-life conflicts. There are also no differences between respondents who have children and those who do not. In the aggregate, far fewer postdocs report experience life-work conflict; only 25% do. Sixteen percent of our respondents experience a high (1 standard deviation above the mean) level of life-work conflict. There are statistically significant differences between single respondents (7%) and coupled respondents (25%) in

[6]Respondents who indicated that they were either "married" or "in a committed relationship" were coded as "coupled."

[7]The mean for this scale is slightly less than 2 which represents "less than once a year"; about 30% of our respondents say they experience unfair treatment more than this. Neither gender nor race is correlated with this variable in our sample.

regard to their reports of life-work conflicts. A much more substantial difference exists between non-parents (12%) and non-parents (58%); 50 % of parents report *high* levels of life-work conflict. These findings support the three H1 hypotheses. The bivariate correlations between coupled/parent status and the work-life/life-work conflict scales (i.e., the entire range of 4–16) used in the regression analyses are described below.

Bivariate Correlations

Table 1 presents bivariate correlations between the independent (work-life conflict and life-work conflict), dependent (generalized anxiety disorder), and selected control variables. We include these correlations both as a presaging of what we are likely to discover about the relationships between the independent/control variables and anxiety and as an opportunity to examine any relationships that might exist between those variables and each other. Certainly, we expect to see that there is a positive correlation between the two kinds of conflict, but there is some value in determining if some postdoc characteristics (e.g., their gender, race, or parental status) are predictive of the degree of work-life and life-work conflict they might experience.

Looking across the rows, the two kinds of conflict are associated with each other and, as predicted, are positively associated with anxiety: The higher one's work-life and life-work conflicts, the higher they are on our measure of generalized anxiety. The other three positive health variables (general health, optimism, and mastery) are all negatively correlated with anxiety. General health is negatively correlated with both kinds of work/life conflicts: The greater the conflict, the lower one's general health. This relationship exists with dispositional optimism, but only with work-vs.-life conflicts.

Of the demographic characteristics, only two are associated with mental health: Being coupled is negatively associated with anxiety, while having high levels of educational debt is positively associated with anxiety. As described previously, family status is unrelated to work-vs.-life conflicts, but positively associated with life-vs.-work conflicts. Parenthood is positively associated with life-vs.-work conflicts, but not anxiety.

Science community appraisals and science efficacy (both, presumably, and positive holdings) are almost consistently[8] associated with lower reports of mental health disorder. Having a faculty mentor also seems to be protective against all four mental health disorder; it is negatively associated with work-life conflicts. Experiences of success (e.g., publishing sole authored papers) are negatively associated with anxiety as well.

Experiences of unfair treatment – which may not always be reflective of an experience of racial/gender discrimination – are positively associated with anxiety and, interestingly, also positively associated with both kinds of work/life conflicts. While our cross-sectional analysis cannot prove a causal ordering here, we suspect this latter association is likely a sign of high-effort coping, a response sometimes referred to as John Henryism when describing the response in African-Americans (James, 1994). James and colleagues developed the John Henry[9] concept in an effort to describe an "individual's self-perception that he can meet the demands of his environment through hard work and determination" (James et al., 1983, p. 263). In the face of blocked opportunities – represented by the Everyday Discrimination scale – our respondents overextend themselves at work in ways that place additional strain on their ability to fulfill their household responsibilities; this creates work-to-family conflict. Likewise, their household responsibilities hinder these attempts to overextend themselves, creating family-to-work conflict.

TABLE 1 | Bivariate correlations between dependent (anxiety), independent (work-life conflict and life-work conflict), and selected control variables.

	Work-life conflict	Life-work conflict	Anxiety
Work-life conflict		0.430***	0.393***
Life-work conflict	0.430***		0.238***
General health	−0.201**	−0.186**	−0.368***
Dispositional optimism	−0.136*	−0.129	−0.428***
Personal locus of control	−0.113	−0.081	−0.502***
Female	0.101	−0.011	0.088
Non-white	0.013	−0.084	−0.015
Coupled	−0.024	0.221**	−0.109
Parent	0.049	0.431***	−0.069
Educational debt is high	0.142*	−0.059	0.090
Science community	−0.106	−0.105	−0.266***
Science efficacy	0.044	−0.090	−0.141*
Has a faculty mentor	−0.163*	−0.075	−0.166*
Experienced job successes	−0.032	−0.068	−0.060
Experienced unfair treatment	0.352***	0.222***	0.395***

*N = 215. *p < 0.05; **p < 0.01; ***p < 0.001.*

Multivariate Regressions

In this section, we turn to multivariate analyses of the relationships between work-life conflicts and anxiety. In these analyses, we examine the covariates alone and then add work-to-life conflict and life-to-work conflict in separate analyses.

Control Variables

In **Table 2**, Column I, we provide a reduced model that includes only the controls. Column I reveals obvious associations between some control variables and some surprising lack of associations

[8]The correlation between science identity centrality and anxiety is insignificant.

[9]The name refers to Black folk-hero John Henry who ultimately died from a heart attack in an effort to beat a steam-powered rock drilling machine in a race to build a tunnel.

between others. This model appears to be fairly comprehensive, with explanatory power of 39.4 percent for anxiety symptoms.

The standardized betas suggest the most powerful explanatory variables are two of the positive health holdings, general health and internal locus of control. These two health covariates are predictive, negatively, of poor mental health conditions. The healthier the person is generally, the less likely they are to suffer from anxiety ($B = -1.91$, $\beta = -0.24$, $p < 0.001$), and the more the person reports an internal locus of control, the less likely they are to suffer from anxiety ($B = -0.44$, $\beta = -0.34$, $p < 0.001$).

Surprisingly, but affirming the bivariate analysis, few of the usual demographic covariates (gender, age, and income) are significantly predictive of generalized anxiety symptoms. Race does seem to matter, as we see that non-Whites in this population are less likely to suffer from anxiety than Whites ($B = -1.31$, $\beta = -0.13$, $p = 0.03$). This aligns with other research on what has come to be called a minority mental health paradox, where racial-ethnic minorities report better mental health than non-Hispanic whites despite experiencing conditions that might seem less conducive to psychological well-being (Williams and Earl, 2007). The other demographic variable associated with poor mental health is high educational debt. When respondents have debt over $40,000, they are more likely to report symptoms of anxiety ($B = 2.18$, $\beta = 0.17$, $p < 0.001$).

Unlike the bivariate findings, among the STEM experience covariates, only experiences of unfair treatment are associated with mental health outcomes. If the respondent has experienced unfair treatment, they are more likely to have symptoms of anxiety ($B = 0.16$, $\beta = 0.14$, $p = 0.01$).

Work-Life Conflict

In **Table 2**, Column II, we show that work-life conflict is predictive of anxiety, even with the various controls represented in the reduced model; hypothesis 2a is supported. The higher the respondents' work-life conflict, the more likely they are to experience anxiety ($R^2 = 0.438$, $B = 0.38$, $\beta = 0.24$, $p < 0.001$). Adding work-life conflict increased the explanatory power of this model by 5 %. General good health ($\beta = -0.20$, $p < 0.001$), personal locus of control ($\beta = -0.33$, $p < 0.001$), being non-White ($\beta = -0.13$, $p = 0.02$), and high educational debt ($\beta = 0.13$, $p = 0.01$) remain statistically significant in the full anxiety model; unfair treatment no longer does.

Life-Work Conflict

In **Table 2**, Column III, we reveal that life-work conflict is also predictive of anxiety. The higher the respondents' life-to-work conflict, the more likely they are to experience higher levels of anxiety ($R^2 = 0.408$, $B = 0.25$, $\beta = 0.16$, $p = 0.02$); hypothesis 2b is supported. Adding work-life conflict increased the explanatory power of this model less than adding work-life conflict ($F = 0.02$). General good health ($\beta = -0.20$, $p = 0.00$), personal locus of control ($\beta = -0.32$, $p < 0.001$), being non-White ($\beta = -0.12$, $p = 0.02$), and high educational debt ($\beta = 0.18$, $p < 0.001$) remain statistically significant in the full anxiety model; again unfair treatment no longer does.

TABLE 2 | Multivariate regression testing the predictive relationship of work-life/life-work conflict on the mental health of stem postdoctoral trainees. Standardized betas reported.

	Covariates only	Work-life conflict	Life-work conflict	Both conflicts
	I	II	III	IV
Work-life conflict		0.237***		0.215***
Life-work conflict			0.156*	0.554
Health covariates				
General health	−0.235***	−0.202***	−0.211***	−0.197***
Dispositional optimism	−0.130	−0.114	−0.118	−0.111
Personal locus of control	−0.335***	−0.333***	−0.332***	−0.333***
Demographic covariates				
Female	0.050	0.038	0.046	0.037
Non-white	−0.129*	−0.126*	−0.124*	−0.124*
Age	0.004	−0.006	0.007	−0.004
Coupled	0.018	0.018	−0.010	0.008
Parent	−0.005	−0.016	−0.071	−0.039
High educational debt	0.173**	0.134*	0.175**	0.139*
High household income	−0.101	−0.097	−0.097	−0.096
STEM experience covariates				
Postdoc year (Year one)	−0.099	−0.064	−0.097	−0.066
Science community	−0.063	−0.066	−0.058	−0.064
Science efficacy	−0.059	−0.071	−0.046	−0.065
Has a faculty mentor	−0.055	−0.031	−0.056	−0.033
Experienced success	0.048	0.043	0.050	0.045
Experienced unfair treatment	0.142*	0.090	0.119	0.087
Adjusted *R*-Square	0.39	0.44	0.41	0.44
Change In *R*-Square		0.05***	0.02*	0.05***

*N = 215. *p < 0.05; **p < 0.01; ***p < 0.001.*

When work-life conflict is added to the life-work conflict model (**Table 2**, Column IV), life-work conflict is no longer significant; it is no longer predictive of anxiety. This suggests that the real driver of the anxiety postdocs feel regarding imbalances between their work responsibilities/time and their home responsibilities/time is the difficulties imposed on their home lives by their work. That is not to say life-work conflicts are irrelevant; they do reduce the explanatory power of the work-life conflicts slightly. But given that more postdocs experience work-life conflict (62%) than experience life-work conflict (26%), it makes sense that more of that third of postdocs who suffer anxiety symptoms likely do so because their work impinges on their home/life.

DISCUSSION

STEM postdoctoral trainees are situated in an unusual space in the academic pipeline. They are neither full-time students

like they were when pursuing the doctorate and they are not full-time workers as they might be if they had taken a faculty or industry position upon graduating. Instead, they are more like medical residents and house staff, still in a training position where they work full-time employee-like hours either learning new skills, deepening their knowledge in material/skills gained in graduate school, or accumulating additional credentials (e.g., publications) necessary for a competitive application for employment beyond the postdoc appointment. Like many full-time workers, it is likely that these kinds of working trainees find it difficult to avoid conflicts between their vocational responsibilities and their leisure, family, and avocational pursuits. We maintained that the majority of postdocs experience incursions of their work on their lives and, presumably, their lives on their work. Like other research on these conflicts, we expected postdocs who struggle with these related phenomena to also incur some mental health challenges as a result.

Our findings show that postdocs do experience conflicts between their work responsibilities and their non-work responsibilities, but the two are not simply opposites of each other. The majority of postdocs report that the demands of their job interfere with their home and family life, but other than parents, the majority of them do not seem to experience incursions of their home/family life on their work responsibilities. While we expected singles to report fewer incursions, only a quarter of coupled postdocs report life-to-work conflicts. The bigger problem, for those seeking a balance between life and work, is children: Nearly 60% of postdoc parents report life-to-work conflicts with most of those suggesting the conflicts are quite significant relative to what others experience.

Unless one has children, it appears that romantic partners ("partners") do not make serious demands on one's time such that postdocs feel that those demands interfere with their ability to meet the responsibilities of their job. This makes sense as partners are likely engaged in their own work responsibilities (79% of our respondent's partners have a full-time job) that overlap with the work hours of the postdoc. Those postdocs (18% of our sample) with children experience less structure and control over their non-work time, and it likely encroaches on the time supposedly dedicated to their work responsibilities. If, as our questions ask, childcare affects one's ability to focus only on work when at work, ability to get to work on time, or (as is common in STEM postdoc appointments) working beyond the regular 9 to 5 schedule, those postdocs are going to suffer more incursions of their life's responsibilities on their work responsibilities.

As research on other workers suggests, these conflicts have consequences; workers with work-life and life-work conflicts have increased mental health difficulties. We show that the higher one's work-to-life conflicts and the higher their life-to-work conflicts, the higher the degree of anxiety they report. These relationships persist even when we control for general health and protective attributes like dispositional optimism. Like prior research on other workers (Frone, 2000), we do not show that gender moderates this relationship; women postdocs do not differ from men in the amount of work-life/life-work conflict they experience and do not differ in the amount of anxiety they experience as a result of it.

LIMITATIONS

This study is not without its limitations. We recognize that the generalizability of this study is limited by the fact that our conclusions are drawn from a non-random sample of the entire postdoc population (including immigrant postdocs). While the sample we used is nearly representative (once gender weights are applied) of the domestic postdoc population, we cannot be certain of ways foreign-national postdocs – who make up nearly 60% of US STEM postdocs – experience work-life or life-work conflict and the impact of those conflict on their mental health. That said, we do not have any reason to believe that the kind of work they are engaged in is any different in these STEM departments than the work domestic (i.e., US citizens and permanent residents) are doing. The work-to-life dynamics may be the same, but the life-to-work dynamics might differ. Certainly, our understanding of these phenomena would benefit from applying our analysis to this larger STEM postdoc population.

Another limitation is our inability to make any claims about causality, that is, whether having work-life or life-work conflict leads to, rather than is simply predictive of, poor mental health. The current study is a cross-sectional analysis and the ordered relationships between the experiences of these imbalances and mental health cannot be established. A longitudinal study would be more appropriate for establishing a causal relationship. Nevertheless, we contend that the positive relationship between the two suggests experiences of one would, at least, be accompanied by the experiences of the other.

CONCLUSION AND RECOMMENDATIONS

These limitations aside, the implications of our findings are especially important for guiding institutions on the structure of the postdoc appointment. These findings support the arguments of prior research that work-life imbalance decreases well-being and is therefore a likely contributor to high burnout and low retention in the academic pipeline. In fact, further analysis of our data reveals that postdocs who experience high levels of work-life conflict are less interested in pursuing careers as either research/teaching-intensive or teaching-intensive-only faculty. Even though 90% say that careers in the academy have more autonomy and flexibility than non-academic careers, 87% also believe that non-academic careers offer better work-life balance. Few STEM postdocs have any experience with non-academic employment – only 28% do and half of those were not working in STEM environments – so it is clear that they are basing these impressions almost entirely on their current experience in their postdocs and, likely, observing the faculty they work with and around.

While there appear to be no statistically significant differences between White and Non-White STEM postdocs or between men and women in the degree to which they experience either work-life or life-work conflict, we argue that the broad patterns this project reveals join other elements (e.g., discrimination) in reducing the appeal of an academic career in STEM to underrepresented minorities and women. This and other disamenities make it more difficult for us to broaden participation in STEM careers and diversify the professoriate.

There are always two approaches to issues like these: One involves changing structures and the other involves advising trainees/workers on how to manage difficulties while waiting for structures to change. Our review of the work-life conflict literature and our conversations with the postdocs who provided the survey data this report is based on led us to the following recommendations for those responsible for structural changes (e.g., postdoc office administrators, principal investigators and mentors) and for the individual postdocs themselves. While there are important structural changes that might benefit particular kinds of postdocs (e.g., more childcare for postdoc parents), most postdocs would not be affected by those changes. Therefore, our suggestions will speak to more global issues. In order to give readers more insight into how postdocs describe their experiences, we provide quotes from some of our respondents to provide some context for the suggestions.

Structural Recommendations

> "I actually had to detach myself from that PI because I was, like, 'you're pressuring me too much on working these 12 h days.' I'm getting sick. I don't want this. This is not for me."

> "This was the kind of lab where you were just expected to produce, and if you weren't producing, you were going to get in trouble. Any time the PI had a whim, you were going to do it and there was no regard for your interests or burnout or anything, you know?"

> "There was not even one weekend that I stayed home and didn't come to work, not even one. I was working on President's Day, all the vacation days I was here in order to be able to manage to do all these things."

The research on work-life conflict is clear: In order for workers to balance their work responsibilities and their non-work responsibilities/experiences, they must have the support of supervisors who understand how important it is to balance these things and who take steps to help them achieve that balance (Jansen et al., 2003).

Academic research is entrepreneurial (Casati and Genet, 2014; Price et al., 2018; Pitt et al., 2020) and as such can take on the same problematic attributes – problematic for both employer (PI) and employee (postdoc) – that we see among new commercial entrepreneurs: having to take on (or delegate) multiple roles/responsibilities, negotiating often ambiguous performance and productivity expectations, and "always being on the job."[10] The autonomy, flexibility, and uncertainty that characterizes academic science (Bailyn, 2003; Fox et al., 2011) often has a knock-on effect, for postdoctoral supervisors themselves, of poor work-life balance and permeability between their work and their non-work lives. They then model poor work-life balance and, worse, impose similar expectations for limitless labor onto their postdoctoral trainees.

Our respondents point to three primary causes for their difficulty constraining work time so it does not take over their lives: the constant and ever-evolving demands on their time at work, the amount of time they believe is required to meet those demands "successfully," and (ironically) the flexibility in scheduling work that is common in academic spaces. All three of these catalysts for work-life conflict can be managed by structural changes either imposed by institutions or adopted by postdoctoral supervisors (PI's) and advisors.

Some changes can be adopted simply by recognizing that, regardless of their formal categorization as employees (often "postdoctoral associates") or non-employees (often "postdoctoral fellows"), most postdocs are *trainees*. They are not only engaged in collaborative research with the postdoctoral supervisors, but they are also supposed to be using these positions as launching pads to independent research careers. Like graduate trainees, they are compelled to engage in multiple tasks with vague metrics for measuring success/completion. Trying to meet both their and their supervisors' expectations leads to long hours and heightened anxiety about whether or not enough hours are being spent. Departments and faculty supervisors must recognize that these sometimes competing performance pressures cause postdoc trainees to lose sight of the boundaries between their work hours and their non-work hours. They must resolve to help postdocs constrain their work to some reasonable number of hours akin to what faculty themselves work or, we argue, better than that.[11]

The fact that work-life conflicts seem to have mental health ramifications means that institutions must provide support, including counseling and psychological services, for postdocs just as they do undergraduate and graduate trainees.

Individual Recommendations

> "This is a job where day after day, you fail, fail, fail. It's important for me to just leave work at work. If the experiments fail, they fail, but then I go home and still enjoy my life outside of the workplace and not feel the pressure of, 'Well, you are failing, so get back to work.'"

[10]According to a 2016 Bank of the West Small Business Growth Survey, 43% of small business owners say "always being on the job" is one of the biggest challenges they face. Other studies show that 33% of small business owners work more than 50 h a week; 25% work more than 60.

[11]While we see parallels between postdocs and medical residents/house staff, the medical internship regime is *not* a model here. While medical residents are constrained to working a maximum of 80 h a week averaged over a month's time—which is terrible in itself—the boundaryless of their work (direct patient care, ancillary care, and paperwork) can cause some residents to work more than 120 h in some weeks.

> "Science is a weird job where you may not always be putting in a ton of work hours, but you put in a huge amount of thought hours. I was working 10 h days, but I was also thinking about stuff at home. A huge amount of thought hours made it feel like I was working all the time."

> "I feel like what happens with people in postdocs is they're just working and working and working and working. They're thinking about that vacation they're going to take, but they don't take it. They love to paint, but haven't painted in three months. I think it's really important to try, even if it's not as much as you'd like, to fit in some of those things that bring you joy."

We have two recommendations for postdocs themselves: engage in an exercise of personal role redefinition and create boundaries around your work and your life.

Just as it critical for PIs to recognize that their postdocs are trainees and not employees, it is also important for postdocs to see themselves in the same light, but with a twist. Because most postdocs are structured in employee-like ways, with responsibilities to produce some "product" either for themselves or for/with their PIs, there is room for reframing scientific work as requiring unending effort (i.e., work hours) and rumination (i.e., thought hours). Creating concrete tasks with narrow measures of success, especially if done in consultation with one's PI, enables postdocs to end each work period feeling like they did "enough" rather than constantly feeling like there's more to be done and it has to be done now. As postdocs put great emphasis on how their PIs experience work-life balance, future research on the impact of postdocs' observations of their PIs' work arrangements and the PIs' perceptions and experiences of their work may further explain the relationship between work-life conflict and mental health of postdocs.

Ironically, the fact that postdocs *are* trainees, makes it hard for them to transition from practices they engaged in as undergraduate and graduate students, practices that do not work as well in the liminal space they are in. The uncertainty students feel about their performance, often caused by delayed positive evaluations of that performance, causes them to think of effort – measured by time spent engaged in something – as the best evidence of commitment and competence. There is pressure to always look like, and for many always be, "actively engaged workers." Some research shows that this uncertainty even leads people to volunteer to work more hours than prescribed for them as a way to look and feel like a serious worker (Sharone, 2005).

Postdocs who have worked in full-time jobs at some point since receiving their baccalaureate degrees suggest that the break from the student-role, with all of its delays in assessments of "good and completed work," enabled them to better craft a sense of themselves as workers with a concrete set of responsibilities to a concrete set of stakeholders limited to a concrete space and amount of time in which to complete them. Gaining some semblance of control of work-life balance in those spaces carried over into their graduate and postdoctoral traineeships. They could see the potential for encroachment more clearly and, when empowered to do so by supervisors who would listen, could head it off by monitoring and circumscribing that encroachment.

Again, the autonomy and flexibility that characterizes academic work often comes with a cost. Without the constraints of hourly wages, offices that shut down at 5 pm and concrete evaluations of productivity (i.e., you have made X number of things this week), it can become very easy to ignore the way work expands to fill the vacuum of a boundaryless non-work life. Families – even children – can be good for balance. They often force postdocs to create boundaries around work. But even then, postdocs tell us that they take work home and continue working on it after their children are asleep. Single and child-free postdocs have to be even more vigilant without family "allies" in their attempts to reduce work's encroachment on their non-work lives and leisure.

It is important that postdocs learn segmentation practices where they create, and maintain, hard boundaries between work and their "life." Attempts to reduce the amount of contact one has with work when engaged in life can go a long way in reducing both the experience of role-conflicts and the sense that the boundaries between the roles are blurry. Boundary marking, or making decisions about ways work can go "this far and no farther," becomes especially important given ways communication technology (e.g., email and smart phones) enables work to follow us into our lives if not constrained.

One important boundary marker can be differentiating between the spaces where work and life happens. For most science trainees, the bulk of their work takes place in an on-campus laboratory or in on-campus offices. Deciding that they will only work in spaces dedicated to their work as postdocs and not allow themselves to engage in work-related activities (or accept work-related contacts) in their home is an important step in creating a boundary between work and life. Often academic workers, postdocs and faculty mentors alike, create dedicated office spaces in their homes. We believe this is a mistake. Just as most employers are still resistant to create spaces for "life" (e.g., daycares, tv lounges, and exercise rooms) in work contexts, postdocs must endeavor to resist creating room (and, literally, rooms) for work in their living spaces.

Notably, the COVID-19 pandemic changed our usual work patterns (Ashencaen-Crabtree et al., 2021; Matulevicius et al., 2021; Möhring et al., 2021) suddenly forcing many science trainees to shift all of their work into their homes. While it remains uncertain how much the new patterns of making work arrangements more flexible (and therefore, less predictable) and shifting more work into workers' homes will persist, it is important to recognize that even prior to the pandemic, both of these patterns were clearly causing problems with work-life balance and boundary marking (Hayman, 2009; Felstead and Henseke, 2017). Our hope (and our recommendation) is that faculty supervisors/employers do not casually embrace these

patterns as norms without counting the costs to their trainees' health.

Creating boundaries between work and life/leisure cannot be left to chance. As the quotes suggest, the culture of academic science seems to expect and privilege over-work. These cultural norms – this is not necessarily a function of the "nature" of science – can be managed and, if we all consider the health consequences of them, undone. Just as scholars (e.g., Cech and Blair-Loy, 2014; McGee, 2021) are pushing us to consider ways the culture of academic science are pushing people of color and women away from academic careers, we hope this project further prompts administrators, faculty, and science-discipline associations to think of how this cultural norm – that a minimal non-work life is expected – might be pushing them away as well.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Behavioral and Social Sciences IRB Office, Vanderbilt University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RP supervised the project and RP, YT, and IS wrote and revised the manuscript. All authors contributed to the article and approved the submitted version.

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Building a Networked Improvement Community: Lessons in Organizing to Promote Diversity, Equity, and Inclusion in Science, Technology, Engineering, and Mathematics

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In 2016, 10 universities launched a Networked Improvement Community (NIC) aimed at increasing the number of scholars from Alliances for Graduate Education and the Professoriate (AGEP) populations entering science, technology, engineering, and mathematics (STEM) faculty careers. NICs bring together stakeholders focused on a common goal to accelerate innovation through structured, ongoing intervention development, implementation, and refinement. We theorized a NIC organizational structure would aid understandings of a complex problem in different contexts and accelerate opportunities to develop and improve interventions to address the problem. A distinctive feature of this NIC is its diverse institutional composition of public and private, predominantly white institutions, a historically Black university, a Hispanic-serving institution, and land grant institutions located across eight states and

Washington, DC, United States. NIC members hold different positions within their institutions and have access to varied levers of change. Among the many lessons learned through this community case study, analyzing and addressing failed strategies is as equally important to a healthy NIC as is sharing learning from successful interventions. We initially relied on pre-existing relationships and assumptions about how we would work together, rather than making explicit how the NIC would develop, establish norms, understand common processes, and manage changing relationships. We had varied understandings of the depth of campus differences, sometimes resulting in frustrations about the disparate progress on goals. NIC structures require significant engagement with the group, often more intensive than traditional multi-institution organizational structures. They require time to develop and ongoing maintenance in order to advance the work. We continue to reevaluate our model for leadership, climate, diversity, conflict resolution, engagement, decision-making, roles, and data, leading to increased investment in the success of all NIC institutions. Our NIC has evolved from the traditional NIC model to become the Center for the Integration of Research, Teaching and Learning (CIRTL) AGEP NIC model with five key characteristics: (1) A well-specified aim, (2) An understanding of systems, including a variety of contexts and different organizations, (3) A culture and practice of shared leadership and inclusivity, (4) The use of data reflecting different institutional contexts, and (5) The ability to accelerate infrastructure and interventions. We conclude with recommendations for those considering developing a NIC to promote diversity, equity, and inclusion efforts.

Keywords: Networked Improvement Community, diversity, STEM, faculty careers, shared leadership

INTRODUCTION

In 2016, 10 research universities in the United States launched a Networked Improvement Community (NIC) through the National Science Foundation's (NSF) Alliances for Graduate Education and the Professoriate (AGEP) program. The NIC's goal, in alignment with AGEP's mission, is to increase the number of scholars from AGEP populations – Black and African Americans, Hispanic and Latinx Americans, and American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders – entering science, technology, engineering, and math (STEM) faculty careers. AGEP populations represent an increasing proportion of the science, engineering, and health academic workforce, rising from 6.4% in 1999 to 8.9% in 2019 (National Center for Science and Engineering Statistics, 2021). However, Black and African American, Hispanic and Latinx, and Native American people comprise approximately one-third of adults 18–64 in the United States, so these populations remain markedly underrepresented in STEM academic roles (National Center for Science and Engineering Statistics, 2021). This disparity persists despite decades of efforts to diversify STEM fields (Leboy and Madden, 2012; Whittaker and Montgomery, 2014).

The purpose of this community case study is to describe and reflect on the establishment and evolution of a NIC in the United States higher education context. In this article, we describe how these 10 universities formed a NIC, adapted the NIC to meet the different campus contexts, and launched structural changes and interventions to promote increased representation of AGEP populations in the STEM professoriate. Further, we offer lessons and insights from our work as a NIC, with particular attention to equity, diversity, and inclusion within the NIC.

WHAT IS A NETWORKED IMPROVEMENT COMMUNITY?

Popularized by the Carnegie Foundation, a NIC creates a highly structured learning and design community (Bryk et al., 2010, 2015). This organizational approach brings together stakeholders focused on a well-specified common goal, deep understanding of the problem, and opportunities for change (Bryk et al., 2010). It leverages the power of improvement science and networks to accelerate innovation and improvement through structured, ongoing intervention development, implementation, and refinement (LeMahieu et al., 2017). In higher education, where professional silos frequently result in divisions between stakeholders (Kezar, 2005; Torres and Renn, 2021), NIC structures also function as "an attempt to redefine professional roles and identities as well as the relationships between these stakeholders" (LeMahieu et al., 2017, p. 24).

Feygin et al.'s (2020) metastudy found seven NICs that were studied in K-12 and undergraduate education, with no studies at the graduate level. The authors found "challenges to NIC implementation, such as inconsistent application of Plan Do

Study Act (PDSA) cycles, frustration with an onerous process, and burden on teachers and principals" (p. 8) and "NICs are complex organizations that are difficult to implement" (p. 10). As NICs are a newer formalized organizational structure, especially in higher education, there is much to learn about them in practice (LeMahieu et al., 2017). Given their potential for system change, we argue that NIC structures offer great promise to the national effort to broaden representation in STEM.

INTRODUCING OUR NETWORKED IMPROVEMENT COMMUNITY

Established in 2016, our NIC was funded through NSF's AGEP program. In alignment with AGEP's mission, the goal of our NIC is to increase scholars' aspirations and persistence in STEM faculty careers primarily by improving campus climate. Efforts to increase compositional diversity and promote inclusion within STEM fields are not new, yet racial disparities persist (Leboy and Madden, 2012; Whittaker and Montgomery, 2014; National Center for Science and Engineering Statistics, 2021). Such a complex and entrenched problem requires multifaceted, adaptive responses. We theorized a NIC organizational structure would provide better understandings of the complex and chronic problem of the underrepresentation of Black, Latinx, and Native scholars in STEM faculty careers than traditional multi-institution organizational structures. A NIC brings together collective expertise and provides time and space to learn about varied local contexts, so each campus can adapt its infrastructure and interventions to its different contexts and local partnerships. Interventions developed and adapted by the NIC described in this article range from faculty member attitudes and behaviors, identity development and self-efficacy of AGEP scholars, inclusive climate of the lab or research group where students spend much of their time, to departmental, college, and university climate.

Previous NICs in educational settings (typically K-12) have strong central organization through their district or charter network (LeMahieu et al., 2017). However, such centrally organized and tightly coupled systems are rare among higher education institutions. Indeed, a distinctive feature of this NIC is its diverse institutional composition. Our member institutions were all part of the Center for the Integration of Research, Teaching, and Learning (CIRTL), a national consortium committed to inclusive STEM higher education. All CIRTL AGEP NIC member universities are high or very high United States research doctoral universities, yet they are structurally and culturally quite different. They include both public and private, predominantly white institutions and minority serving institutions (a historically Black university and a Hispanic-serving institution), and several land grant institutions located across eight states and Washington, DC, United States.

Our NIC's dispersed membership was particularly valuable for gathering information about different initiatives and their potential at institutions with varied contexts, missions, and cultures. Institutional representatives to the NIC held different positions within their institutions, including faculty, staff, administrators, and graduate students. The varied positionalities of individual members was a strength, offering important and complementary expertise for the conceptual and practical work at the NIC-level and on our campuses. Each individual had access to varied levers of change, which influenced their perspectives and contributions to the NIC, and led to a renewed focus of the NIC on building local infrastructure. As such, each institution chose its own interventions to be responsive to campus needs.

The authors of this community-case study are all active participants in the NIC. Three are graduate students, six are professional staff members in a graduate school, three are professional staff members in a teaching and learning center, two are faculty members in STEM, three are faculty members in higher education, four are assistant or associate deans in the graduate school, and three are deans of a graduate school. Graduate students received assistantships, faculty received some summer salary, while administrators on 12-month appointments were not paid any additional amount for NIC work.

In the following sections, we share our initial steps in forming the NIC, work to improve and create a more inclusive NIC, the interventions we implemented on different campuses, and the lessons we have learned along the way. We drew on evaluation data, including bi-weekly and annual meeting observations, interviews, and surveys, as well as members' reflections to inform this community case study.

INITIAL STEPS IN FORMING OUR NETWORKED IMPROVEMENT COMMUNITY

Carnegie describes four recommended parts for a NIC as a well-specified aim, a deep understanding of the problem, the utilization of improvement science methods, and a focus on accelerating interventions (McKay, 2017). In the initial stages of our CIRTL AGEP NIC, we worked on these four components.

Well-Specified Aim

The group coalesced during the writing period for the grant around the main goal of the AGEP Request for Proposals, which is to increase participation of those from backgrounds historically marginalized in STEM faculty careers. The aim for our project needed to be narrowed in order to be achievable within the 5-year period of the grant and be within the scope of participating universities. After several rounds of discussion, we defined the aim to be:

"Increase the number of Ph.D. candidates/postdocs who are interested in faculty careers by 50%."

This had several advantages: (a) Interest in faculty careers was something we could influence; (b) Such interest is a logical prerequisite for students and postdocs applying for faculty positions; (c) Prior research indicates interest in faculty careers drops significantly for those from historically marginalized backgrounds (Gibbs et al., 2014); and (d) It did not depend on factors outside the project's scope such as university hiring committees. In a pilot survey of some NIC universities, we defined interest in a faculty career as "interested" or "strongly

interested" in a faculty career in either a 4-year university or college with a research mission, a teaching mission, or a combination, or a faculty career in a 2-year or community college. Final data on students' interest in faculty careers have not been collected at this point in the project.

Understanding the Problem

The driver diagram (**Figure 1**) represents our NIC's understanding of the main influences or primary drivers for reaching the aim (or goal). These are shown progressively to the right of our goal. On the far right are initiatives or projects that could help make progress on the drivers. If progress was made on each driver, we would achieve the project's aim.

Our CIRTL AGEP NIC built the driver diagram through iterative, collaborative, and consensus decision-making processes over several months with revisions in subsequent years as the project progressed and matured. The CIRTL AGEP NIC built consensus on the five primary drivers ("What/Causes" blue boxes) using evidence-based research to reach a common understanding of the importance, value, and meaning of each driver: the climate of program/lab; students' identity development and self-identity; beliefs about a faculty career; faculty members' attitudes and behaviors toward the student; and the students' sense of belonging. Moving to the right of the driver diagram, the "Where/Levers" column (maroon boxes) identifies locations or times in the system where these drivers can be affected through changes in norms, policies, or structures. The final column lists possible interventions that could change or improve specific practices that occur in these locations/times. In this diagram, the green boxes represent student-focused initiatives and orange boxes are faculty-focused initiatives. Reading the driver diagram from right to left, the improvement hypothesis is that by implementing these interventions, we improve experiences of future faculty from historically marginalized backgrounds at these locations/times, which improves the five primary drivers, which then helps reach the goal of increasing interest in faculty careers among the AGEP population.

There are more interventions on the right-hand side of our driver diagram than can be implemented on any given campus by any one team. The diversity of institutions in our NIC, the different contexts, and the variety of local partners and resources mean certain interventions are more viable on some campuses than others. The list of possible interventions is a multi-layered approach to achieving our goal, with each institution implementing select interventions deemed most appropriate for their campus and students, most often in collaboration with other campus units not directly engaged in the NIC. Select interventions are described later in this paper. Putting the driver diagram into practice gave us the opportunity to try multiple approaches toward achieving the same goal, which facilitated critical learning within the NIC. In some cases, interventions started on one campus were adopted or modified on one or more other NIC campuses, but no campus implemented all interventions and some interventions were attempted by only one campus.

Improvement Science

The NIC theory of improvement hypothesizes that if the project can improve the drivers, we will make progress toward our target goal. We constructed a comprehensive survey instrument

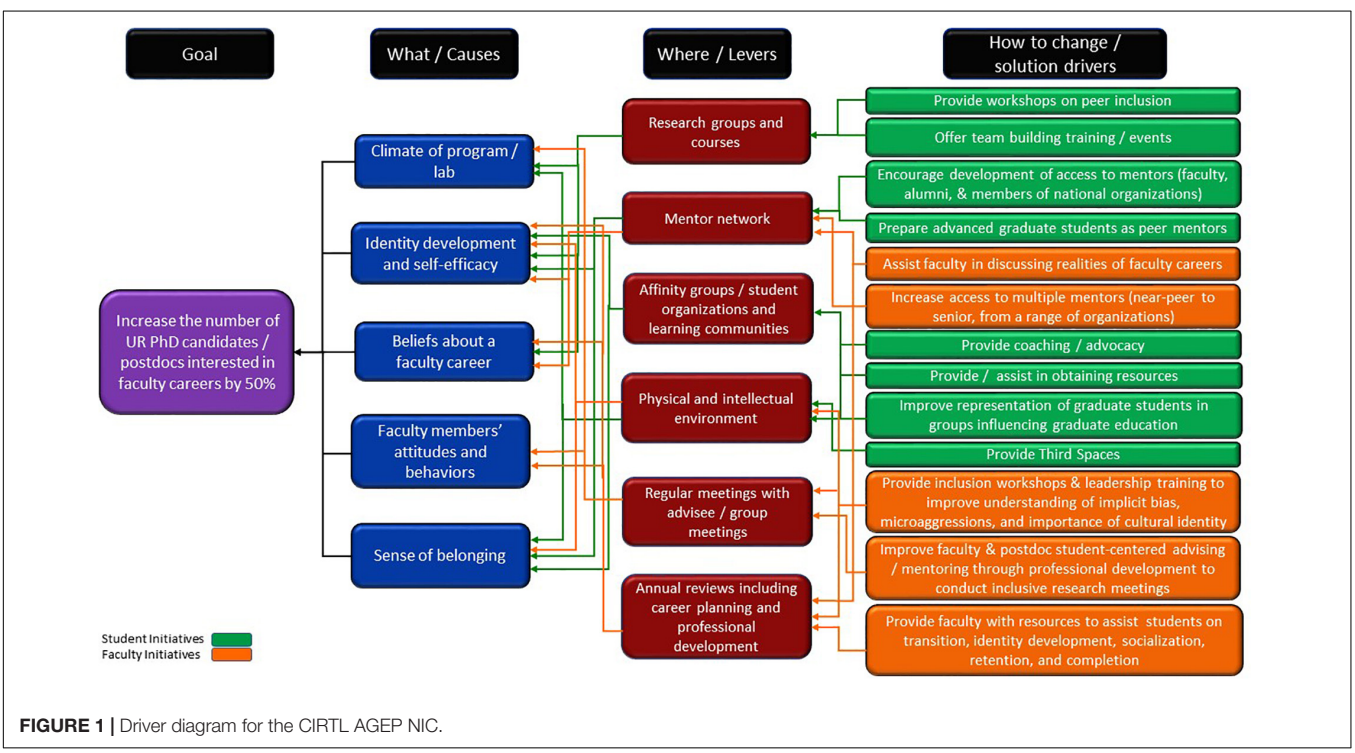

FIGURE 1 | Driver diagram for the CIRTL AGEP NIC.

containing questions related to each of our five primary drivers. Although the survey provided a partial initial baseline for the project, it was not useful for improvement science. Only five of nine universities (the tenth university's role was evaluation of the 9-institution NIC) were able to distribute the survey to their graduate students, postdocs, and/or faculty; the other universities relied on data from similar surveys already established at their institutions. As the project progressed, concerns were expressed that the survey was too long and was not validated appropriately, so it was not re-administered after the initial data collection.

Formative evaluations of campus interventions that collected information about the impact workshops had on participants proved more useful. Questions such as "when were you most or least engaged?" were used to improve workshops (Brookfield, 1995). These evaluations were not identical across campuses (although that is a recommended practice for NICs) because workshops were tailored to each campus and therefore, different in content and structure. In some cases, evaluation instruments already in place on a campus or widely used by campus partners were used.

Accelerate Interventions

Each participating university worked toward our shared goal by utilizing different approaches, e.g., improving inclusiveness of the climate in departments and research groups, holistic admissions processes, peer mentoring, and improved advising. They implemented local interventions focused on different portions of the driver diagram such as faculty member attitudes and behaviors, identity development and self-efficacy of AGEP scholars, and the inclusive climate of the lab, research group, or department. In all cases, campus interventions were joint projects with local campus partners, e.g., workshops on climate were done in conjunction with department, college, and university initiatives.

Some sharing of workshops between NIC campuses occurred, most notably on holistic graduate admissions. Selection and design of interventions were influenced by the varying local contexts and the interests of partners on each campus. As the CIRTL AGEP NIC developed, the local context, existing or potential on-campus partnerships, and the extent of local capacity all became more important factors than sharing workshop materials produced at different NIC institutions. As a result, instead of sharing and adopting multi-campus interventions, our NIC focused more on strategies to identify and foster local partnerships and infrastructure that might be most effective for introducing and accelerating local interventions appropriate to each campus context. By partnering with local units on a campus, the interventions differed across the NIC.

Finally, we learned that analyzing and addressing failed strategies is as important to a healthy NIC as sharing the learning from successful interventions. These discussions required a level of trust among members and willingness to share concerns, biases, and institutional challenges often kept silent in cross-university funded projects. Trust-building discussions were intentionally added to annual and bi-weekly meetings of the NIC. As a result, deeper understanding emerged from sharing experiences in this way, often facilitating campus efforts more quickly than when partners only share context-specific "best practices."

CONTINUOUS IMPROVEMENT IN OUR NETWORKED IMPROVEMENT COMMUNITY

The formation of our NIC relied on pre-existing relationships among individuals who had come to know one another through their interactions via the CIRTL Network, leading to assumptions about how we would work together based on past patterns rather than making explicit how the NIC would establish norms, understand common processes, and manage changing relationships. However, both the goals and the structure of the NIC were different from the prior context where these relationships started. During the initial period of our NIC, it became apparent to evaluators that the people and institutions involved varied in: (1) Available resources, (2) Capacity of people who could work on the project, and (3) Positions that NIC members held on their campuses, which ranged from graduate students to graduate deans, STEM faculty to social science faculty, and staff working on diversity, equity, and inclusion (DEI) initiatives. Results from our evaluation team indicated that not all voices felt heard, and some members felt they could not raise concerns. Some perceived there to be dominant and secondary voices/institutions.

As we struggled to create a more inclusive NIC, we examined our leadership model. Innovation, efficiency, collaboration, and transformation are sacrificed when all voices are not heard and valued. How could we structure our group differently from traditional collaborative projects? Was there a different paradigm? To reduce traditional hierarchies, we adhered to the basic tenets of inclusion and equity.

We found the single Principal Investigator (PI) or PI group model was not fully serving the NIC's evolving values and aspirations, even though the funding source for our NIC project required identification of and responsibilities from designated PIs. Our NIC sought to avoid break-away affinity groups, dominance of certain voices, backroom conversations/alliances with corresponding lack of transparency, and equivocation. There may be safety and comfort (for some) in the known PI structure but it can present challenges to inclusive leadership. During these discussions, there was a confluence of two additional changes: (1) Some individuals and an institutional member left the NIC and (2) The NIC moved to a more collaborative leadership model (Routhieaux, 2015) adopting rotating responsibility for setting meeting agendas, sharing meeting facilitation, and continued use of a more sociocratic decision-making process. Emergence of new voices and energies investing in the process served as a key indicator that our strategy for increasing inclusivity was working.

For example, historically Black colleges and universities (HBCUs) lead the way in producing Black undergraduates who enter and succeed in STEM doctoral programs (Upton and Tanenbaum, 2014), yet these institutions are often relegated to subordinate roles in multi-institution consortia. Their presence

at the table when discussing graduate education can be seen as tokenism rather than valued representation. In our evolving CIRTL AGEP inclusive leadership approach, Howard University took on a larger role and shared their successful mentor model across the new NIC.

Moving toward a more inclusive NIC also meant we increased discussions about the context of each university, the positionality of NIC members at their university, and their local partners, conversations that had not happened since early in the grant. Local infrastructure, partnerships, and capacity to implement change became paramount. By providing more opportunities for people to share their context and discuss possible solutions that could be adapted from other campuses, this NIC model accelerated change on multiple campuses.

We found restructuring our NIC with a focus on inclusivity turned the challenge of a variety of institutions and contexts into a strength of diversity. We learned from each other, especially how to work with different partners on each campus and build organizational capacity. In a few instances, adapted interventions provided diverse contexts to test and led to stronger solutions on each campus.

Our CIRTL AGEP NIC model is represented in **Figure 2**. Each campus is shown as implementing interventions in their own context and with key campus partners, while at the same time the members of the NIC seek to connect with each other equitably across the network to share what is working and what challenges they may have.

An unresolved issue is the necessary infrastructure underlying this NIC model. Our project did not originally budget for a project manager or person with responsibility for facilitating the administrative needs of the NIC. Doing so would have undoubtedly helped with various organizational tasks, such as ensuring meeting agendas were set and communicated in a timely manner, attending to logistics of hosting in-person meetings, providing technical support for facilitating virtual meetings, tracking NIC activities, and coordinating outreach efforts. However, having a single project manager could have given more perceived influence to a single voice, potentially decreasing the NIC's inclusivity.

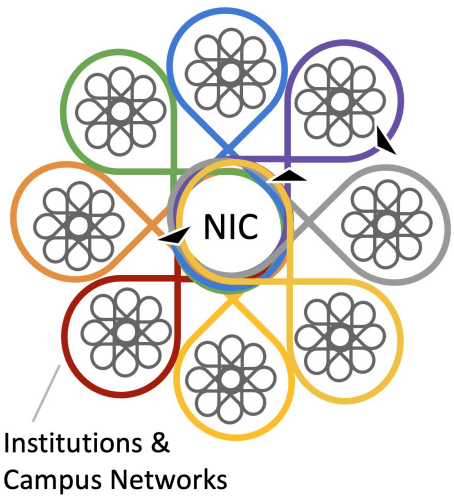

FIGURE 2 | A schematic representation of a NIC that recognizes each campus' context, shares possible solutions and ideas for infrastructure, and hence accelerates change on each campus. The colors represent different NIC institutions. The arrows represent the information flow between institutional members and the NIC, and from the NIC to institutional members.

In **Table 1**, we compare principles and purposes of a traditional NIC with our CIRTL AGEP NIC. The main differences in our more inclusive NIC are explicit attention to shared leadership, understanding and respect for different contexts and local partners, positionality and capacity of the organizations, and the focus on infrastructure in addition to interventions.

We continue to interrogate our CIRTL AGEP NIC model, and what is required to incubate and accelerate transformation toward equity, diversity and inclusion. As a result of these changes from a traditional NIC, this more inclusive NIC structure has required significant engagement within the group, more intensive than traditional multi-institution organizational structures. This structure has also highlighted the value of building intentional, trusting relationships and those relationships' role in advancing DEI work.

CHANGES ON OUR NETWORKED IMPROVEMENT COMMUNITY CAMPUSES

Throughout development of the CIRTL AGEP NIC, from the initial steps following the four-part NIC model to the more inclusive NIC model, members of the NIC have been implementing changes on each campus to make progress on project goals. A sample of these interventions is listed in **Table 2**. Where more than one university is listed next to an intervention, members of the NIC used an intervention started on one campus and adapted it to a new context. Differences in local contexts and the need to work with local partners required that different interventions be implemented across the NIC.

Interventions listed in **Table 2** are categorized by the different drivers of our driver diagram (**Figure 1**). Campuses worked with local partners to strengthen faculty members' understanding of DEI concepts and to improve the processes of admissions, advising, and mentoring. Other campuses implemented peer support and professional development for scholars from historically marginalized backgrounds to increase their interest in and preparation for faculty careers. A third group of campuses focused their interventions on the climate of labs and research groups through mini-grant programs or by partnering with ongoing DEI work in departments or colleges.

- *My Voice, My Story* sessions pair video monologues – constructed from experiences of graduate students – with facilitated discussions. The primary objectives are to utilize the power of narrative to achieve greater understanding of the lived experiences of graduate and professional students, share stories that frequently

TABLE 1 | A comparison between the principles of a traditional (Carnegie) NIC and our CIRTL AGEP NIC.

Traditional NIC (Carnegie NIC)	CIRTL AGEP NIC
Well-specified aim	Well-specified aim
Understanding the problem and how to address it	Understanding the systems in which the problem is located, including the variety of contexts, local partnerships, and different organizations
Improvement science methods, such as Plan, Do, Study, Act (PDSA) cycles	Incorporating data that reflect different campus contexts and varied analytical approaches while providing utility to the collective
Leadership models are not specified	Culture and practice of shared leadership in determining questions to be addressed and actions to take, centered around inclusivity in our practices
Accelerate interventions	Accelerate local partnerships, infrastructure and interventions

TABLE 2 | Sample of interventions and their alignment with CIRTL AGEP's driver diagram.

Driver	Solution drivers	Examples
Faculty member attitudes and behaviors	Strengthen understanding of DEI	• My Voice My Story (Cornell University, University of Georgia, University of Maryland) • Inclusion workshops (University at Buffalo, Howard University, Iowa State University) • Inclusive teaching (Northwestern University, The University of Texas at Arlington)
	Improve admissions, advising, and mentoring	• Holistic admissions (University of Georgia, University of Maryland, Cornell University) • Faculty advising and mentoring (University of Maryland, University of Georgia, Cornell University)
Identity development and self-efficacy	Increase peer support and professional development	• Peer mentoring (Howard University, The University of Texas at Arlington) • NextGen Professors (Cornell University) • Formation of a Graduate Student of Color Association (University at Buffalo)
Climate of lab/research group	Work with DEI partners and other offices on campus	• Mini-grants for department or college DEI initiatives (Boston University, Northwestern University) • Diversity partners in colleges (Cornell University, Iowa State University, University at Buffalo, The University of Texas at Arlington)

go untold, and develop strategies on how to create more inclusive and supportive research and learning environments (Cornell University, 2021a).

- Inclusion workshops, separately offered for graduate students and faculty, promote more in-depth knowledge and understanding of privilege, marginalization, microaggressions, implicit bias, and structural racism. These workshops can be run by content experts or in a train-the-trainer mode. In the latter, approximately 1.5 days of training helps prepare faculty and graduate student facilitators to run inclusion workshops.
- The inclusive teaching initiatives center department conversations on diversity, equity and inclusion as a core part of faculty's work. Departments adapt a set of inclusive teaching principles to their context within a university-wide framework.
- Holistic admissions adapts the framework developed by Posselt (2016). Programs reflect on what strengths and attributes they are really looking for in graduate students and find ways to gather that information when a student applies. Admission decisions draw on this broader range of information, and as a result some programs elect to not require GRE scores. Others ask for both an academic statement of purpose and a personal statement with a diversity focus from all applicants.
- Professional development for faculty on advising and mentoring graduate students draws on several resources, e.g., Center for the Improvement of Mentored Experiences in Research (CIMER Center for the Improvement of Mentored Experiences in Research, n.d.; see also Branchaw et al., 2020) and Sloan University Centers for Exemplary Mentoring (Alfred Sloan Foundation, 2021). They feature an inclusive, student-centered framework, with discussions on understanding both one's own and students' social identities, jointly agreeing to expectations, communication, empowerment, and faculty support for the broad range of careers a student may be interested in.
- Peer mentoring provides an opportunity for new graduate students from AGEP populations to learn from more experienced graduate students. Training is provided for the mentors, as well as a suggested structure for the conversations and how to develop the mentoring relationship. Community is built by gathering the mentors and mentees together during the first year. This program helps new students transition and addresses many of the challenges that students are experiencing.
- NextGen Professors is a career-development program focused on preparing graduate students and postdocs for faculty careers across institutional types. The primary audience is doctoral students (in year three or beyond) and

postdocs from backgrounds historically underrepresented in the professoriate, and/or those with a demonstrated commitment to advancing diversity, inclusion, access, and equity in academia (Cornell University, 2021b).
- The formation of a Graduate Student of Color group provides space for students to share their issues and experiences, support each other, and come together as one voice articulating their needs and requests to improve their education.
- Mini-grants aim to improve the local climate in departments and research groups by allowing them to drive their own local change. Interested departments or colleges apply to a broad request-for-proposals with diversity and inclusion initiatives that best address their local context.
- Partnering with ongoing DEI initiatives being run by local campus partners serves two purposes: (1) It connects graduate-level work with university-wide initiatives, and (2) Helps sustain the work past the life of the NIC by building capacity and local infrastructure.

RECOMMENDATIONS

We offer several recommendations for consideration by future NICs as they plan their formation and work to establish a culture of equity and engagement.

1. NICs should use an inclusive, shared leadership model. Welcoming all voices contributes to innovation, efficiency, collaboration, and transformation. Perhaps because of initial relationships and ways of interacting established before the start of our NIC, participants brought different assumptions and expectations to the group regarding how these processes would operate, leading at times to awkwardness, fractured relationships, and institutional and individual departures from the NIC. After changing to a more shared leadership model, we saw the emergence of new voices and energies investing in the process. In our CIRTL AGEP NIC, our shared leadership model helped equalize voices independent of the institutional prestige and the professional position of the member. Shared leadership in collaborations like a NIC can help reduce hierarchies and the potential for exclusion based on previous relationships, while also helping build upon those relationships in the new context.

2. NICs should define membership in the NIC, including the associated responsibilities and benefits of membership, as well as how member contributions will be recognized and honored, and should devote time to building an inclusive, shared NIC culture. In NICs, membership is a combination of institution and individual. With new individuals in the NIC as well as some continuing from CIRTL came a new culture that needed attention and time to build equitable norms and expectations about individual roles and shared leadership. Additionally, over the scope of a multi-year NIC project, individuals within an institution change. Welcoming and onboarding efforts are needed to bring new individuals (even from existing institutions) into the NIC fold, but also important, the NIC culture must be amenable to adapting to its own changing composition and the new ideas that come with new participants. As the Carnegie Foundation notes, "A well conceived and supported NIC builds trusting relationships that allow members to respect the contributions that each brings to the collective effort" (LeMahieu, 2015, p. 8).

3. NICs should have an organizational structure agreed to by all members. Project funding should include support for maintaining and scaffolding the organizational structure, e.g., a project manager. Careful coordination is required for NICs to work well (LeMahieu, 2015). Our NIC relied on the good will and largely uncompensated efforts of individuals within the NIC to volunteer to take on various administrative and organizational tasks, such as setting meeting agendas, hosting in-person meetings, facilitating virtual meetings, tracking NIC activities, coordinating outreach efforts, etc. Over time, willingness and/or ability to volunteer for these duties diminished. Having a funded project manager for the duration of the project with well-defined duties and responsibilities, could benefit the group's functioning and productivity within a shared leadership structure, including a focus on strengthening inclusive practices.

4. NICs should articulate mechanisms for conflict resolution, decision-making, data management, onboarding and offboarding, and other processes necessary to provide a transparent, respectful climate required for the types of sharing and learning necessary in a well-functioning NIC. This is particularly true when the different group members are from organizations with different resources. Additionally, such mechanisms will help address the inevitable challenges of individual members changing over the course of a multi-year project.

5. NICs should wrestle with the challenge of individual members holding different positions in their respective institutions, with varied access to resources and varied levels of influence on levers of change. In some member institutions, key university administrators (e.g., academic deans) with clear budget authority were active NIC participants while in other member institutions active NIC participants were professional program staff experts in program delivery. Budgets and access to partners in each NIC institution varied widely, with some institutions having considerable budget flexibility and many willing campus partners while other institutions' representatives worked within significant budget constraints and with few, if any, campus partners beyond their own units. At times, such disparities caused tensions within our NIC group discussions. Because grant-funded project budgets are unlikely to be able to equalize such institutional disparities, NIC members need to deal openly with these inequities and agree on productive ways to work together to the best of each institution's and each individual's abilities, budgets, and resources.

LIMITATIONS

In this community-case study paper we restricted ourselves to United States-based research universities working together on a

government-funded project. Some findings may not be applicable to NICs or universities in other cultures or countries. Our focus has been on the climate in STEM disciplines, so this discussion may not be fully applicable to humanities and social sciences.

CONCLUSION

We began this article by summarizing the Carnegie Foundation's four components of a NIC, including a well-specified common aim, an articulated understanding of the problem and theory of change to reach that aim, ability to engage in improvement science, and coordination to accelerate interventions toward addressing the identified problem. However, within this model, our NIC at the early stages struggled with its leadership structure, was not able to fully engage in improvement science, and benefited in only a few instances where universities partnered on common interventions. Differences in local contexts and the need to work with local partners required that different interventions be implemented across the NIC.

Intense reflection, discussion, time, and effort led to a revised, more inclusive NIC. We continue to interrogate our CIRTL AGEP NIC model and what is required to incubate and accelerate transformation in equity, diversity, and inclusion. In our NIC model, the main differences from a traditional NIC are explicit attention to shared leadership, inclusive practices, understanding and respect for different contexts, local partnerships, positionality, and capacity of different organizations in the NIC, and a renewed focus on using examples from across the NIC to learn how to support and strengthen the infrastructure and local capacity on each campus. NIC structures have much to offer those seeking to advance DEI efforts in the STEM higher education landscape, especially as a means of accelerating learning, support for improving change practices, and when the group forming and maintaining a NIC engage in their own work to create an inclusive organization.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Iowa State University IRB. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CN took the lead in writing this manuscript with significant contributions from BK, CM, CO, AD, KD, PS, JM, and MA. All co-authors edited and reviewed the manuscript. MA, JC, AD, CM, RM, CN, and AW did the work to change to an inclusive NIC. LC, KD, JF, BG, TH, GH, SH, TH-B, OK, BK, JM, CO, NR, PS, and AW led campus initiatives. AG, CN, and MA gave evaluation results. RM, RP, and SR gave social science input and results.

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Social and Professional Impact of Learning Communities Within the Alliances for Graduate Education and the Professoriate Program at Michigan State University

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At Michigan State University (MSU), the AGEP learning community features the participation of over 70% of the African-American, Latinx, and Native-American under-represented minorities (URM), also referred to as Black, Indigenous, and People of Color (BIPOC) doctoral students in fields sponsored by the National Science Foundation (NSF). Monthly learning community (LC) meetings allow AGEP participants to create dialogues across disciplines through informal oral presentations about current research. The learning communities also offer opportunities to share key information regarding graduate school success and experience; thus providing a social network that extends beyond the academic setting. At MSU, AGEP also provides an interdisciplinary and multigenerational environment that includes graduate students, faculty members, post-docs and prospective graduate students. Using monthly surveys over a 4-year period, we evaluated the impact of this AGEP initiative focusing on the utility of the program, perceptions of departmental climate, career plans and institutional support. Findings indicate that AGEP participants consider their experiences in the program as vital elements in the development of their professional identity, psychological safety, and career readiness. Experiences that were identified included networking across departments, focus on career placement, involvement in minority recruitment and professional development opportunities. Additionally, AGEP community participants resonated with the "sense of community" that is at the core of the MSU AGEP program legacy. In this article, we proposed a variation of Tomlinson's Graduate Student Capital model to describe the AGEP participants' perceptions and experiences in MSU AGEP. Within this 4-year period, we report over 70% graduation rate (completing with advanced degrees). More than half of Ph.D. students and almost 30% of master's degree students decided to pursue academia as their careers. In addition, we found a high satisfaction rate of AGEP among the participants. Our analysis on graduate student

capital helped us identify motivating capital development by years spent at MSU and as an AGEP member. These findings may provide some insight into which capitals may be deemed important for students relative to their experiences at MSU and in AGEP and how their priorities change as they transition toward graduation.

Keywords: professional identity, learning community, diversity, minority student, graduate education, career readiness, STEM workforce, graduate student capital

INTRODUCTION

The Alliances for Graduate Education and the Professoriate (AGEP) program at MSU was seeded with funding from the National Science Foundation (NSF). The overarching goal of AGEP is to produce a national professoriate that reflects the diversity of the domestic population. A key and unique feature of the MSU program is the diverse AGEP Learning Community. Graduate students, post-docs, prospective graduate students and faculty who participate in the MSU AGEP Learning Community seek to help contribute to transforming the culture of United States colleges and universities to embrace building world-class STEM and the social, behavioral and economic sciences (SBE) faculties who fully reflect the diversity in race, gender, culture, and intellectual talent of the United States population. The MSU AGEP program was a part of the former Michigan AGEP Alliance (MAA), a consortium of five public universities: Michigan State University, the University of Michigan, Western Michigan University, Wayne State University, and Michigan Technological University.

What makes the MSU AGEP program unique are opportunities for information sharing, career skill-building, and leadership opportunities for participants to actively contribute to the success of the program. Lynch et al. have shown that a multi-prog approach like the MSU AGEP program are useful retention strategies (Lynch and Kathy, 2011). In response to a lack of diversity of faculty in United States universities, the goal of the MSU AGEP program is to aid in the recruitment and retention of graduate students and postdoctoral associates (or "post-docs") from historically under-presented groups. Specific strategies used to summarize MSU AGEP program activities include: Community Building, Science Advocacy, Science Literacy, Outreach, and Leadership. The sense of community can be observed at the monthly MSU AGEP Learning Community (LC) meetings which fosters a multidisciplinary community of graduate students, post-docs, faculty members and undergraduate students.

In-person attendance ranges from 40 to 60 students per meeting. There were typically 11 LC meetings **per year** (2014–2018) between September and May. The meetings allow AGEP attendees to engage across disciplines while sharing "best practices" for succeeding in graduate school. Recurring activities with MSU AGEP LCs include the Student Chalk Talk presentations, faculty panels about academic careers, alumni panels about job searching, community acknowledgments, and networking discussion about student success strategies, career planning and science advocacy. Featured aspects of the community are cross-disciplinary discussions of a presenter's research, called CrossTalks. An important hallmark of the MSU AGEP LC meetings were the interdisciplinary discussions and inter-generational conversation among students of different stages, faculty and invited undergraduates. Graduate student and post-doc recruitment for MSU AGEP meetings involved campus welcome events, national conference recruitment and presentations during faculty staff meetings.

Over the years, the AGEP Learning Community has developed into a model scholarly community, stimulating academic interests, promoting professional development, and cross-generational interactions among the students and participant alumni. Activities related to science advocacy include interactions with policy makers, science literacy through the annual AGEP Science Today Bulletin, outreach through cross-generational mentoring with MSU SROP students and leadership through active student engagement on the AGEP Student Steering Committee and during the annual Fall AGEP conference hosted by Michigan State University AGEP program. Student AGEP participants not only receive information, but they also contribute their expertise and expressions of graduate capital to the AGEP Learning community. We seek to use a proposed variation of Tomlinson's model of graduate capital as a framework to describe our observations of open-ended responses to participant perceptions of their experiences of the MSU AGEP program. Our evaluation hopes to contribute to existing literature on peer-mentoring communities and professional identity formation within graduate education (Kim-Prieto et al., 2013; Russell et al., 2018).

The scope of this paper is to describe an exploratory study we conducted while analyzing survey data collected from 2014 to 2018 about how students perceive their engagement, learning outcomes, and application of knowledge based on their interaction with the MSU AGEP community. We also included our survey questions about their satisfaction within their home departments and future plans. We examined if there any differences in the responses among BIPOC and non-BIPOC attendees, as well as gender, STEM/social science degrees and years in AGEP and MSU. Over this 4-year period, we report a high graduation rate of AGEP community members. Our hope is that using the model of Graduate Student Capital and learning and environment measures will help to describe the reasons for these outcomes.

BACKGROUND AND RELEVANT LITERATURE

Under-Representation in Academia and Its Ramifications

The low proportional representation of BIPOC scholars in faculty positions in the United States, jeopardizes the nation's ability to innovate and address current global challenges (Hong and Page, 2004; U.S. Department of Commerce, National Economic Council, 2012; Freeman and Hrabowski, 2014). The contemporary composition of faculty demographics creates a barrier for the recruitment of BIPOC graduate students (Austin, 2002). Even when recruitment efforts have taken form, retention is still an issue among BIPOC graduate students and junior faculty due their elevated experiences of discrimination, marginalization and isolation, and impostor syndrome in comparison to their white counterparts (Gibbs and Griffin, 2013; Gibbs et al., 2014). In response, organizations such as the Alfred P. Sloan Foundation, NSF, and NIH have established programs to increase URM students' access to advanced degrees in STEM disciplines. Examples of scholarship and capacity-building programs developed by NSF and NIH include the NSF's Alliances for Graduate Education and the Professoriate (AGEP) and the Louis Stokes Alliance for Minority Participation (LSAMP), as well as NIH's MARC U STAR and Bridges to the Doctorate (R25).

Professional Identity Formation During Graduate School

Sutherland et al. (2010) explained that professional identity is one's identity related to their professional roles and status. Berkenkotter et al. (1988) described the life of graduate students as that of becoming initiated into a research community through scholarly reading and writing practices, through interactions with faculty and peers as well as exposure to research methodology.

Ducheny et al. (1997) suggested that graduate student professional identity development typically includes three primary elements: (a) the importance of continued training and familiarity with relevant research, (b) the influence of a supportive peer group or mentor, and (c) the organization of professional development into stages articulated by formative events and level of training. Geraniou (2010) describes the life cycle of graduate students into three distinct stages, Adjustment, Expertise and Articulation. Geraniou describes the Adjustment stage as the natural process of coming to terms with what a Ph.D. degree is like and adjusting to its nature. The Expertise stage is articulated as applying background knowledge to solve the research problem. The third stage, Articulation Stage, involves the writing down the results in the form of a thesis/dissertation.

Gazzola et al. (2011) investigated what experiences and conditions counseling psychology doctoral students perceive as contributing to their professional identities. Their reported results showed that the following hindered students' professional identity development: experiencing negative views of the profession, disappointment with institutional training, and internal conflicts (i.e., concerns about completing their graduate program). Gazzola et al. also reported, in contrast, positive experiences with clients during clinical training and achievements in the program confirmed their views of their professional identity.

The Tomlinson model is based on internal resources an individual has within the five dimensions of self (Tomlinson, 2017). These include **Human** (Gary Becker, 1993), **Identity** (Giddens, 1991; Beck and Beck-Gernsheim, 2002) **Cultural** (Bathmaker et al., 2013) (Burke, 2015), **Social** (Bourdieu, 1986), and **Psycho-social** (Brown et al., 2012). His model suggests that these forms of internal capital are acquired through graduates' formal and informal experiences. We used a modified version of the Tomlinson model as a framework for analysis of our open-ended responses.

This paper attempts to modify the Tomlinson model somewhat and relabel Human capital as **Technical capital**, the development of specific discipline skills. In the context of our program, Technical capital is most often expressed in the technical chalk presentations. We also relabeled, Tomlinson original "Identity capital" as **Career Identity capital** but in agreement with Tomlinson original definition as the development of personal employment narrative.

Furthermore, we define **Cultural capital** as cultural confidence and desire to seek professional camaraderie with students/professionals of color. Tomlinson, originally conceived this as the formation of culturally valued knowledge, dispositions and behaviors that are aligned to the workplaces that graduates seek to enter.

Tomilson defines **Social capital** as relationships and networks that help mobilize graduates' existing human capital and bring them closer to the labor market. Tomilson defines Psychological capital as the psychosocial resources which enable graduates to adapt and respond proactively to inevitable career challenges.

Our interest in adapting individual elements of this model can be further substantiated by other researchers for each of our proposed dimensions of Technical (building technical skills) (Ann et al., 2009; Choe and Borrego, 2020), Social (peer-mentoring and networking) (Tull et al., 2012; Bottoms et al., 2013; Montgomery, 2017; Williams, 2018), Psychological (psychological safety) (Lyman et al., 2020; Soares and Lopes, 2020), Cultural (cultural resilience) (Espino et al., 2010; Julia et al., 2020), Career Identity (socialization within the profession) (Kim et al., 2018; Bentley et al., 2019), see **Figure 1**.

The Value of Peer Mentoring and Learning Communities in Graduate Education

Improving the mentoring relationship between faculty and their proteges has been proposed by many scholars to increase the academic success, self-confidence and motivation of graduate students (Komarraju et al., 2010). However, a growing number of scholars are also investigating the role fellow graduate students have on the academic and professional training of their peers as well as their socialization within the profession (Vosloo et al., 2014). Watson et al. (2009) study, they found that 46% of graduate students described peer mentoring as equally, if

FIGURE 1 | Proposed variation of graduate student capital model.

not more, effective than professional mentoring from faculty. However, only 25% of all individuals surveyed in the Watson et al. (2009) report indicated that a formal or informal peer mentoring program was in place within their academic program. Though institutions at the department level offer formal and informal programs for the development of future faculty, many are purely focused on the development of specific skills like teaching or the development of teaching philosophy and portfolios (Viall et al., 2008). Many students have shown that for BIPOC students, learning communities that address both the professional skill building as well as their unique experiences associated with their personal identity, can lead to higher retention rates (Tull et al., 2012; Drane et al., 2019).

MATERIALS AND METHODS

Michigan State University Alliances for Graduate Education and the Professoriate Learning Community Demographics

The demographic information was obtained from AGEP community graduate students through their student records: gender, ethnicity, incoming year, graduation year (if applicable), and department affiliation. Demographic information from the AGEP community attendees (N = 299) was taken from members who attended at least one AGEP community meeting from January 2014 to May 2018.

Students who enrolled in graduate programs within the College of Natural Science, Engineering, Human Medicine and Veterinary Medicine were classified as **"STEM."** Students who enrolled in graduate programs in the Chicano/Latino Studies or African and African-American Studies Program, College of Social Science and some selected programs in the College of Communication Arts and Sciences were designated as **"SBE"**. Other students, mostly those enrolled in the Colleges of Education and Music, were classified as **"Other."** Collectively, the categories of SBE and Other will be combined as non-STEM for statistical analysis.

Completion results were based on the number of AGEP participants who graduated with a degree (Masters or Doctoral) by 2020. Students who graduated by December 2020 were categorized as **"Alumni,"** those who were still enrolled as **"Current." Current participants** were divided into two groups based on their degree program, **Masters** or **Doctoral**. Participants who had not been enrolled since Fall 2020 and had not graduated, were designated as **"No-Degree."** Students who left the university because they were denied graduation or dropped out are also included in this category. Students that self-identify as Black, Indigenous, and People of Color, they will be collectively referred to as BIPOC. White, non-Hispanic students will be referred to as White or Non-BIPOC.

Program Evaluation and Survey

Program evaluations were distributed through monthly paper surveys. Participants were instructed to fill out the surveys once per semester. Even though responses were anonymous, participants were asked to enter the last 4-digits of the student ID number to monitor duplicates. For statistical analysis only one entry per student was used (first observation, N = 155). We did not use data from multiple observations from the person but plan those for future studies.

With our survey instrument, we investigated how students were interacting within the community (community interaction), which aspects of the program they found most important (important aspects), what strategies they learned (important strategies), how they perceived the larger MSU environment especially their home department (MSU Environment), as well as their future plans. Dependent variables we sought to determine any influence included race, gender, time in MSU AGEP, time at MSU, and major (STEM vs. non-STEM). We chose to look at the differences between years in AGEP at MSU versus years at MSU in general in order to examine if there differences in student responses based on their time on campus in comparison to their time within the MSU AGEP program itself.

Other questions that were asked but not analyzed in this report include their involvement in the AGEP community, stress coping strategies as well as current academic milestones (passed comprehensive exams, etc.).

Alliances for Graduate Education and the Professoriate Community Interaction

The following 4-item measure was developed to capture *Community Interaction*: (1) My participation has helped me attain my educational goals; (2) I encourage more students to participate in AGEP; (3) I feel more confident in my career because of AGEP; (4) I have an opportunity to learn from other

graduate students. All items were assessed using a 5-point Likert-type scale (from 1 = "Strongly disagree" to 5 = "Strongly agree").

Student Perceptions of Important Aspects of the Alliances for Graduate Education and the Professoriate Program

Responses to the open-ended question of "What is one of the most important aspects of the MSU AGEP Learning Community?" were coded based on the Graduate Student Capital model (**Figure 1**).

Below is a list of some of the qualitative responses from students based on the open-ended question of "What is one of the most important aspects of the MSU AGEP Learning Community?"

Technical

"Opportunity to present work and receive feedback."

"The opportunity to present my research to a diverse audience."

"Opportunity to hear interdisciplinary research, learn new concepts and see intellectual presentations."

Social

"Opportunity to engage with students from across the U [University] (Appreciate that community members are welcome to bring their kids)."

"Building community with other like-minded students."

"The friendship that I have formed, I use the community as support both academically and non-academically."

Psychological

"Network, knowing that we are all in the struggle. Not feel alone."

"Community, comfortability, access, belonging."

"Unity, involvement and support."

Cultural

"Being around scholars of color and across disciplines."

"I think it's the ability to discuss issues of diversity openly. There are a number of social issues we discuss in meetings and it's always okay for people to address issues of underrepresented populations."

"Interacting with a truly diverse community of scientists."

Career

"Exposure to work in other disciplines and not only at the doctoral level. Access to role models in higher ed and administration and faculty."

"Getting experiences socializing into academia."

"Learning about opportunities for professional development, research funding, and post-doc information."

Student Perceptions of Important Strategies of the Alliances for Graduate Education and the Professoriate Program

Responses to the open-ended question of "What is one of the most important strategies you have learned from AGEP meetings?" were coded based on the Graduate Student Capital model (**Figure 1**).

Below is a list of some of the qualitative responses from students based on the open-ended question of "What is one of the most important strategies you have learned from AGEP meetings?"

Technical

"How to talk about my research to a broad audience."

"How to present and collect research and facilitate meeting and group talks."

"Using visuals to represent concepts that may be unfamiliar to people outside of your disciplines."

Social

"Strategies for networking outside of my department and college."

"The importance and necessity of making connections w/fellow students. There connection provide interesting discussion topics and interdisciplinary perspectives to my work."

"I liked the opening prompts that got us started at our tables."

Psychological

"Have a community of support – seek out help if needed."

"Talking across disciplines for advice and support."

"Conflict resolution."

Cultural

"To truly be a part of something bigger than yourself."

"Initiating conversations with people in a diverse setting."

Career

"A multiple approach of building your CV."

"Seek resources within the graduate school."

"How to negotiate effectively for an academic position."

Michigan State University Environment Satisfaction

An eight item measure was developed to capture *MSU environment satisfaction*. Sample items for this measure include, "I am confident I will complete my degree," "I am satisfied with my research project," and "I am satisfied with the professional development I am receiving within my department." All items were assessed using a 5-point Likert-type scale (from 1 = "Strongly disagree" to 5 = "Strongly agree"). Alpha or internal reliability for this measure was 0.79. For all analyses, a factor score consisting of all eight items was used.

1. I am confident I will complete my degree.
2. I am satisfied with my choice to come to MSU.
3. I am satisfied with my faculty advisor choice.
4. I am satisfied with my faculty committee choice.
5. I am satisfied with my research project.
6. I feel my undergraduate experience prepared me well.
7. I am satisfied with the social climate within my department.
8. I am satisfied with the professional development I am receiving within my department.

Future Plans of Participants

The future plans of the participants were assessed by asking them to check all that apply from a range of options that are listed below. Majority of the current participants selected (1) becoming a faculty member or (2) working in industry as part of their future

plans. These two response options were used for subsequent analysis as outcome variables in examining their correlations with our main demographic variables.

1. Work in industry.
2. Work in a government lab or agency.
3. Go to professional school.
4. Become a faculty a member.
5. Start a business or become an entrepreneur.
6. Enter the military.
7. Teach at K-12 Schools.
8. Become a post-doc.
9. Other (specific here).
10. Undecided.

Statistical Analysis

Our analytical approach included examining the associations between our focal independent variables along with several key outcomes of interest. To determine group differences, we used Fisher's exact test for categorical variables, Kruskal–Wallis test for categorical and continuous variables, and Pearson's correlation for two continuous variables. *P*-values of <0.05 were considered statistically significant. We also conducted moderated linear regressions with ordinary least square (OLS) as the estimation method. All moderation analyses were performed using the SPSS software. For each outcome (e.g., MSU environment satisfaction), the main effects and the interaction term were entered simultaneously. Significant interactive effects were further probed by creating a graph that illustrates the nature of the interaction. Lastly, simple slopes analyses were conducted for significant interaction terms.

RESULTS

Michigan State University Alliances for Graduate Education and the Professoriate Placement Data

Of the **299** LC attendees, **241** are now listed as alumni who completed an advanced degree and **58** are still completing their degrees as of December 2020. Other community members included **4** completed their post-docs, 10 left with no-degree, and 1 deceased member. From the **241** alumni, **203** completed a doctoral degree and **38** completed a masters degree. From the doctoral alumni pool, **53.7%** are in academic positions, **20.2%** are in the private sector, **13.0**% are in other and **12.8%** have unknown placement. Within the masters pool, **28.9%** are in academic positions, **31.6%** are in the private sector, **23.7%** are in other, and **15.7%** have unknown placement. The category of "other" for career placement is defined for AGEP alumni working in government, non-profit, independent contractor, or K-12 education. From the **4** post-doc alumni, **2** are in academic positions. See **Table 1** for MSU AGEP participant demographics for January 2014-May 2018. See **Tables 2**, **3** for breakdown of MSU AGEP alumni by demographics and job placement respectively as of December 2020.

TABLE 1 | Demographics of MSU Alliances for Graduate Education and the Professoriate (AGEP) learning community attendees from 2014 to 2018.

	STEM	SBE	Other	BIPOC	White	Male	Female
Doctoral	81	116	55	231	21	81	171
Masters	18	15	10	40	3	17	26
Post-doc	4	0	0	4	0	0	4

TABLE 2 | Demographics of MSU Alliances for Graduate Education and the Professoriate (AGEP) learning community demographics of 2014–2018 alumni who completed degrees.

	STEM	SBE	Other	BIPOC	White	Male	Female
Doctoral	62	95	46	188	15	67	136
Masters	17	14	7	35	3	16	22

TABLE 3 | Job placement of MSU AGEP learning community alumni as of December 2020.

	Academia	Private-sector	Other-sector	Unknown
Doctoral stem	18	24	8	12
Masters stem	5	4	4	4
Doctoral non-stem	91	17	19	14
Masters non-stem	6	8	5	2

TABLE 4 | Community interaction results.

My participation has helped me attain my educational goals	86.6%
I encourage more students to participate in AGEP	98.1%
I feel more confident in my career because of AGEP	86.1%
I have an opportunity to learn from other graduate students	100.0%

Alliances for Graduate Education and the Professoriate Community Interaction

Table 4 shows the overall percentage of responders that said "Agree" or "Strongly Agree" for the Community Interaction measure. We find that over time students increase their agree/strongly agree ratings (not shown in tables). When analyzing these trends using years at MSU and years in AGEP as variables, we calculated correlations for MSU years (0.3220) and AGEP years (0.2753) with respective *p*-values at 0.0002 and 0.0015.

Student Perceptions of Important Aspects of the Program

Here, we examined how students at different stages of their graduate career and years of participation in MSU AGEP program (as measured in years at MSU and years in AGEP, respectively) expressed their varied learning outcomes from their AGEP community engagement. A summary table of each of the coded 155 responses are in **Table 5**. We statistically compared years in AGEP/MSU to their coded qualitative responses (see **Table 6**). We found no significant differences between groups.

TABLE 5 | Summary of coded responses to important aspects and strategies open-ended questions.

	Aspects	Strategies
Technical	44	56
Social	35	21
Career	17	28
Psychological	26	12
Cultural	23	2
No response	10	36

TABLE 6 | Response analysis from important aspects open-ended question.

	Aspects					
	Career	**Cultural**	**Psychological**	**Social**	**Technical**	***p*-value**
Years at MSU						
Median, IQR	2 (2−4)	4 (1−5)	1.5 (1−4)	1 (2−4)	2.5 (1−4)	0.340
Years in AGEP						
Median, IQR	1 (1−3)	2 (1−5)	1.5 (1−2.5)	1 (0.5−4)	2 (0−3)	0.331

TABLE 7 | Response analysis from important strategies open-ended question.

	Strategies					
	Career	**Cultural**	**Psychological**	**Social**	**Technical**	***p*-value**
Years at MSU						
Median, IQR	1.5 (1−3)	2.5 (2−3)	2 (1−3)	2 (1−4)	3 (2−5)	0.017
Years in AGEP						
Median, IQR	1 (0−3)	3 (1−5)	2 (1−2)	1 (0.5−3)	3 (1−4)	0.044

Student Perceptions of Important Strategies Learned

We also examined how students at different stages of their graduate career and years of participation in MSU AGEP program (as measured in years at MSU and years in AGEP, respectively) expressed their varied learning outcomes from their AGEP community engagement. A summary table of each of the coded 155 responses are in **Table 5**. We statistically compared years in AGEP/MSU to their coded qualitative responses (see **Table 7**). We found statistically significant associations between graduate career stages and learning outcomes from their AGEP community engagement.

Student Responses to Michigan State University Environment Satisfaction Questions

Presented in **Table 8** are the regression results for the outcome variable of MSU environment satisfaction. We found that gender interacted with BIPOC status to predict MSU environment satisfaction ($b = -0.83$, $p < 0.05$) (see **Table 8** and **Figure 2**). Simple slopes analysis indicated that the effect of gender on MSU environment satisfaction was significant for non-BIPOC AGEP members ($b = 0.86$, $p < 0.05$), as compared to BIPOC members ($b = 0.03$, *ns*). To further probe the MSU environment satisfaction measure, we did separate analyses on the item level to determine which items were contributing to the observed differences. **Table 8** shows that of the eight total items that make up the MSU environment satisfaction measure, only three items were significant and reproduced similar results as seen in the overall measure. These items were: "I am satisfied with my choice to come to MSU," "I am satisfied with the social climate within my department," and "I am satisfied with the professional development I am receiving within my department." **Figures 2–5** shows the pattern of the interaction effect, which are also consistent with an interaction effect found for the overall MSU environment measure.

Future Plans of Alliances for Graduate Education and the Professoriate Participants

Presented in **Table 9** are the inter-correlations among the focal variables in the study. Gender, STEM versus non-STEM, years in AGEP, and years at MSU were significant correlates of the two outcome variables of interest: Plans to become a faculty member and working in industry.

DISCUSSION

In this article, we proposed a variation of Tomlinson's Graduate Student Capital model to describe the AGEP participants' perceptions and experiences in the MSU AGEP program and presented the findings of our 2014–2018 survey of MSU AGEP participants. Within this 4-year period, we report over 70% graduation rate (completing with advanced degrees). More than half of Ph.D. students and almost 30% of master's degree students decided to pursue academia as their careers. In addition, we found a high satisfaction rate of AGEP among the participants. Our analysis on graduate student capital helped us identify motivating capital development by years spent at MSU and as an AGEP member. These findings may provide some insight into which capitals may be deemed important for students relative to their experiences at MSU and in AGEP and how their priorities change as they transition toward graduation. Our initial findings show that students report that the strategies learned within the MSU AGEP community vary at slightly different rates across their years in AGEP and MSU. Furthermore, we also see that environmental factors become salient when we consider both gender and race together instead of analyzing them separately.

Additionally, we did not include the entire dataset since there were multiple observations from the same participant. We plan to conduct longitudinal studies on the dataset in the future that will take into account the repeated measurements presented in the data.

TABLE 8 | Gender interacting with BIPOC to predict MSU environment satisfaction questions.

Predictor	MSU environment satisfaction (overall measure)		I am satisfied with my choice to come to MSU		I am satisfied with the social climate within my department		I am satisfied with the professional development I am receiving within my department	
	Beta[a]	SE[b]	β	SE	β	SE	β	SE
Intercept	4.02		4.18		3.56		3.33	
Gender[c]	0.86**	0.38	0.82*	0.44	1.44**	0.69	1.67***	0.68
BIPOC[d]	0.29	0.19	0.43**	0.22	0.26	0.38	0.39	0.39
Gender X BIPOC	−0.83**	0.39	−0.88*	0.46	−1.32*	0.75	−1.34*	0.75
F-Statistic	1.93		1.66		1.52		2.37	

N = 118; [a]Unstandardized beta coefficient; [b]Standard error; [c]Gender coded (0 = females, 1 = males); [d]BIPOC coded (0 = Non-BIPOC, 1 = BIPOC).
**p < 0.10, **p < 0.05, ***p < 0.01.*

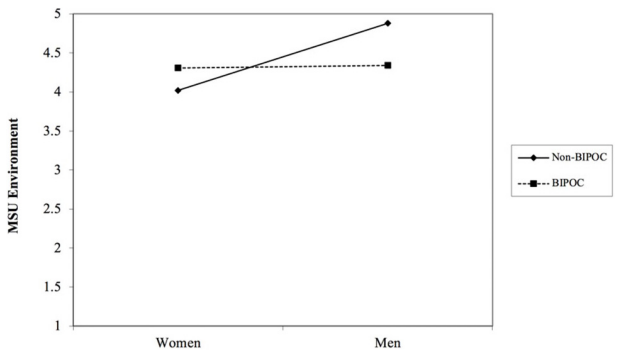

FIGURE 2 | Gender interacting with BIPOC to predict MSU environment (overall measure).

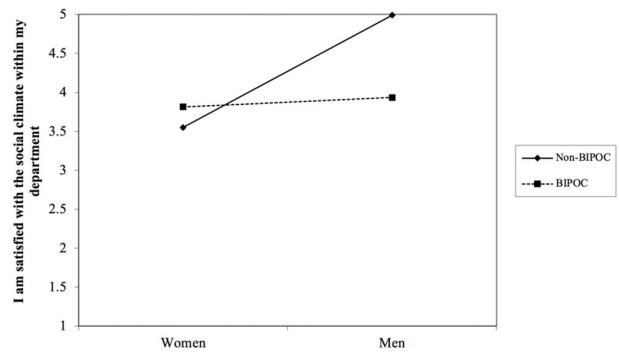

FIGURE 4 | Gender interacting with BIPOC to predict MSU environment item "I am satisfied with the social climate within my department."

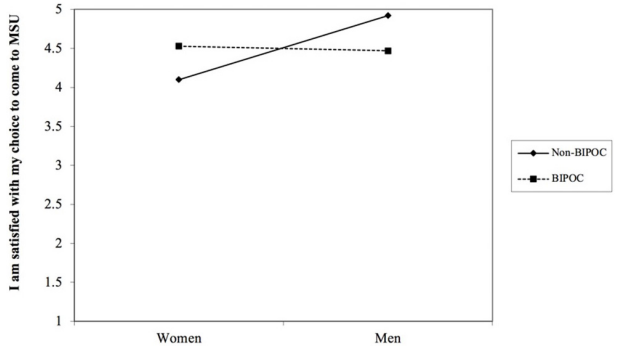

FIGURE 3 | Gender interacting with BIPOC to predict MSU environment item "I am satisfied with my choice to come to MSU."

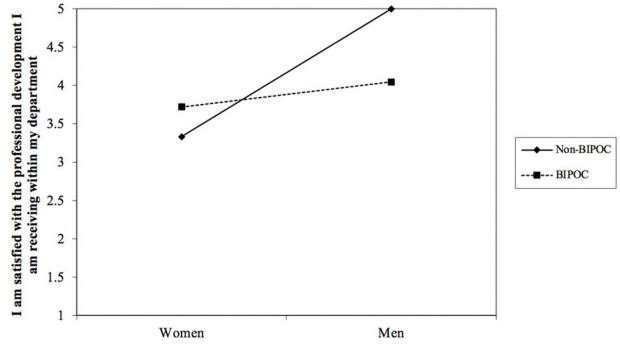

FIGURE 5 | Gender interacting with BIPOC to predict MSU environment item "I am satisfied with the professional development I am receiving within my department."

Michigan State University Alliances for Graduate Education and the Professoriate Placement Data

In this study, we examined the placement rate of our MSU AGEP alumni who attended Learning Community meetings from January 2014 to May 2018, we have shown a high retention rate of our attendees leaving MSU with an advanced degree. Over 50% of our doctoral members are working in academia and almost 30% masters student alumni are well. We also find that our STEM students are open to a wider variety of job sectors due to their high demand skill sets. This is in alignment with our survey results related to their future plans.

Alliances for Graduate Education and the Professoriate Community Interaction

When we asked about how the AGEP program helped with their goals, confidence and career, over 80% of respondents stated that

TABLE 9 | Correlations between demographics and future plans variables.

Variables	Future plans: Become faculty member	Future plans: Work in industry
Gender[a]	0.21**	0.05
BIPOC[b]	0.17	−0.03
STEM[c]	−0.31***	0.52***
Years in AGEP	0.18**	0.03
Years at MSU	0.20**	−0.15*

N = 134; [a]Gender coded (0 = females, 1 = males); [b]BIPOC coded (0 = Non-BIPOC, 1 = BIPOC); [c]STEM coded (0 = Non-STEM, 1 = STEM).
**p < 0.10, **p < 0.05, ***p < 0.01.*

they agree or strongly agree. Over the years, we received a higher percentage of "agree" or "strongly agree" responses.

Student Perceptions of Important Aspects of Program

All five aspects of the adapted Tomlinson model were present in how the attendees operationalized their experiences in AGEP and warrants further investigation into their perceptions of their employability (**Table 6**).

Student Perceptions of Important Strategies Learned

We see from **Table 7** that first year graduate students (years at MSU) and first year AGEP attendees (years at AGEP) are self-identifying different strategies they are learning in comparison to their third year counterparts. For example, first-years are gravitating toward building their career identity capital (identifying resources and socializing within their desired career sector), while third-year students are focusing on their technical skill building capital (presentation skills). Students within their second year begin to value the strategies related to psychological safety, peer-mentoring and cultural resilience.

Student Responses to Michigan State University Environment Satisfaction Questions

Our findings about gender and race are consistent with other researchers (Ellis, 2001; Cortland and Kinias, 2019). Cortland and Kinias (2019) observed that women in the workforce feel less work satisfaction when they feel less role models, sponsors, or peer support are available. Ellis investigated the experiences of black and white doctoral students at a predominantly white research institution to determine whether there were differences in student socialization, satisfaction with doctoral study, and commitment to degree completion based on race or gender. Overall, Ellis reported that women of color were negatively affected the most. Our findings about departmental level professional development dissatisfaction are also consistent with other scholars (Williams, 2002). Williams examined the perceptions of the amount and types of social support reported by BIPOC and White doctoral students during graduate school. White doctoral students reported greater program satisfaction, more positive perceptions of the academic environment, and fewer program problems than Black doctoral students. Black doctoral students reported more negative perceptions of the social environment than the other group in the Williams study.

Closing Thoughts

Our program evaluation hopes to contribute to existing literature on peer-mentoring communities and professional identity formation within graduate education (Trede, 2012). Insight into professional identity formation can be helpful in improving the education of advanced degree earners (Cruess et al., 2015). Our application of a graduate student capital model can be used as a framework to describe student experiences/needs using affirming vocabulary versus deficit models when examining and implementing minority student-centered programming and workforce development.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Michigan State University. Written informed consent for participation was not required for this study in accordance with the National Legislation and the Institutional Requirements.

AUTHOR CONTRIBUTIONS

ST supervised the project and wrote the manuscript with support from AA, KA, DA, and NW. ST, AA, and KA verified the analytical methods. DA and NW cleaned and prepared the data for analysis. All authors contributed to the article and approved the submitted version.

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The Changing Landscape of Doctoral Education in Science, Technology, Engineering, and Mathematics: PhD Students, Faculty Advisors, and Preferences for Varied Career Options

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The landscape of graduate science education is changing as efforts to diversify the professoriate have increased because academic faculty jobs at universities have grown scarce and more competitive. With this context as a backdrop, the present research examines the perceptions and career goals of advisors and advisees through surveys of PhD students (Study 1, $N = 195$) and faculty mentors (Study 2, $N = 272$) in science, technology, engineering, and math disciplines. Study 1 examined actual preferences and career goals of PhD students among three options: research careers, teaching careers, and non-academic careers in industry, and compared the actual preferences of students with what they perceived as being the normative preferences of faculty. Overall, students had mixed preferences but perceived that their advisors had a strong normative preference for research careers for them. Moreover, students who ranked research positions as most desirable felt the most belonging in their academic departments. Further analyses revealed no differences in career preferences as a function of underrepresented minority (URM) student status or first-generation (FG) status, but URM and FG students felt less belonging in their academic departments. Study 2 examined faculty preferences for different careers for their advisees, both in general and for current students in particular. While faculty advisors preferred students to go into research in general, when focusing on specific students, they saw their preferences as being closely aligned with the career preference of each PhD student. Faculty advisors did not perceive any difference in belonging between their students as a function of their URM status. Discrepancies between student and faculty perceptions may occur, in part, because faculty and students do not engage in sufficient discussions about the wider range of career options beyond academic research. Supporting this possibility, PhD students and faculty advisors reported feeling more comfortable discussing research careers with each other than

either non-academic industry positions or teaching positions. Discussion centers on the implications of these findings for interpersonal and institutional efforts to foster diversity in the professoriate and to create open communication about career development.

Keywords: graduate education, professoriate, diversity, norms, STEM education and careers

INTRODUCTION

> "I would feel relatively uncomfortable, mostly because my advisor pushes all of their graduate students to apply for academic research positions because prestige is a value that is highly important to them. If I were to approach my advisor about this (industry or teaching position), and I have before, the response is not dismissive, but they are not completely supportive. I know that they would be disappointed because I would not carry on their academic lineage after they put so much work into my research program."
>
> -STEM PhD Student, on why one might not feel comfortable discussing industry or teaching positions with an advisor.

> "My job is to help my students get to the right place for them. I like it when they go into research positions because it means I'll continue to see them regularly at conferences—I like my students and having them move into career paths where I likely will not see them again is a personal loss for me—but that is grounded in the deepest and narrowest of my selfish desire to remain connected. But my job is to try to help them get the skills and tools they need to pursue their directions. So if they will need more than research-related skills, I try to help them get those tools."
>
> -STEM Faculty Advisor on how one helps students prepare for non-academic positions.

The landscape of graduate science education is changing in multiple ways, raising new challenges for students, faculty, and educational institutions. The professoriate has increased ethnic and racial diversity, although not at the same rate as students (Davis and Fry, 2019; National Center for Education Statistics, 2020). Recognizing the importance of a diverse professoriate for training the next generation of scientists, there are increasing efforts to foster greater diversity. The National Science Foundation has a specific program, the Alliances for Graduate Education and the Professoriate, whose goal is to "to increase the number of historically underrepresented minority faculty in STEM (Science, Technology, Engineering, and Mathematics) fields (National Science Foundation, 2021)."

A second change to the landscape of graduate science education relates to the eventual professional pathways that those who earn their doctoral degrees pursue. The expectation has historically been that after obtaining a PhD degree, a student will pursue a tenure-track research-focused academic position. This is no longer the case. In 2017, there were as many PhD holders working in the private sector (42%) as there were in educational institutions (43%; National Center for Engineering and Statistics, 2017; Langin, 2019). And a 2019 international survey of PhD students by the journal *Nature* found that 56% ranked academic positions as the sector of work they would most like to pursue, whereas 28% ranked industry highest.

Within this changing context, graduate students entering PhD programs must figure out how to succeed and, at some point, what the next step will be in their professional journey. To guide their decisions, students are likely to look to the norms and expectations of powerful people in their new environment (Austin, 2002). In PhD programs, the *perceived descriptive norms*, that is, what people believe others do, are inferred by watching the actions of senior graduate students and faculty. People are motivated to conform to the perceived norms of successful and powerful individuals (Cialdini and Trost, 1998). For entering PhD students, those successful and powerful people are their department's faculty, with particular importance attached to their own graduate advisor. People's behavior is also impacted by *injunctive* norms, or what they believe important others approve of or believe should be done (Cialdini et al., 1991). Because these norms are not stated explicitly, PhD students and advisors may misperceive each other's goals and desires.

What underlies this program of research is the possibility that PhD students and their advisors may not have accurate information about the beliefs and goals of each other – and that directly ascertaining that information could be beneficial for communication between them. In this way, the paper is consistent with the central assumptions of social norms interventions expressed by Miller and Prentice (2016, p. 340): "…accurate information about what peers or relevant others think, feel, or do is not always known or salient to people… providing people with this information has the potential to alter their understanding of group norms, their standing in the group, and the evaluative significance of the behavior in question. This altered understanding may, in turn, lead them to act differently."

Potentially, inaccuracies in perceptions could influence PhD students and advisors alike, affecting their behavior toward each other. The first goal of this research is to identify the actual preferences STEM PhD students have about pursuing different career outcomes – and what they perceive to be the preferences of STEM faculty advisors (Study 1). We focus on three primary career options that students in PhD programs consider: teaching-oriented academic positions, research-oriented academic positions, and non-academic positions (including industry and government). We examine whether there are discrepancies between PhD students' preferences and their perceptions of their advisors' preferences for them. We further

investigate whether these preferences are related to important outcomes such as perceived support and belonging and how this may be moderated by factors such as underrepresented minority (URM) status or being the first in the family to attend college.

The second goal is to examine the actual normative beliefs that STEM professors have about their students' career paths. In Study 2, faculty advisors indicate their career preferences for specific students that they are currently advising and their preferences for students they train in general. We also examine the comfort of faculty advisors in discussing different career options.

Together these studies seek to elucidate the dynamic between PhD students and their advisors by examining the perceptions that each has about career development and mentorship. By examining both PhD students and advisors, the research can foster constructive dialogue by revealing information about how students and advisors perceive each other's goals for graduate student career development.

The Pathway to the Professoriate: Choices and Context

The journey from an undergraduate major in STEM to the professoriate involves making difficult choices and investing energy in uncertain paths. PhD students may be guided in these choices by their academic advisors, who have achieved professorial positions. They may also be guided by cues they observe in their academic environment, cues that could affect their sense of belonging in academia (Walton and Cohen, 2007; Purdie-Vaughns et al., 2008) and their perceived social support in their department. Cues that signal belonging foster greater connection to an academic setting and shape an individual's self-concept (Cohen and Garcia, 2008; Walton et al., 2012), and interventions that secure belonging in potentially threatening academic environments can lead to long term positive outcomes (see Walton and Brady, 2020 for review). For URM students[1] and those who are the first of their family to attend college (hereafter first-generation students or FG), there may be additional uncertainty surrounding their graduate school experiences that may further impact their feelings of belonging in academia (Walton and Cohen, 2007; Byars-Winston, 2014; Mosley and Hargrove, 2014; Council of Graduate Schools, 2015).

The extent of URM and FG representation in the professoriate can impact a student's desire to pursue and ability to complete a graduate degree, by framing their ability to imagine themselves succeeding in those roles (see Smith et al., 2002 for discussion). Approximately 12% of all full-time faculty in degree-granting postsecondary institutions are underrepresented minorities, while the remaining professoriate consists of 75% White and 11% Asian/Pacific Islander individuals (statistics as of 2018; National Center for Engineering and Statistics, 2020). Statistics on faculty members who identify as first-generation (FG) college students are less readily available. One national survey that contained data about faculty member's parental education was conducted in 1999, revealing that FGs represented approximately 25% of all faculty members in R-1 (i.e., PhD granting universities with very high research activity) and R-2 universities (i.e., PhD granting universities with high research activity; National Center for Education Statistics, 2002).

Research using different methodologies from various disciplines conducted with students throughout the academic pipeline suggests that greater diversity in the professoriate may relate to differential educational and professional choices. Qualitative research with undergraduate students who are Latinx and FG revealed that those who had faculty mentors who could better relate to their cultural identities and provide guidance and insight about applying for graduate school expressed greater interest in pursuing doctoral study themselves (Martinez, 2018; see also Brazziel and Brazziel, 2001). Without a role model to provide adequate guidance in research and academia, many undergraduate URM and FG students may overlook their potential as scientists and the possibility of pursuing a graduate degree. At the graduate level, a good relationship between PhD students and their advisors is an important factor for thriving (see Brunsma et al., 2017 for review). PhD students who had positive perceptions of their relationships with their advisors met more frequently with their advisors (Heath, 2002), had a greater sense of belonging in their academic department (Lovitts, 2001), and were less likely to leave their doctoral studies before completion (Golde, 2005). Such positive relationships are particularly beneficial and crucial for students from underrepresented backgrounds, yet these groups of students may be at a disadvantage due to many faculty advisors' lack of experience in mentoring them (Davis, 2008). Minority PhD students who perceived greater social support and sense of belonging viewed themselves as competent and successful (Ostrove et al., 2011), completed graduate school at higher and quicker rates (Lovitts, 2001; Curtin et al., 2013), and were more likely to pursue a research career after graduating (Spalter-Roth et al., 2013).

However, when faculty advisors are less aware of the challenges that URM and FG students face (e.g., lack of understanding of graduate education systems or lack of familial experience in higher education), they may fail to provide adequate instrumental and social support to address their students' needs (Davidson and Foster-Johnson, 2001). Indeed, a recent study has identified the persistence of this issue. This study of 1,375 graduate students in the 100 chemistry departments in the United States that receive the greatest share of federal research funding found that women, and URM women in particular, reported fewer positive interactions with their faculty advisors. Moreover, URM students, and URM men in particular, reported receiving less than desired amounts of interpersonal support (Stockard et al., 2021).

Furthermore, some URM students express an inability to "fit the mold" of what is expected of them from their departments (Gardner, 2010a). Similar sentiments were shared among FG students who expressed that they do not "know the rules" of

[1]We use the term URM students to refer to students whose racial/ethnic group are underrepresented in STEM disciplines. NSF has identified that Blacks, Hispanics, and Native Americans/Native Alaskans are under-represented in science and engineering professions National Science Foundation (2017) and we use the term in this specific sense.

the system and that they are "living in two worlds," needing to switch between identities as a family member and as a graduate student (Gardner and Holley, 2011). URM students and FG students are statistically more likely to come from lower socioeconomic backgrounds, which place greater emphasis on community and strong social ties, and thus, they may be less accustomed to the independent norms in academia (Stephens et al., 2012). Family members who are less familiar with academic norms may not provide the same knowledge and support, leading some students to be more attuned to the norms of faculty advisors. In addition to the challenges imposed by coursework and research, these sociocultural factors can exacerbate URM and FG students' perceived lack of belonging and social support. For these reasons, interactions with advisors can powerfully influence decisions about what type of career to pursue after completing their doctorate.

Norms and Conversations About Career Choices

Departmental norms and the specific relationships that PhD students have with their advisors have implications for PhD students' career trajectories. In an academic research institution (i.e., at an R-1 university) for doctoral students, the injunctive norms (i.e., the perception of what most people approve or disapprove of) and the descriptive norms (i.e., the perception of what most people do) both support pursuit of an academic research career at an R-1 university (Golde, 2004, 2005). While PhD students often rely on their advisors for career advice, this may become challenging for students who are less interested in pursuing an academic career. A survey of doctoral students across life sciences, physics, and chemistry, revealed that students who are toward the end of their program (preparing for employment) rated a non-academic career as more attractive and a faculty career as less attractive compared to ratings of less advanced students (i.e., students who have not completed their qualifying exams; Sauermann and Roach, 2012). However, when asked about the type of careers encouraged by their advisors, students generally perceived a strong expectation that they pursue academic research positions. Moreover, little research has examined different types of academic positions, such as the research-oriented vs. teaching-oriented faculty positions. If students believe that they will no longer receive support for pursuing other career paths beyond academic research positions, they may opt to leave their graduate program before completion (Golde, 2005). Given the centrality of a faculty advisor in shaping their students' future careers, conversations about career preferences are important.

While faculty advisors are the central resources for PhD students who wish to pursue academic careers, students with non-academic career goals often obtain their information from other sources. Interviews with 104 PhD students across 60 US chemistry departments revealed that PhD students lack awareness of specific career paths besides the two broad options of academia and industry and lack understanding of the skill sets and responsibilities required by non-academic positions (Thiry et al., 2015). With fewer resources outside of their programs (e.g., familial guidance, professional role models), URM and FGs, in particular, reported less awareness of other career options. When asked about the sources of their career information, students reported that they primarily learned from peers who were already in their job-search process. Only about 29% of the students mentioned that they learned about non-academic careers from their current advisor. Students who did not seek information from their advisors perceived their advisors to be unhelpful toward, and even openly unsupportive of, their decision to pursue a non-academic career (Thiry et al., 2015).

Similar patterns have been found in other studies examining faculty and program support for PhD students with non-academic career goals. Although PhD students expressed interests in career options besides tenure-track faculty positions, those with non-academic career goals perceived lower levels of support from their advisors and programs and were less likely to seek advice from their advisor or other faculty members (Golde, 2004; O'Meara et al., 2014; St. Clair et al., 2017). Faculty members may find it more difficult to provide advice on other career paths due to their own focus on academic research and lack of knowledge about other careers. The lack of role models for other career paths, along with the perceived lack of support from their academic advisors, contributes to students' experience of low self-efficacy in their career advancement and a lack of perceived belonging in their program (O'Meara et al., 2014; Thiry et al., 2015; Jaeger et al., 2017).

Faculty advisors are aware of their role as a resource for graduate students for career advice, but some may overlook the possibility or not feel prepared to assist with their students' career preferences if they are not in academia (Gardner, 2010b). Traditionally, the role of a faculty advisor has been to train the next generation of independent researchers for academic positions (Gardner, 2010b), and many students do enroll in doctoral programs with an aspiration to be a professor (Golde and Dore, 2001; Fuhrmann et al., 2011). However, as students progress in their doctoral programs, their interest in pursuing an academic career path often shifts (Fuhrmann et al., 2011; Sauermann and Roach, 2012). Without adequate communication, a mismatch between faculty advisors and PhD students can arise. For instance, with the assumption that their students are still interested in an academic research career, faculty advisors may not change their approach to career-related guidance, even if they have the resources and experience to advise them about non-academic positions. In turn, students may perceive their advisors as unhelpful in their non-academic career development and may be less likely to seek advice from them when faculty members may, as the opening quote illustrates, be quite willing to seek resources to assist them.

Although it is important to have conversations about career development, the prevalence or content of such conversations between PhD students and their advisors is unclear, despite the call in the sciences for PhD students and faculty advisors to create individual development plans (IDP; Austin and Alberts, 2012). Prior research suggests that these conversations do not typically occur until the

student is already in the job-hunting process, if they happen at all (Golde, 2005; Fuhrmann et al., 2011; Haley et al., 2014). Bounded by the norms supporting the pursuit of a tenure-track academic position, students who wish to pursue a non-academic career may not be comfortable revealing their career preference to their advisors while they still need their support to complete the degree program. Such discomfort may be greater for URM and FG students, who may already question whether they fit in with expectations at their academic departments (Gardner, 2010a).

Overview of Studies

The present research investigates potential gaps in career preferences and expectations between graduate students and advisors in STEM fields and the implications of possible discrepancies in normative perceptions. To foster better communication between PhD students and faculty advisors requires identifying what each group actually believes about different career options. Therefore, we conducted two studies to examine the perceptions that PhD STEM students and STEM faculty advisors have of different career paths and the desired options students have for themselves (Study 1) and advisors have for students they advise (Study 2). This research examines academic vs. non-academic options (as previous research has done) and looks at different types of career paths (research vs. teaching) within academia.

More specifically, in Study 1, a survey of STEM PhD students at two R-1 universities, we examine the following questions:

1. Do PhD students prefer a career in research-focused positions, teaching-focused positions, or non-academic positions?
2. Out of those three career options, what do PhD students believe their faculty advisors prefer, both in general (i.e., their normative perceptions) and for them in particular?
3. How does PhD student career preference relate to their sense of belonging and perceived social support?
4. How comfortable are PhD students in discussing these different career options?
5. Are the patterns of career preferences identified similar or different for students as a function of their status as first (vs. continuing) generation students or as underrepresented minorities vs. non-underrepresented minorities? We include these analyses to examine whether interest in different careers, and perceptions of belonging and support, would be different for those from these groups that are traditionally less represented in PhD programs.

In Study 2, a survey of STEM faculty advisors in the same two R-1 universities, we examine the parallel questions about how they think about advising students in general, and specific students they are currently advising in particular. (The two studies are independent, and thus the advisors from Study 2 were not matched, or able to be matched, with the particular students from Study 1). To facilitate better dialogue between PhD students and advisors requires understanding the perceptions that each side has of the other, as well as their meta-perceptions (i.e., what do PhD students think that their advisors are thinking about them.) Together, the goal of these studies is to paint a portrait of how the experience and preferences of PhD students and faculty advisors are shaped by their perceptions of the career norms and their expectations of each other's preferences. By examining perceptions of *both* sides and their responses to analogous questions about each other, there is a greater opportunity for identifying inaccurate perceptions of norms where they exist.

Data, code, materials, and supplemental analyses for both studies are available at https://osf.io/4uyxh/. Data analyses were not conducted until data collection was complete.

STUDY 1

Method

Participants

One hundred ninety-five PhD students from the University of California Santa Barbara (UCSB, $N = 123$) and the University of California Merced (UCM, $N = 72$) completed an online survey after being recruited *via* email. Students were recruited from all STEM disciplines as defined by the National Science Foundation (NSF). We also used the NSF categorization of Blacks, Hispanics, and Native Americans/Native Alaskans as being from under-represented groups in science and engineering professions (National Science Foundation, 2017). 35.9% of participants in the sample were students from under-represented racial/ethnic groups. 33.3% of participants were FG college students (FG). 57.4% had advanced to candidacy, 41.5% had not, and 1.0% did not report their candidacy status. All participants were compensated with a $10 electronic gift card. **Table 1** lists complete demographics, including the discipline of study (see **Supplementary Material** for additional information about PhD student sample and population characteristics).

Procedure

A sample of 500 graduate students from UCSB ($N = 350$) and UCM ($N = 150$) in STEM disciplines was recruited to complete the survey online using their university email addresses.[2] Participants were contacted by the graduate divisions of their respective universities. Students from the NSF-defined URM groups were over-sampled based on demographic information obtained by the graduate division in order to ensure sufficient representation for analyses. The 195 students who responded and completed the study corresponds to a 39% completion rate (UCM = 47%, UCSB = 35%). Ethics approval was granted by the Human Subjects Committee at the University of California, Santa Barbara. Informed consent was given digitally at the beginning of the survey before proceeding to the following measures.

[2]Sample size was determined based on analysis of graduate student demographics to enable adequate representation students from engineering, natural science, physical sciences, and social sciences as well as URM. We targeted $N = 250$ and had 195 complete all measures. Multiple recruitment notices were sent out by graduate division at each university.

TABLE 1 | Students' demographic characteristics.

Characteristics		*N* (%)
Age *M*(*SD*)	27.81 (3.51)	
School		
UC – Santa Barbara		123 (63.1)
UC – Merced		72 (36.9)
Gender		
Male		90 (46.2)
Female		102 (52.3)
Other/Missing		3 (1.5)
Race		
Asian/Asian-American		24 (12.3)
Black/African-American		17 (8.7)
Hispanic/Latino-American		46 (23.6)
Native American		4 (2.1)
Native Pacific Islander		3 (1.5)
Other/Missing		14 (7.2)
White/Caucasian American		87 (44.6)
URM status		
URM		70 (35.9)
Non-URM		123 (63.1)
Other/Missing		2 (1.0)
Year in PhD program		
First-year		3 (1.5)
Second-year		57 (29.2)
Third-year		44 (22.6)
Fourth-year		34 (17.4)
Fifth-year		38 (19.5)
Sixth-year		16 (8.2)
Seventh-year or more		3 (1.5)
Advancement status		
Pre-advancement		112 (57.4)
PhD candidates		81 (41.5)
Other/Missing		2 (1.0)
National status		
International student		45 (23.1)
Domestic student		149 (76.4)
Other/Missing		1 (0.5)
College generation status		
First-generation college student		65 (33.3)
Continuing-generation college student		129 (66.2)
Other/Missing		1 (0.5)
Field of study		
Engineering		39 (20.0)
Life and environmental sciences		45 (23.1)
Other/Missing		11 (5.6)
Physical sciences		33 (16.9)
Social sciences		67 (34.4)

Measures

Desirability of Career Options

Participants were first asked to assess the desirability of three different career options after the completion of their PhD. These options were divided into broad categories and always presented using the same terminology: "non-academic position (e.g., industry, government, non-profit organization)," "teaching-focused academic position (professor at college *without* a PhD program)," and "research-focused academic position (professor at university *with* a PhD program)."

Participants indicated the desirability of these three options in two ways – one that resulted in a categorical variable and one that resulted in a continuous variable. First, they ranked the three options based on *their personal preferences* such that 1 indicated the option most desirable to them, 2 indicated an option moderately desirable to them, and 3 indicated the option least desirable to them. This forced choice was intended to categorize their priorities. Second, they rated the desirability of each of the three options on a scale from 0 (not at all desirable) to 10 (extremely desirable).

Participants then completed the same ranking and desirability questions for the same three career options but this time from *their advisor's perspective*, as they understood it. Participants reported what they believe their advisor would prefer for them personally (i.e., the PhD student) to pursue professionally after completing their degree. Participants also answered the same set of questions about their perception of their advisors' *general* preference for careers chosen by the various PhD students they train.

To assess department norms, the participants also completed the same ranking and desirability questions about the perceived preferences of *other faculty members* in their department *in general,* as well as their perception of how *other graduate students* in their department were thinking about their specific careers. Thus, in total, participants indicated their ranking and scaled desirability of the same three career options from their perspective, their perception of their advisors' preference *for them*, their perception of their advisors' preference *in general*, their perception of other faculty members' preferences *in general*, and their perception of other graduate students' preferences for *their own* specific careers.

Comfort With Discussion

Participants reported how comfortable they felt discussing each of the three career options with their advisor and other faculty members in the department. Participants responded on a scale from 0 (very uncomfortable) to 10 (very comfortable). They were also provided with space to elaborate on their reasons for feeling comfortable or uncomfortable with these conversations.

Perceived Social Support

Participants completed an adapted version of a perceived social support scale (Zimet et al., 1988) which was designed to assess their experience of feeling valued, cared about, and respected by important others. Modifications to the 8-item scale were made to focus on the experience of feeling socially supported by their PhD advisors specifically; responses ranged from 1 (strongly disagree) to 7 (strongly agree; $M = 5.52$, $SD = 1.23$, $\alpha = 0.93$). Sample items include, "My graduate advisor is available when I need to meet," and "I can count on my graduate advisor when things are not going well."

TABLE 2 | Frequency table for PhD student's self and perceived others' career preferences.

	Non-academic	Teaching	Research	Total
	N (%)*	*N* (%)	*N* (%)	*N*
Normative perceptions				
Perception of advisors' general career preference	22 (13.0)	10 (5.9)	137 (81.1)	169
Perception of other faculty members' general career preference	16 (9.3)	3 (1.7)	153 (89)	172
Perception of other PhD students' career preference	81 (45.5)	20 (11.2)	77 (43.3)	178
Personal perceptions				
PhD students' self-reported career preferences	89 (45.6)	40 (20.5)	66 (33.8)	195
PhD students' perception of advisors' career preference for them	23 (13.9)	12 (7.2)	131 (78.9)	166

**Note that % excludes missing cases.*

Belonging

Participants completed an adapted version of the Belonging Scale (Walton and Cohen, 2007), which was designed to assess the extent to which people feel as though they are liked and accepted within a particular context (Walton and Cohen, 2007). Participants reported their feelings of belonging within their academic department on 11 items; responses ranged from 1 (strongly disagree) to 7 (strongly agree; $M = 4.73$, $SD = 1.20$, $\alpha = 0.92$). Sample items include, "I fit in well in my academic department," and "I am similar to the kind of people who succeed in my academic department" and "When something bad happens, I feel that maybe I don't belong in my academic department (reverse scored)."

Additional Measures

Several additional measures were included that focused on views of faculty advisors and different professional development opportunities (included in **Supplementary Material** in Open Science Framework).

Results

PhD Students' Normative Perceptions of Career Preferences in Their Academic Departments

To determine how PhD students perceived the norms in their academic departments, we assessed their perception of their advisors' general career preferences, their perception of other faculty members' general career preferences, and their perception of other PhD students' career preferences. We assessed these perceptions in two ways, categorical rankings and numerical ratings, and the results were generally consistent for the two types of measures. We examined the three occupational categories the PhD students ranked highest on the 1–3 ranking scale to determine their categorical preferences. **Table 2**, first row, indicates that PhD students' perceptions of advisors' general preferences strongly supported research careers, with 81.1% ranking that option highest, 13.0% ranking non-academic careers highest, and 5.9% ranking teaching highest. Other faculty in the academic department were also viewed as primarily supporting research careers, as shown in **Table 2**, second row. Thus, the norms of the department faculty across STEM fields are seen as being strongly in favor of research as perceived by PhD students in their programs.

Participants saw their fellow PhD students (**Table 2**, third row), by contrast, as being much more balanced in their career preferences: 43.3% ranked research highest, 45.5% ranked non-academic highest, and 11.2% ranked teaching highest. In sum, PhD student participants saw a divide between faculty preferences for students in general and the preferences of their fellow students for their careers. They perceived the normative faculty preference as oriented almost solely toward research whereas the normative PhD student preference was more balanced between research, teaching, and industry positions.

Participants' continuous assessments of the perceived desirability of the different career options (on scales from 0 to 10) were consistent with their rankings. We conducted a 3 (Career Option: Non-Academic, Teaching, Research) × 3 (Target of Perception: Advisors, Other Faculty Members, Other PhD Students) Repeated Measures ANOVA. There was a main effect of career option, $F\ (2,\ 384) = 15.9$, $p < 0.001$, $\eta_p^2 = 0.08$, a main effect of target of perception, $F\ (2,\ 384) = 88.13$, $p < 0.001$, $\eta_p^2 = 0.32$ and an interaction between the two, $F\ (4,\ 768) = 115.77$, $p < 0.001$, $\eta_p^2 = 0.17$. The nature of the interaction (see **Figure 1**) was that for estimates of general faculty preferences (both other faculty in the department and students' own advisors), research careers were the most desirable with teaching and non-academic options roughly similar. By contrast, students perceived their fellow PhD students as seeing both non-academic and research careers being more desirable, and teaching less so. In short, across both categorical and continuous measures, there was a discrepancy between what students perceived as the normative career preferences among faculty in general and among their fellow PhD students.

PhD Students' Own Career Preferences, and What They Perceive Their Advisors' Preferences Are for Them

We next examined how PhD students view those same three career options for themselves specifically and how they see their advisors' preference for them as students in particular. We examined the three occupational categories the PhD students

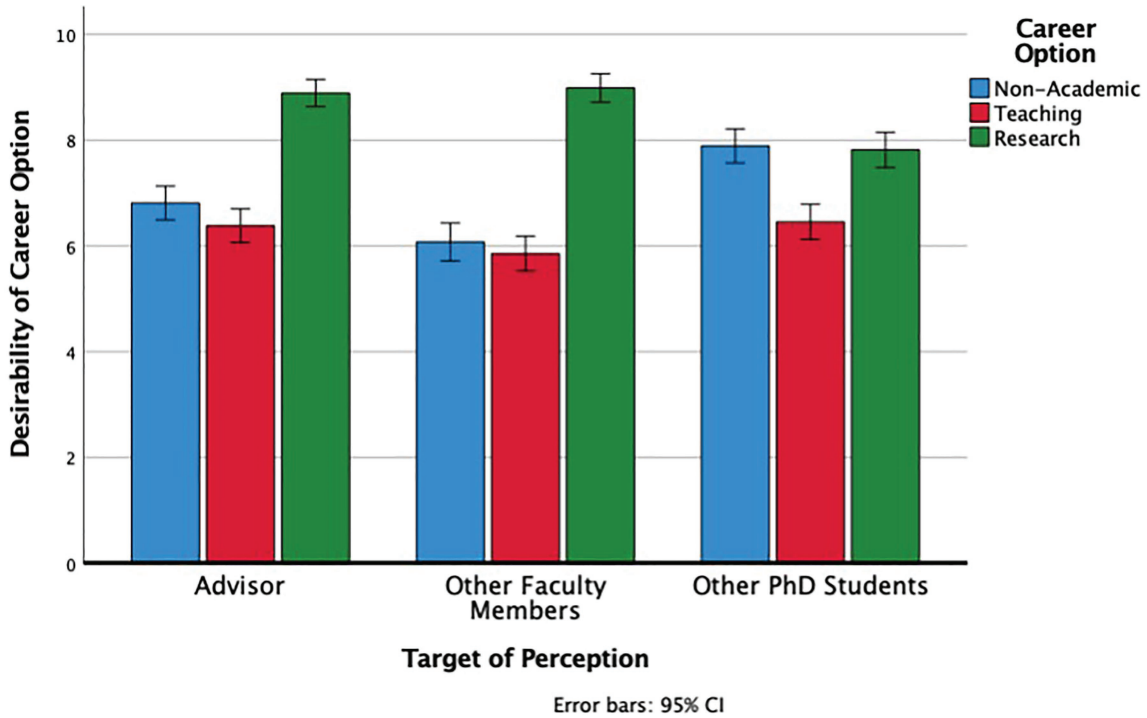

FIGURE 1 | PhD students' perceptions of advisors' general desirability ratings, faculty members' general desirability ratings, and other graduate students' desirability ratings for their own careers for each career option.

ranked highest on the 1–3 ranking scale to determine their categorical preferences. **Table 2**, fourth row, indicates that 45.6% of PhD students ranked non-academic careers highest, 20.5% ranked teaching careers highest, and 33.8% ranked research careers highest. This contrasted with what the students perceived as their advisors' preferences for them. **Table 2**, fifth row, indicates that the vast majority of students, 78.9%, perceived that their advisor would rank research careers highest, whereas 13.9% thought their advisor would rank non-academic careers highest, and 7.2% thought their advisor would rank teaching career highest. In short, the PhD students perceived that their advisors wanted them to go into research – that their advisors' preferred career choices for them, in particular, were similar to their advisors' general career preferences. This was discrepant from their own preferences, that were much more balanced across the options.

This discrepancy was represented in PhD students' continuous perceptions as well. We conducted a 3 (Career Option: Non-Academic, Teaching, Research) × 2 (Target of Perception: PhD Students' Own Preference, PhD Students' Perception of Advisors' Preference for Them) Repeated Measures ANOVA. There was a main effect of career option (Non-Academic: $M = 7.11$, $SD = 1.90$; Teaching: $M = 5.81$, $SD = 2.29$; Research: $M = 7.76$, $SD = 1.98$), $F\,(2, 388) = 41.31$, $p < 0.001$, $\eta_p^2 = 0.18$. There was also a main effect of target (PhD Students' Own Preference: $M = 6.76$, $SD = 1.27$; PhD Students' Perception of Advisors' Preference for Them: $M = 7.03$, $SD = 1.33$), $F\,(1, 194) = 6.73$, $p = 0.01$, $\eta_p^2 = 0.03$, and an interaction between the two, $F\,(2, 388) = 49.93$, $p < 0.001$, $\eta_p^2 = 0.21$. As **Figure 2** illustrates, PhD students saw their advisors as strongly preferring research careers for them over the other two options, whereas they preferred non-academic positions most and were much more balanced, overall, in their assessments of the three options. Thus, PhD students as a whole perceived a discrepancy between what they wanted for their post-PhD career and what their advisors wanted for them. We turn next to examining demographic and categorical differences in career preferences to identify similarities and differences across categories associated with greater (vs. lesser) representation in PhD programs.

Demographic and Categorical Differences in Preferences for Career Options

Next, we examined whether the categorical preferences varied as a function of the participants' URM and FG status. A series of χ^2 analyses in **Table 3** indicates that across URM-status and FG status, participants were balanced in their preferences for research and non-academic positions, with teaching positions being clearly less preferred whereas they perceived that their advisors preferred them to go into research. That is, the trends observed overall for PhD students were consistent across URM status and generation status.

A similar conclusion was obtained when we examined continuous assessments of the same variables – PhD students' career preferences – as a function of participants' URM and FG status. We conducted a 3 (Career Option: Non-Academic, Teaching, Research) × 2 (URM status: URM, non-URM)

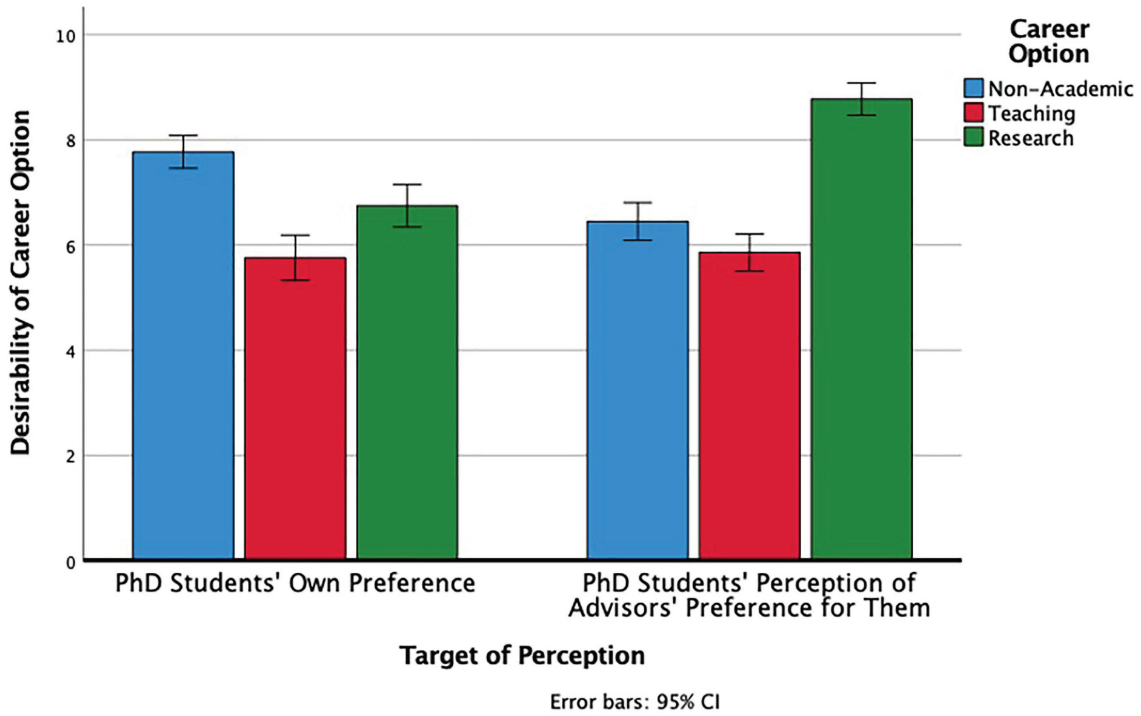

FIGURE 2 | PhD students' desirability ratings for each career option **(left)**, and their perception of their advisors' desirability ratings for each career option for them **(right)**.

TABLE 3 | PhD students' own and perception of advisors' preferences for them by demographic categories.

	Non-academic	Teaching	Research	Total	χ^2
	N (%)	*N* (%)	*N* (%)	*N*	
PhD students' preferences					
URM	32 (45.7)	14 (20 .0)	24 (34.3)	70	χ^2 (2, N = 193) = 0.003, p = 0.99
Non-URM	56 (45.5)	25 (20.3)	42 (34.1)	123	
PhD students' perception of advisors' preferences for them					
URM	6 (10.5)	6 (10.5)	45 (78.9)	57	χ^2 (2, N = 166) = 2, p = 0.37
Non-URM	17 (15.6)	6 (5.5)	86 (78.9)	109	
PhD students' preferences					
FG	26 (40 .0)	17 (26.2)	22 (33.8)	65	χ^2 (2, N = 194) = 2.52, p = 0.29
CG	63 (48.8)	22 (17.1)	44 (34.1)	129	
PhD students' perception of advisors' preferences for them					
FG	7 (12.7)	7 (12.7)	41 (74.5)	55	χ^2 (2, N = 166) = 3.71, p = 0.16
CG	16 (14.4)	5 (4.5)	90 (81.1)	111	

mixed-model ANOVA. There was a main effect of career option (as noted above). There was no main effect of URM status (URM: M = 6.81, SD = 2.11; non-URM: M = 6.77, SD = 1.59), F (1, 191) = 0.06, p = 0.80, η_p^2 < 0.001. Critically, there was no interaction between the two factors, F (2, 382) = 0.29, p = 0.75, η_p^2 = 0.01. The PhD students rated research and non-academic positions as more desirable than teaching positions, and this was consistent across URM status. A similar mixed-model ANOVA with participants' generation status as the between-subject variable revealed a consistent pattern. Again, there was a main effect of career option. There was no main effect of first generation (FG) status (FG: M = 6.74, SD = 2.21; Continuing Generation (CG): M = 6.78, SD = 1.56), F (1, 192) = 0.04, p = 0.84, η_p^2 < 0.001. And critically, there was also no interaction between the two factors, F (2, 384) = 0.49, p = 0.62, η_p^2 = 0.003. FGs and CGs rated research and non-academic positions as more desirable than teaching positions. In all, our results revealed no demographic differences in career interest.

Moreover, neither URM status nor generation status moderated these assessments when examined continuously. We conducted a 3 (career option: non-academic, teaching, research) × 2 (URM status: URM, non-URM) mixed model ANOVA with perceived advisor's desirability for them to pursue each career option as a dependent variable. There was a significant main effect of career option (as noted above), and no main effect of URM status (URM: $M = 6.88$, $SD = 2.18$; non-URM: $M = 7.14$, $SD = 1.65$), F (1, 191) = 1.74, $p = 0.19$, $\eta_p^2 = 0.01$. There was no significant interaction, F (2, 382) = 1.42, $p = 0.24$, $\eta_p^2 = 0.01$ as both URMs and non-URMs perceived that their advisor had a strong desirability for them to pursue research positions compared to non-academic and teaching positions. For generation status, there was a main effect of FG status (FG: $M = 6.75$, $SD = 2.28$; CG: $M = 7.17$, $SD = 1.62$), F (1, 192) = 4.24, $p = 0.04$, $\eta_p^2 = 0.02$, but no interaction between career option and generation status, F (2, 384) = 0.91, $p = 0.40$, $\eta_p^2 = 0.01$. Taken together, there was consensus among all PhD students that their advisors perceived research careers to be most desirable, relative to the other options.

Relationship Between Career Preferences of PhD Students and Belonging and Perceived Social Support

We next investigated the relationship of different career preferences to students' feelings of belonging and perceived social support to answer the question as to whether students who ranked the normative choice (among faculty) as their highest choice feel the most belonging and supported. Students were classified based on their top-ranked career preference. We first conducted a Multivariate ANOVA (MANOVA) with belonging and social support as the outcomes and top-ranked career preferences (Non-Academic, Teaching, Research) as the independent variable. The main effect of career preference was significant on belonging, F (2, 192) = 6.48, $p = 0.002$, $\eta_p^2 = 0.06$ (see **Figure 3**). Students who ranked research positions highest felt the most belonging ($M = 5.11$, $SD = 1.20$), followed by those who ranked non-academic positions highest ($M = 4.63$, $SD = 1.16$). Students who ranked teaching positions highest reported the least belonging ($M = 4.31$, $SD = 1.14$).

There was also a marginally significant effect of career preference on perceived social support, F (2, 192) = 2.75, $p = 0.067$, $\eta_p^2 = 0.03$ (see **Figure 4**). Students who ranked research positions highest perceived the greatest social support from their advisors ($M = 5.80$, $SD = 1.13$), followed by students who ranked teaching positions highest ($M = 5.46$, $SD = 1.12$). Students who ranked non-academic positions highest perceived the least amount of social support ($M = 5.35$, $SD = 1.32$). In short, PhD students whose career preferences were consistent with what was normative among faculty felt the most belonging in the department and felt most socially supported by their advisors.

Demographic Differences in the Impact of Career Preferences on Belonging and Support

Next, we conducted a series of analyses to examine whether this greater feeling of belonging among those who preferred research was similar or different as a function of URM and college generation status. The results, in short, indicated consistency in findings across both variables and important

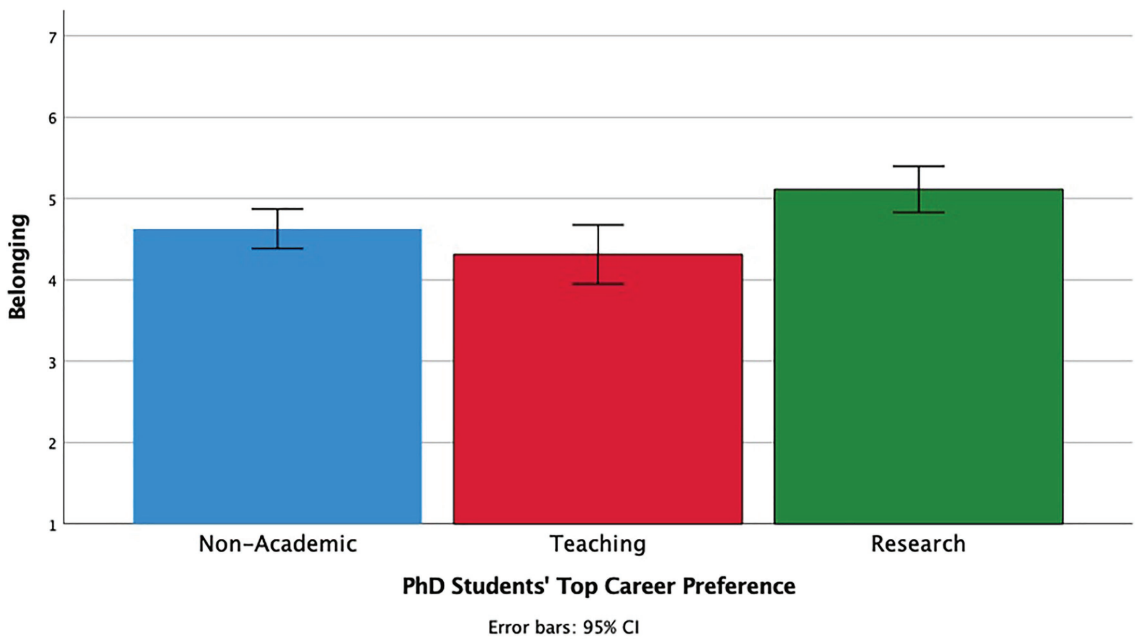

FIGURE 3 | The relationship between PhD students' own career preference and their sense of belonging in the academic department.

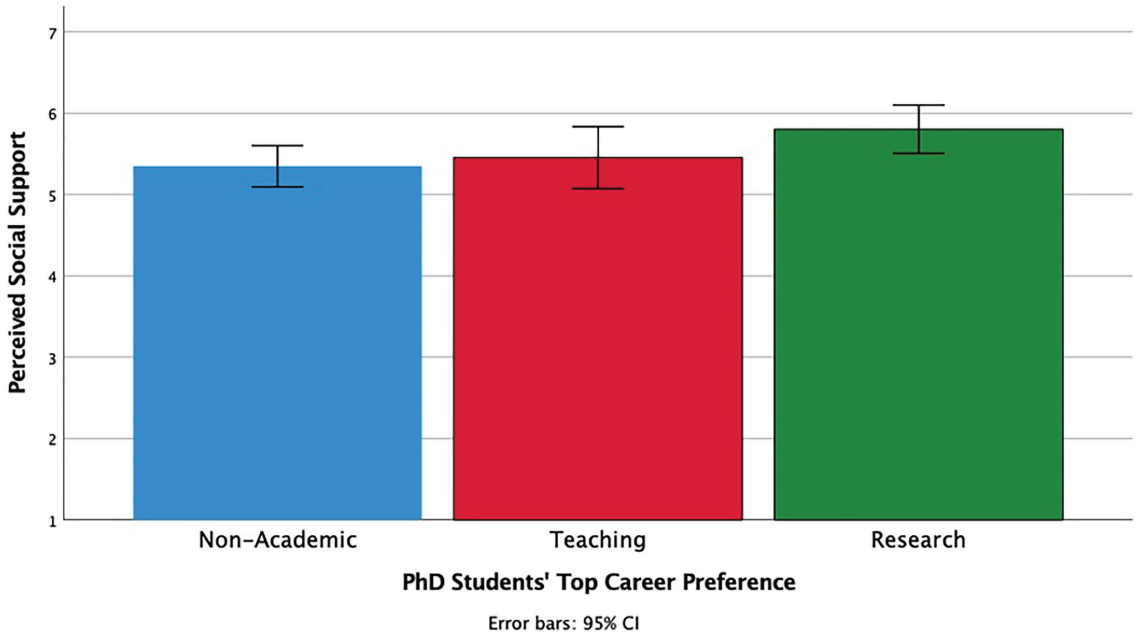

FIGURE 4 | The relationship between PhD students' own career preference and perceived social support within the department.

main effects as a function of the demographic variables. First, we conducted a 3 (Career Preference: Non-Academic, Teaching, Research) × 2 (URM status: URM, non-URM) between-subjects ANOVA with belonging as the dependent variable. There was a main effect of career preference (as noted above) and a main effect of URM status (URM: $M = 4.25$, $SD = 2.01$; non-URM: $M = 4.94$, $SD = 1.51$), F (1, 187) = 14.85, $p < 0.001$, $\eta_p^2 = 0.07$. However, there was no interaction between the two factors, F (2, 187) = 1.18, $p = 0.31$, $\eta_p^2 = 0.01$. Similarly, while there was a significant main effect of generation status (FG: $M = 4.29$, $SD = 2.00$; CG: $M = 4.90$, $SD = 1.54$), F (1, 188) = 11.65, $p = 0.001$, $\eta_p^2 = 0.06$, there was no significant interaction between the two factors F (2, 188) = 0.23, $p = 0.80$, $\eta_p^2 = 0.01$. FGs felt less belonging than CGs, and URM students felt less belonging in their academic departments than non-URM students. However, these factors did not moderate the relationship between career choice and belonging in the department.

We ran a similar analysis examining the impact of URM status, college generation status, and career preference on how graduate students felt socially supported by their advisors. There was no main effect of URM status, F (1, 187) = 1.63, $p = 0.20$, $\eta_p^2 = 0.01$ and no interaction between URM status and career choice, F (1, 187) = 0.72, $p = 0.49$, $\eta_p^2 = 0.01$. URM students felt equally supported by their advisors as non-URM students, regardless of their career preferences. Similarly, there was no main effect of college generation status, F (1, 188) = 1.50, $p = 0.22$, $\eta_p^2 = 0.008$ and no interaction with career choice, F (2, 188) = 0.08, $p = 0.93$, $\eta_p^2 = 0.001$. FGs felt equally supported by their advisors as CGs, and URMs felt equally supported as non-URMs, regardless of their career preferences.

Comfort in Discussing Different Career Options

We investigated students' comfort in discussing different career options with their advisors. Would students feel more comfortable discussing what they perceived to be the more preferred option among their faculty advisors? We first conducted a repeated-measures ANOVA, with comfort discussing the three career options (Non-Academic, Teaching, and Research) as the within-subject variable. PhD students were much more comfortable discussing research careers, the career option that they perceived as normative among the faculty. The repeated measures ANOVA revealed a significant difference, F (2, 388) = 44.87, $p < 0.001$, $\eta_p^2 = 0.19$. Students felt more comfortable discussing research positions with their advisors ($M = 8.82$, $SD = 1.99$) than non-academic positions ($M = 7.32$, $SD = 2.95$), $p < 0.001$ or teaching-focused positions ($M = 7.23$, $SD = 2.72$), $p < 0.001$, with no difference between teaching and non-academic, $p = 0.57$.

Next, we tested whether the URM status or generation status of graduate students affects their comfort level in discussing different career options with their advisors. We conducted a 3 (Career Option: Non-Academic, Teaching, Research) × 2 (URM Status: URM, non-URM) Mixed Model ANOVA predicting students' comfort in discussing each career option. There was a main effect of different career options (as noted above), and a main effect of URM status (URM: $M = 7.38$, $SD = 3.46$; non-URM: $M = 8.03$, $SD = 2.61$), F (1, 191) = 4.39, $p = 0.04$, $\eta_p^2 = 0.02$. Overall, non-URM students were more comfortable discussing different career options with their advisors compared to URM students. There was no interaction between the two factors, F (2, 382) = 2.14, $p = 0.12$, $\eta_p^2 = 0.01$. Conducting analogous analysis with generation status revealed no main effect of generation status, F (1, 192) = 1.90, $p = 0.17$, $\eta_p^2 = 0.01$, and no

interaction between the two factors, F (2, 384) = 1.47, p = 0.23, η_p^2 = 0.01. Overall, all PhD students were more comfortable discussing careers related to research with their advisors, compared to teaching and non-academic positions.

Discussion

In Study 1, we first examined whether there was a discrepancy in normative career preferences of PhD students and what they perceived to be their faculty advisors' career preference for them. We were particularly interested in whether these patterns differ as a function of students' URM or generation status. Using both categorical and continuous measures, we found that PhD students, regardless of their demographic backgrounds, preferred non-academic positions and research positions roughly equally, followed by teaching positions, and that they perceive a similar distribution among their peers. However, students perceived their advisors and other faculty members in their department as strongly preferring research positions with no difference in preference between teaching and non-academic positions. In general, there were discrepancies between students' career preferences and the careers that they thought their advisors wanted them to pursue after graduation. We speculate that this resulted in several important consequences for the student-advisor relationship.

First, this discrepancy may have contributed to a lower sense of belonging in their department and perceived social support from their advisors. In general, students who preferred research positions felt the most belonging and social support. An important caveat to note is that these factors almost certainly vary as a function of the year in the program and academic discipline – for example, second- and sixth-year students and psychology and engineering students were all included in the sample and likely differ meaningfully. However, the sample size did not enable a detailed examination at that level. We chose, rather, to focus on two moderators related to diversity in the professoriate – URM status and generation status.

In considering students' demographic backgrounds, URM and FG students felt less belonging yet equally supported overall relative to non-URM and continuing generation students. The lack of interaction suggested that coming from different demographic backgrounds and having distinct career preferences did not exacerbate or bolster students' sense of belonging and perceived social support.

Second, students' comfort in having career discussions with their advisors differed depending on the career options. Students were most comfortable discussing research positions, the positions they perceived as most normatively preferred among faculty at their departments. We also found an effect of students' URM status. Overall, URMs were less comfortable having career discussions with their advisors than non-URMs; there were no differences between FGs and CGs.

Taken together, Study 1 provides a clearer picture of the discrepancies between what PhD students perceive as the norm in their departments and what they desire for their own careers. Students see their advisors as not being particularly attuned to their own interests. Although many students desire teaching or non-academic careers, they do not feel as comfortable discussing these careers with their advisors as they do for discussing research careers.

URM and FG students overall experienced less perceived belonging in their department, although this did not interact with their career choices. Regardless of whether they desired to pursue research, teaching, or industry, URM and FG students felt less belonging, and URM students felt less supported. This may be related to their hesitation to discuss these different career paths.

To put these results into a fuller context, it is important to examine the perspective of faculty advisors who are mentoring PhD students in STEM fields. We turn to that in Study 2.

STUDY 2

In Study 1, PhD students in STEM fields perceived that their advisors strongly favored academic research careers for them, whereas they were more evenly divided in what careers they desired most for themselves among non-academic and academic research careers, and to a lesser extent, academic teaching careers. To the extent that actions are driven by perceptions of norms, it is important to determine, broadly speaking, the accuracy of these norms.

We reasoned that faculty members might have competing motivations for the career preferences of their students. As indicated with the quote from a faculty member to begin the paper, they may prefer entering PhD students to pursue academic research careers in the abstract. However, they may also see themselves as being responsive to the preferences of their specific advisees. Thus, faculty members may have discrepancies between what they prefer in general and what they prefer for particular students. Moreover, because discussions about different career options may be relatively rare (Fuhrmann et al., 2011), this flexibility may not be communicated in full to the PhD students. If the perception of PhD students in Study 1 is based on the view that advisors have in the abstract, and advisors feel differently in the abstract than they do about particular students they advise (as examined in Study 2), there may be room for both parties to communicate their goals more clearly and effectively.

We seek to further understand these issues in Study 2, conducted with a sample of STEM faculty advisors. We raise the following questions:

1. Out of the three career options, research-focused positions, teaching-focused positions, or non-academic positions, what do faculty advisors actually prefer, both in general and for specific students they are advising?
2. Are faculty advisors' career preferences for students they advise more strongly related to their perceptions of the students' preferences or their own general preferences?
3. How comfortable are faculty advisors having discussions related to each of the three career options?

4. How do faculty members perceive levels of belonging among students they advise, and how do these perceptions vary by their perceptions of characteristics of the students (their career preferences and demographics)?

By addressing these questions, our goal is to shed further light on the relationship between graduate students and their advisors. We note again that while the faculty members in Study 2 were from the same universities and departments as the PhD students in Study 1, they were not matched as the advisors of the student participants in Study 1, as each group responded voluntarily (and anonymously) to participate in the respective studies.

Method

Participants

Three hundred one STEM faculty members from the University of California Santa Barbara (UCSB, $N = 177$) and the University of California Merced (UCM, $N = 97$) completed an online survey sent *via* email to all STEM faculty at the two universities (27 provided data and were included in analyses but did not include demographic characteristics including university). Our target sample was 300 to allow adequate coverage of the different disciplines, and we sent multiple contact emails in order to attain that. STEM disciplines were defined using the National Science Foundation standards. All participants were compensated with a $20 electronic gift card. Demographics of the sample are presented in **Table 4** (see **Supplementary Material** for additional information about faculty sample and population characteristics).

Procedure

A sample of 692 faculty members from UCSB ($N = 525$) and UCM ($N = 167$) in all STEM disciplines was recruited to complete the survey online using their university email addresses. All faculty members across all STEM disciplines at UCSB and UCM were recruited to complete the survey online using their university email addresses. The 301 faculty members who responded and completed the study corresponds to a 43.4% completion rate.[3] Informed consent was given digitally at the beginning of the survey. Faculty were asked how many graduate students they were currently advising before proceeding to the dependent measures and were asked to complete all of the following measures for their three most senior current students (or fewer if they were currently advising less than three students). Faculty were informed that this was a study supported by the Graduate Divisions of both schools and funded by the National Science Foundation.

Desirability of Career Options

Faculty members were asked to assess the desirability of the same three career options that PhD students were asked to consider in Study 1, using the same language: "non-academic position (e.g., industry, government, non-profit organization)," "teaching-focused academic position (professor at college *without* a PhD program)," and "research-focused academic position

TABLE 4 | Faculty demographic characteristics.

Characteristics		N(%)
Age M(SD)	49.1(11.6)	
Years in Professoriate	16.2(12.1)	
School / Field of Study		
UC - Santa Barbara		177(64.6)
Social Sciences		52(29.3)
Life Sciences		48(27.1)
Physical Sciences		17(9.6)
Engineering		28(15.8)
Math		18 (10.2)
Other/Unspecified		14(7.9)
UC - Merced		97(35.4)
Social Sciences		33(34.0)
Life Sciences		18(18.5)
Physical Sciences		17(17.5)
Engineering		21(21.6)
Other/Unspecified		8(8.2)
Missing		27
Gender		
Male		165(60.7)
Female		105(38.6)
Other		2(0.7)
Missing		29
Race		
Asian / Asian-American		31(11.7)
Black / African-American		3(1.1)
Hispanic / Latino-American		21(7.9)
Multi-Racial		10(3.2)
Native American		1(0.4)
Other		12(3.8)
White / Caucasian American		188(70.7)
Missing		35
Professor Status		
Assistant Professor		75(27.4)
Associate Professor		51(18.6)
Full Professor		144(52.6)
Other		4(1.5)
Missing		27
US Born		
U.S. Born		176(64.9)
Non-U.S. Born		95(35.1)
Missing		30
College Generation Status		
First-Generation College Student		61(22.6)
Continuing-Generation College Student		209(77.4)
Missing		31

Note that % excludes missing cases

[3]Sample size goal of $N = 300$ was determined by the goal of seeking disciplinary balance across engineering, natural science, physical sciences, social sciences across the two campuses with a minimum of $N = 50$ per discipline. Multiple recruitment emails were sent to faculty to try to achieve this sample. The percentage of faculty who participated was 301/692 overall (43.4%), 177/525 for UCSB (33.7%), and 97/167 for UCM (58.1%). More detailed descriptions on samples and fields of study are described in supplemental materials on the study link on Open Science Framework.

(professor at university *with* a PhD program)." They ranked the three options based on *their personal preferences* such that 1 indicated the option most desirable to them, 2 indicated an option moderately desirable to them, and 3 indicated the option least desirable to them. This forced choice was intended to categorize their priorities.

First, faculty advisors ranked their *general preferences* for PhD students they may train. In particular, they were told: "We are interested in your general preferences for career options for the PhD students that you train. Please answer the next set of questions thinking about an ideal PhD student you recruit in the future." Participants responded such that 1 indicated the option most desirable to them, 2 indicated an option moderately desirable to them, and 3 indicated the option least desirable to them. As in Study 1, this forced choice enabled a categorical assessment of their most highly preferred option. Second, they provided continuous assessments as they rated how desirable each of the three options was on a scale from 0 (not at all desirable) to 10 (extremely desirable). Thus, faculty advisors indicated the desirability of these three options in the same ways graduate students were asked about in Study 1.

Next, faculty advisors were asked to think of the three most senior students in their lab, labeling the most senior "Student A," the second most senior "Student B," and the third most senior "Student C." The participants were then instructed: "For each student, we will first ask about your own perspective on his/her ideal career path and then ask what you believe that student's preferences to be. Let us start with the most senior PhD student in your lab. We will call this person 'Student A.' If you have two equally senior students, choose either one as Student A. Please take a moment to bring an image of this student to mind and answer the next set of questions about him/her specifically." After thinking about Student A, participants were asked: "In terms of career options for Student A after obtaining a PhD, please drag and drop the following options to rank them according to your own perspective" and used the same scale such that 1 indicated the option most desirable to them, 2 indicated an option moderately desirable to them, and 3 indicated an option least desirable to them. Participants then rated each option on a scale from 0 (not at all desirable) to 10 (extremely desirable).

Faculty participants then reported *their perception* of what each students' preferred career path might be, as they understood it. Specifically, they ranked the same three options from Student A's perspective, as they understood it from 1 (most desirable), 2 (moderately desirable), and 3 (least desirable) when Student A is thinking about his/her career options after obtaining a PhD. Participants then rated each option on the scale from 0 (not at all desirable) to 10 (extremely desirable).

Faculty participants then completed a shortened, 3-item belonging measure for each student, adapted from the scale used in Study 1 (Walton and Cohen, 2007), to assess how well they believed that student fit into the department. They made ratings on seven-point scales anchored at 1 (strongly disagree) and 7 (strongly agree) for Student A: "This student is similar to the kind of people who succeed in the department." "This student gets along well with people in the department." And "This student fits in well in the department." The reliabilities were high for all students (α for belonging for Student A, B, C were 0.83, 0.84, 0.85, respectively). Finally, participants responded to the question: "Have you discussed career goals with Student A?" on a scale 1 (not at all) to 5 (a great deal). After completing these responses for Student A, participants evaluated Student B and Student C (their next most senior students, as applicable).

Faculty participants provided demographic details for each student they reported, including a year in the program, race, generation status, and gender identity.

In addition to the primary dependent measures, several additional measures (both quantitative and open-ended) were included to assess faculty members' general preferences and perceptions, independent of any particular student (see **Supplementary Material**).

Finally, faculty participants indicated their own demographic information. Participants were then debriefed and thanked for their assistance.

Results

Preferences for PhD Students' Careers

We first examined the career that each faculty advisor would choose for a hypothetical "ideal" student they may imagine themselves working with, what we will refer to as *Advisor's General Career Preference for PhD Students*. As can be seen in **Table 5**, top line, 84.0% of STEM faculty surveyed imagine their ideal student pursuing a research career, while 11.1% prefer a student who would pursue a non-academic career, and 4.9% prefer a student who would prefer a teaching-focused academic career.

We next turned to an examination of how faculty felt about their students in particular. We expected that when considering *specific* students currently in their labs, STEM faculty would report more balanced career preferences. This was supported by the responses of the faculty (see rows 2–4, **Table 5**). When asked to consider career preference for their three most senior students, the most commonly chosen option was research (ranging from 43.5 to 48.4%), then non-academic (ranging from 35.4 to 38.6%), followed by teaching (ranging from 15.5 to 20.2%).

These preferences of the faculty closely mirror the proportions that the faculty reported when asked what their perceptions were of their students' career goals (rows 5–7, **Table 5**), with the most commonly chosen option being research careers (ranging from 46.0 to 55.2%), then non-academic careers (ranging from 28.1 to 42.7%), followed by teaching careers (ranging from 11.3 to 17.1%). Together, these results suggest that while faculty may ideally prefer to train students who follow paths in academic research similar to their own, they adjust these preferences when considering the skills and interests of particular students.

The continuous ratings of the desirability of the three positions on the 0 to 10-point scale confirmed this basic pattern. We conducted a 3 (Source: General Advisor's Preference vs. Advisors' Preference for Student A vs. Perceived Student A Preference) × 3 (Option: Non-Academic vs. Teaching vs. Research) Repeated Measures ANOVA with both factors within-subjects, and it revealed a significant interaction, $F(4, 972) = 24.12$, $p < 0.001$, $\eta_p^2 = 0.09$. As **Figure 5** shows, for General Advisor's Preference, research ($M = 9.00$, $SD = 1.45$) was seen as more desirable than non-academic ($M = 7.31$, $SD = 1.93$), pairwise comparison, $p < 0.001$, which in turn was more desirable than teaching positions ($M = 6.66$, $SD = 2.18$), pairwise comparison, $p < 0.001$. By contrast, for Advisor's Preference for Student A, there was no difference between research ($M = 7.41$, $SD = 2.78$) and non-academic ($M = 7.58$, $SD = 2.20$), pairwise comparison $p = 0.504$, which were both higher than teaching ($M = 6.42$, $SD = 2.68$), both pairwise comparisons $p < 0.001$. Similarly, for Perceived Student A Preference, there was no difference between research ($M = 7.37$, $SD = 2.84$) and non-academic ($M = 7.41$, $SD = 2.47$), pairwise comparison $p = 0.882$, which were both higher than teaching ($M = 6.27$, $SD = 2.87$), both pairwise comparisons $p < 0.001$. Similar interactions and patterns of results occurred for faculty perceptions of Student B, $F(4, 740) = 19.61$, $p < 0.001$, and of Student C, $F(4, 468) = 12.16$, $p < 0.001$, which are presented in **Supplementary Material**. Although faculty had a clear preference for their students to pursue research careers in general, when considering a specific student, they were more balanced in their career preferences between non-academic and research positions.

Predicting Preferences for PhD Students

We next examined whether faculty career preferences for specific students would be driven more by their perception of the *student's* preference or by their own general preferences.

TABLE 5 | Frequency table for advisors' own and perception of their students' career preferences.

	Non-academic	Teaching	Research	Total
	N **(%)***	***N*** **(%)**	***N*** **(%)**	***N***
Advisors' general career preference for PhD students				
	27 (11.1)	12 (4.9)	205 (84)	244
Advisors' career preference for their specific students				
Student A	80 (38.6)	37 (17.9)	90 (43.5)	207
Student B	58 (36.0)	25 (15.5)	78 (48.4)	161
Student C	35 (35.4)	20 (20.2)	44 (44.4)	99
Advisors' perception of their students' career preference				
Student A	76 (36.2)	36 (17.1)	98 (46.7)	210
Student B	64 (42.7)	17 (11.3)	69 (46.0)	150
Student C	27 (28.1)	16 (16.7)	53 (55.2)	96

**Note that % excludes missing cases.*

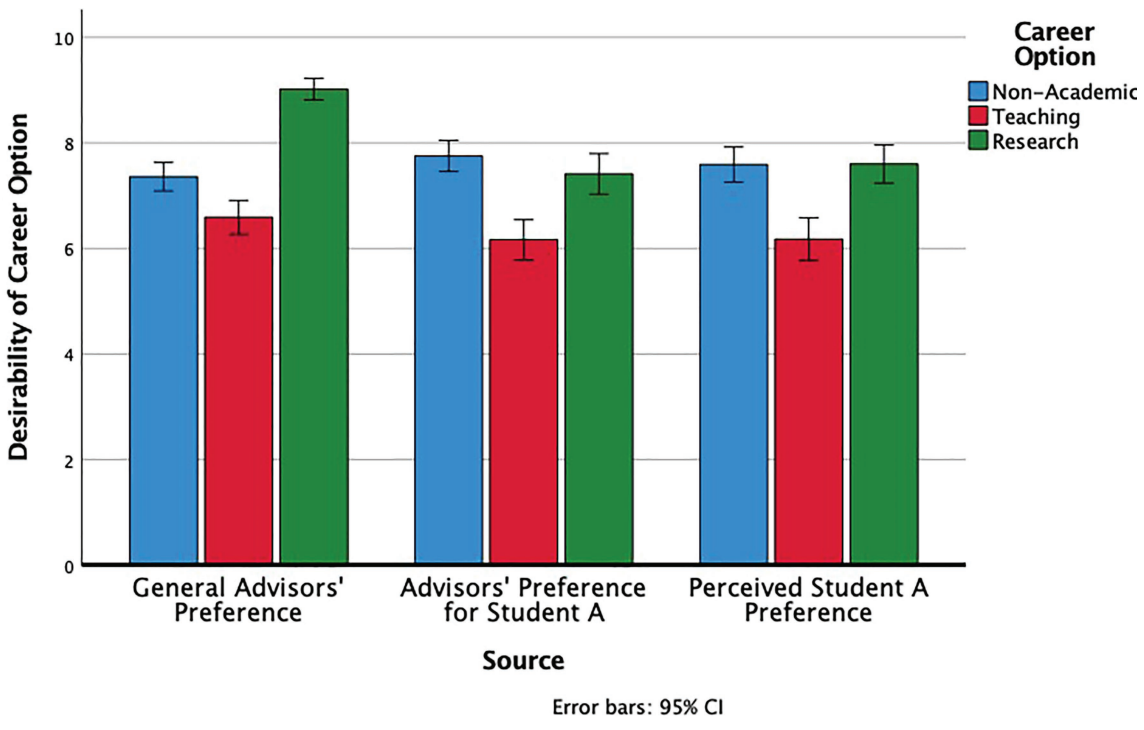

FIGURE 5 | Advisors' general desirability ratings for each career option **(left)**, desirability ratings for each career option for Student A (their most senior PhD student; **middle**), and their perception of Student A's desirability ratings for each career option **(right)**.

TABLE 6 | Advisor's own career preference for students in general and advisors' perception of student A's (most senior PhD student's) career preference.

			Advisor's preference for student A (Rank)			
			Non-academic	**Teaching**	**Research**	**Total**
Advisor's general career preference	Non-academic	Count	**10**	2	4	16
		%	**62.5**	12.5	25.0	100
	Teaching	Count	3	**1**	4	8
		%	37.5	**12.5**	50.0	100
	Research	Count	53	27	**68**	148
		%	35.8	18.2	**45.9**	100
	Total	Count	66	30	76	172
Advisor's perception of student A's career preference	Non-academic	Count	**53**	4	6	63
		%	**84.1**	6.3	9.5	100
	Teaching	Count	3	**22**	7	32
		%	9.4	**68.8**	21.9	100
	Research	Count	12	7	**59**	78
		%	15.4	9.0	**75.6**	100
	Total	Count	68	33	72	173

% refers to percentage within general advisor's preference (for top) and within advisor's perceived Student A preference (for bottom). Bold numbers indicate concordance between row and column

We present a detailed analysis for the faculty of their most senior PhD student (Student A). **Table 6** presents two χ^2 analyses. The top cross-tabulation indicates that there is no correspondence between the advisors' general preferences and the advisors' preferences for Student A, χ^2 (4, $N = 172$) = 4.57, $p = 0.33$. Examining the diagonal (bolded) indicates that within the category of advisors' general preferences, there is modest concordance. By contrast, the bottom cross-tabulation indicates strong concordance between the advisors' perceived Student A preference and the advisors' preference for Student A, χ^2 (4, $N = 173$) = 142.05, $p < 0.001$. Examining the diagonal (bolded) indicates that within the category of advisors' perceived preference of student A, there is very strong concordance. In short, while advisors preferred research in general, this does not appear to be what is most predictive of their preference for Student A, but rather, what they perceive as student A's preference. In **Supplementary Material**, we present the same χ^2 analysis for Student B and Student C. In each case, the analysis indicates much stronger concordance between the advisors' perceived student preference and the advisors' preference for the student.[4]

Next, we examined the continuous preference rating for Student A, and these analyses provide convergent evidence for the categorical results above. We conducted three regression analyses where the outcome variable was advisors' preferences for Student A to pursue each career option (non-academic top; teaching middle; research bottom), and the two predictors were their general preference and their perception of the students' preferences, all on the continuous scale (see **Table 7**). In each regression, the strength of the perceived student preference was much stronger (non-academic standardized $\beta = 0.67$ vs. 0.31; teaching standardized $\beta = 0.70$ vs. 0.29; research standardized $\beta = 0.70$ vs. 0.09). In sum, while general preferences of advisors play a role in what they prefer for their most senior student, their preferences were much more strongly driven by what they perceive the student as preferring for their career. Similar findings were obtained for Student B and Student C (see **Supplementary Material**).

Comfort in Discussing Different Career Options With PhD Students

We conducted a repeated measures ANOVA to examine how STEM faculty advisors felt about advising their students in regard to the different career options. In particular, we examined whether they had varying levels of comfort discussing the three different options. The repeated measures ANOVA revealed a significant difference, F (2, 548) = 64.98, $p < 0.001$, $\eta_p^2 = 0.19$, as, consistent with the perceptions of students, faculty advisors felt more comfortable discussing research careers ($M = 9.36$, $SD = 1.03$) than non-academic positions ($M = 8.17$, $SD = 1.97$), $p < 0.001$, or teaching focused positions ($M = 8.16$, $SD = 2.12$), $p < 0.001$, with no difference between teaching and non-academic, $p = 0.96$.

Faculty Advisors' Perceptions of Their Students' Belonging

Faculty advisors rated their perception of belonging levels within their academic departments for the same three most senior students, which provides the opportunity to see how faculty advisors assess their students as a function of how they perceived their career trajectories. We transposed the data so that each student ($N = 614$) is an individual case, however, multiple students were reported by individual advisors (122 faculty members rated three students, 69 faculty members rated two students, and 110 faculty members

[4]The pattern is very similar for Student C, whereas, for Student B, there is also significant concordance between general preference and preference for Student B, although the concordance is weaker than with the perceived preference of Student B and faculty preference for Student B.

rated one student). Faculty advisors reported what they thought each of those students would rank highest in terms of career preference for themselves; 167 students were perceived as ranking non-academic positions highest, 68 students were perceived as ranking teaching positions highest, and 220 students were perceived as ranking research positions highest, with 159 missing (possibly because faculty did not know and left that blank). We also asked faculty advisors to report each student's race/ethnicity, from which we coded the students as non-URM (Asian/Asian Americans, White/European Americans, $N = 418$) and URM (Black/African American; Hispanic/Latino American; Native American; Pacific Islander; Multi-Racial/URM, $N = 100$; Other, $N = 41$; Missing/Unspecified = 55) and perceived FG status (first in family to attend college, $N = 101$; not first in generation to attend college, $N = 282$; Not sure, $N = 177$; Missing/Unspecified, $N = 54$).

We conducted an ANOVA to examine faculty advisors' perceptions of their students belonging in the department, as a function of their perceived top career choice (Non-Academic, Teaching, Research) and their demographic status as URM (vs. non-URM). Overall, there was a main effect of career choice, F (2, 404) = 5.53, $p = 0.004$, $\eta_p^2 = 0.027$, as students perceived to prefer research were seen as belonging more in the academic department ($M = 6.04$, $SD = 0.94$) than those who prefer non-academic ($M = 5.70$, $SD = 0.99$), pairwise comparison $p = 0.002$, or those who prefer teaching ($M = 5.46$, $SD = 1.29$), pairwise comparison $p < 0.001$. There was no main effect of URM status, F (1, 404) = 0.49, $p = 0.49$, as faculty perceived URM students to feel just as much belonging ($M = 5.84$, $SD = 1.06$) as non-URM students ($M = 5.82$, $SD = 1.03$). This is noteworthy, considering that URM students felt less belonging than non-URM students, as reported in Study 1. There was also an interaction, F (2, 404) = 3.15, $p = 0.044$, depicted below in **Figure 6**. The interaction appears to be driven by perceptions of the non-URM students' belonging, as it was seen to be much higher for those interested in research ($M = 6.06$, $SD = 0.88$) than either teaching, ($M = 5.27$, $SD = 1.39$), $p < 0.001$, or non-academic careers ($M = 5.73$, $SD = 0.98$), $p = 0.006$. By contrast, there was no significant difference for URM students in their perceived belonging between teaching ($M = 5.91$, $SD = 0.91$) and research ($M = 5.98$, $SD = 1.11$), $p = 0.79$, with only non-academic being somewhat less than research ($M = 5.46$, $SD = 1.04$), $p = 0.068$.

We conducted a similar ANOVA to examine faculty advisors' perceptions of their students, belonging in the department as a function of their perceived top career choice (Non-Academic, Teaching, Research) and the perceived FG status of the PhD student. As reported above, there was a main effect of career choice. There was also a main effect of generation status, F (2, 436) = 3.54, $p = 0.03$, $\eta_p^2 = 0.02$. Interestingly, when faculty advisors reported that they were not sure of the generation status of the PhD students they were advising, they perceived that student as belonging less ($M = 5.65$, $SD = 1.17$) than either students who they perceived as first in the family to go to college ($M = 5.90$, $SD = 0.99$), $p = 0.09$ or not first in the family to go to college ($M = 5.93$, $SD = 0.99$), $p = 0.01$. There was no interaction between the variables, F (4, 436) = 0.78, $p = 0.54$ (see **Figure 7**).

Discussion

In Study 2, we explored faculty advisors' career preferences for PhD students, both in general and for specific students they are advising. Through both categorical and continuous measures, we found that faculty advisors, in general, preferred their students to pursue research-focused academic positions. In this way, their preferences were consistent with what the PhD students perceived in Study 1. However, when thinking of a specific student, faculty advisors reported a more balanced career preference, and the patterns were similar to their perception of that student's career goals. This appears to be discrepant with the PhD students' perceptions in Study 1, the majority of whom thought that their advisors preferred them, specifically, to pursue research careers, even though they were more balanced in their career goals. Of course, because these are two separate samples, we are cautious in our interpretation about claims of "accuracy" but it does appear that what PhD students perceived in Study 1 to be true of their advisors' goals for them corresponds better to STEM advisors' abstract goals, than

TABLE 7 | Determinants of advisors' career preferences for student A.

Outcome variables: advisors' desirability ratings for career options for student A		*b*	*SE*	*β*	*t*	*p*
Non-academic	Constant	0.58	0.33		1.79	0.08
	Advisor's desirability ratings for non-academic positions for their students in general	0.36	0.04	0.31	8.23	<0.001
	Perceived student A's desirability ratings for non-academic positions	0.59	0.03	0.67	17.45	<0.001
Teaching	Constant	–0.06	0.29		–0.19	0.85
	Advisor's desirability ratings for teaching positions for their students in general	0.36	0.04	0.29	8.09	<0.001
	Perceived student A's desirability ratings for teaching positions	0.66	0.03	0.70	19.66	<0.001
Research	Constant	0.74	0.78		0.95	0.34
	Advisor's desirability ratings for research positions for their students in general	0.18	0.09	0.09	2.07	0.04
	Perceived student A's desirability ratings for research positions	0.69	0.05	0.70	15.39	<0.001

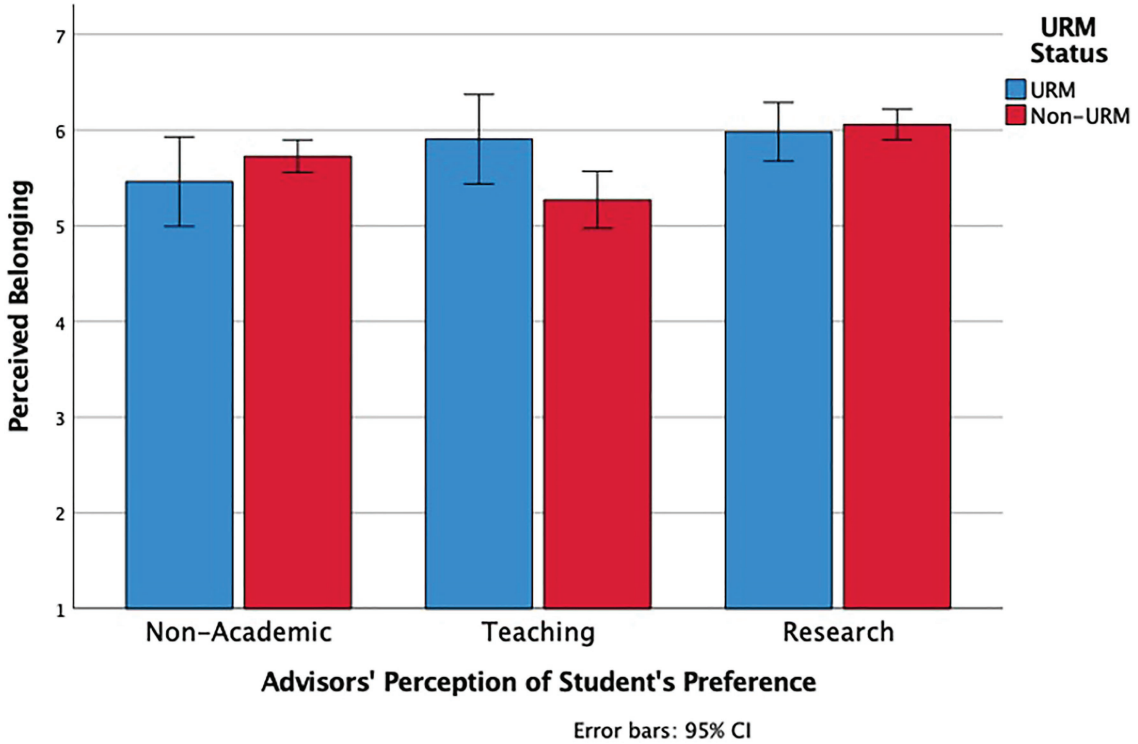

FIGURE 6 | Advisors' perception of their students' sense of belonging, as a function of URM status and their perception of students' career preference.

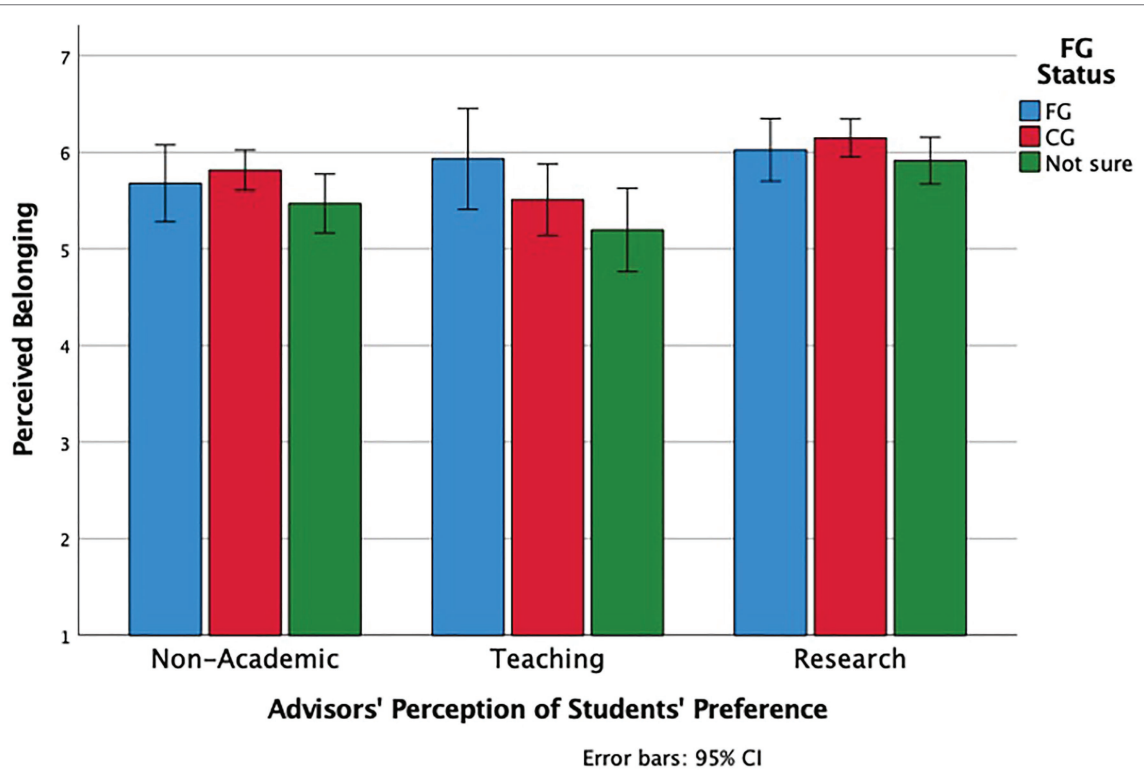

FIGURE 7 | Advisors' perceived belonging of their students, as a function of first-generation (FG) status and their perception of students' career preference.

the goals that STEM advisors' report having for their specific students.

We further examined whether the patterns in career preferences were more strongly related to advisors' own general preferences or to their perception of the preferences of students they advise. We found that faculty advisors' career preferences for specific students they advise were primarily driven by their perception of the student's career preference instead of their own general preference. In other words, according to their own assessments, faculty advisors do not generally impose their self-preference when thinking about the career development of students they advise. Instead, they seemed to orient their mentorship to what they perceived that the PhD students preferred. We then examined how comfortable faculty advisors are in advising students with regard to the different career options. The patterns mirror the students' perception from Study 1. Faculty advisors were significantly more comfortable discussing research positions than non-academic or teaching positions with students they advise.

Faculty advisors who perceived the top career preference of students they advise to be research rated those students as experiencing more belonging in the department, compared to those who preferred non-academic or teaching positions. In considering students' demographic characteristics, faculty advisors did not differ in their overall perception of the sense of belonging experienced by URM and non-URM students. This finding is important to consider as it contrasts with the students' feelings of belonging in Study 1, where non-URM students felt more belonging in the departments than URM students. However, faculty viewed non-URM students interested in research as experiencing much more belonging than those interested in teaching and non-academic positions. There was no significant difference for URM students with different career preferences. Finally, faculty advisors who were uncertain about their students' generation status perceived them as feeling less belonging compared to FGs and CGs, regardless of their career preferences. This unexpected finding may be due to a third variable, such as closeness between advisor and student; advisors who are less close to students may not know them (and details such as generation status) as well and perceive them as belonging less.

GENERAL DISCUSSION

Integrating the results of Study 1 and Study 2 suggests that STEM PhD students are accurate in their perception that faculty, in general, would prefer students in their labs to pursue research-focused academic positions. They are also accurate in their perception that faculty advisors are more comfortable discussing research careers than other options. Faculty, by contrast, perceive themselves as being aligned with graduate students' preferences in their post-PhD pursuits, regardless of which of the three directions they believe the student desires to pursue. When faculty think about specific students, they adjust their goals to align with what they perceive the students' goals to be.

Such adjustments, of course, may not be explicitly communicated to PhD students by their advisors. When students realize that they are interested in pursuing non-academic careers, they may see themselves as misaligned with their advisors' interest, and they may persist in thinking that their advisors want them to pursue research. These students more interested in non-research careers are discrepant from what they see as normative in their departments, and this discrepancy is associated with students feeling a lack of belonging and social support, factors which are associated with academic performance (Cohen and Garcia, 2008).

Interpersonal and Institutional Implications

The present findings suggest several implications on the interpersonal (i.e., faculty advisor-student) and institutional (i.e., departmental and university) levels. First, more discussions about students' career development should be encouraged, and faculty should be more explicit and open about their support for students' various career preferences. Although students may have initially expressed interest in pursuing research careers, some students preferences change over time, and they may not be comfortable revealing such changes to their advisors (Sauermann and Roach, 2012). Approximately 20% of the PhD students in Study 1 indicated that teaching was their career preference, which would lead them to join the professoriate, and yet they felt a lower sense of belonging than those who preferred research-oriented careers, a finding with implications for diversifying the professoriate. Having more regular conversations about career development and knowing about their advisors' support may increase students' comfort in having discussions about pursuing teaching and non-academic career paths and, therefore, their ability to pursue and secure resources to help them reach those goals. The present findings suggest that creating individual development plans (IDP; Austin and Alberts, 2012) between faculty advisors and doctoral students in the sciences would be helpful, particularly if they are regularly revisited as students progress through their academic programs.

Second, faculty may not be fully aware of how demographic characteristics of PhD students affect their sense of belonging and perceived social support. Faculty advisors in Study 2 did not perceive any difference in belonging for URM students compared to non-URM students, whereas PhD students in Study 1 reported such a discrepancy. This discrepancy across studies could be due to many factors, including inaccurate perceptions of faculty, or the faculty participants in our studies were assessing a different sample of participants as those who participated in Study 1. Research that includes dyadic assessments (where advisors and students participate as pairs) would help clarify this discrepancy. When examining faculty members' perception of students' belonging as a function of their generation status, faculty who were unsure of the college generation status of students they advised perceive them as experiencing less belonging. For faculty who know about the college generation status of students they advise, their perceptions of the students' belonging mirrored the student experiences, such that FGs felt less belonging than CGs. Although we did not find any significant difference in FGs and CGs' perceived social support from their advisors (in Study 1), understanding students'

demographic backgrounds can inform faculty members about ways they can provide social support to bolster FGs' and URMs' sense of belonging. Mentorship training and institutional practices that incorporate greater discussion of backgrounds may be particularly useful, such as the University of California's program that highlights FG status of students and faculty alike (University of California, 2021).

At the institutional level, we examined norms within the academic department, where students receive advising and interact with multiple faculty members. Overall, PhD students in Study 1 perceived a strong normative preference from their advisors and other faculty members for pursuing research careers. While students are accurate in reflecting the general preference of faculty members, they may not recognize that faculty can be responsive (and see themselves as wanting to be responsive) toward student preferences (as indicated in Study 2), thus missing out on potential opportunities to discuss alternative career paths with their advisors and mentors, including teaching positions which would enable them to continue on the path to the professoriate. The norms that faculty communicate informally to students can influence their psychological experience and choices.

The Power of Perceptions

A recent study shows the power of the perceived beliefs of STEM faculty members (LaCosse et al., 2020). The researchers had students evaluate STEM courses that were taught by professors who, via random assignment, either expressed fixed or growth mindset beliefs about intelligence. Students anticipated more negative experiences in the classes purportedly taught by faculty who believed that intelligence is fixed than those taught by faculty who believed intelligence is malleable, anticipating that they would perform worse in such classes and exhibiting less interest in taking them (LaCosse et al., 2020). This pattern occurred for all students but was particularly strong for the female STEM students.

In the present research, it appears that PhD STEM students may perceive that faculty in their departments, including their advisors, have a relatively fixed view on what career is most desirable (research), whereas the faculty view themselves as possessing a more malleable view that is adaptive to their students' needs. We suspect that students' perceptions of faculty advisors' preferences as relatively stable may lead them to feel less efficacious about discussing other options. We also suspect that to the extent that faculty advisors see themselves as malleable in their career preferences for students, this malleability may not be explicitly communicated to students. Together, it may be advisable for both parties to have structured career discussions and to normalize and explicitly signal support for diverse careers paths.

Prior studies revealed that PhD students in highly structured STEM doctoral programs (e.g., that promoted an early and systematic involvement in research) with explicit publication expectations had fewer publication gaps between URMs (vs. non-URMs) and women (vs. men; Mendoza-Denton et al., 2017). What the authors describe as a "culture of structure" and a clearly outlined path led to greater success for a wider range of students (Fisher et al., 2019). Approaches that foster a culture of structure to help emphasize the support available to pursue diverse career paths can potentially be incorporated into doctoral students' career development. A culture of structure may be beneficial to faculty members as well, with clearly defined benchmarks for advising. Departments can signal their support for diverse career options as well and take actions to promote them by integrating career exploration into doctoral program milestones, encouraging summer internships, and holding workshops for teaching and non-academic career preparation. This may require more training of faculty to communicate that career development is part of mentoring and provide them with resources to mentor their students on non-research careers.

Limitations

Several limitations in this research warrant mention. First, although we investigated career preferences from both students' and faculty advisors' perspectives, we did not have a matched sample. We would like to emphasize that we cannot assess the accuracy of their different perceptions in the current research (as we could in a design that examined PhD student-advisor dyads). We cannot verify the accuracy of the students' views in Study 1 (students may be incorrect in what their advisors' preferences are for them), nor can we verify the accuracy of advisors' views in Study 2 (advisors may be incorrect in their assumptions of what career path the students they advise wish to take). Future research examining advisor-mentee dyads would be useful to understand the communicative context more clearly. Second, we did not have sufficient sample size to explore the variability between different URM groups or examine the intersectional relationship between race/ethnicity and gender. Moreover, we did not have a sufficient sample size to examine how variability amongst the STEM disciplines influences the perceptions of students and faculty alike. Given the still-limited ethnic and racial diversity in many graduate programs, a larger study undertaken across many more universities in order to develop a complete picture of these important layers could reveal a more nuanced and detailed picture. STEM areas have a varying degree of focus on applied (vs. basic) research, which can manifest in different attitudes and connections with institutions and organizations outside academia. For example, researchers in computer science have more connections and collaborations with technology companies, whereas those in some basic sciences may lack those connections and knowledge of research conducted beyond academia and the potential for diverse professional paths within those fields. A closer examination of the attitudes toward non-academic careers will help better identify fields that have stronger norms and preferences toward academic and non-academic careers.

Closing Thoughts

From the perspective of the PhD student in STEM fields, career development is an integral part of their doctoral studies. The present studies highlight an asymmetry between perceived and actual norms in career preferences from the students' and faculty

advisors' perspectives and point out that faculty may not be as unsupportive toward teaching and non-academic careers as students may perceive them to be. Having more explicit and frequent conversations at both the interpersonal and institutional levels can not only address such asymmetries, but more importantly, may also create a more welcoming and supportive academic environment that is attuned to the contemporary constraints and opportunities in academia and industry.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found at: https://osf.io/4uyxh/.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by UCSB ORAHS 61-21-0256. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DS developed and executed the research described in the paper and analyzed the data. LO executed the research plan and collected the data. SL analyzed the data. DS, LO, and SL wrote the manuscript. CK and MH commented on the manuscript and helped to organize the data collection. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.711615/full#supplementary-material

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METHODS
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An Ecological Approach to Evaluating Collaborative Practice in NSF Sponsored Partnership Projects: The SPARC Model

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From co-authored publications to sponsored projects involving multiple partner institutions, collaborative practice is an expected part of work in the academy. As evaluators of a National Science Foundation (NSF) Alliances for Graduate Education and the Professoriate (AGEP) grant awarded to four university partners in a large southern state, the authors recognized the increasing value of collaborative practice in the design, implementation, evaluation, and dissemination of findings in the partnership over time. When planning a program among partnering institutions, stakeholders may underestimate the need for, and value of, collaborative practice in facilitating partnership functioning. This method paper outlines an evaluative model to increase the use of collaborative practice in funded academic partnership programs. The model highlights collaborative practice across multiple stakeholder groups in the academic ecology: Sponsors of funded programs (S), Program partners and participants (P), Assessment and evaluation professionals (A), academic researchers (R), and the national and global Community (C). The SPARC model emphasizes evidence-based benefits of collaborative practice across multiple outcome domains. Tools and frameworks for evaluating collaborative practice take a view of optimizing partnership operational performance in achieving stated goals. Collaborative practice can also be an integral element of program activities that support the academic success and scholarly productivity, psychosocial adjustment, and physical and psychological well-being of stakeholders participating in the program. Given the goal of our alliance to promote diversification of the professoriate, the model highlights the use of collaborative practice in supporting stakeholders from groups historically underrepresented in STEM fields across these outcome domains. Using data from a mixed-methods program evaluation of our AGEP alliance over 4 years, the authors provide concrete examples of collaborative practice and their measurement. Results discuss important themes regarding collaborative practice that emerged in each stakeholder group. Authors operationalize the SPARC model with a checklist to assist program stakeholders in designing for and assessing collaborative practice in support of project goals in funded academic partnership projects, emphasizing the contributions of collaborative practice in promoting diversification of the professoriate.

Keywords: collaborative practice, assessment and evaluation, higher education, NSF alliance and partnership programs, STEM education and careers, diversity, equity, and inclusion (DEI)

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INTRODUCTION

This is a story of model discovery and evolution told from the perspective of the authors, serving on an evaluation team for an Alliance for Graduate Education and the Professoriate (AGEP) partnership grant, sponsored by the National Science Foundation (NSF, 2016). From the inception of the partnership proposal to presently entering the fifth and final year of funding, the evaluation team promoted collaborative practice across stakeholders through focused measurement and reporting. This method paper outlines an evaluative model to assist the stakeholders of similar programs who seek to promote the use of collaborative practice across the academic ecology of a funded program. The model further identifies links between collaborative practice and diversifying the professoriate, the overall goal of the AGEP program, and the theme of this special journal issue.

In March of 2018, program and evaluation partners from a newly funded AGEP alliance (hereafter called "our" alliance) joined partners from all concurrently funded AGEP alliances at the *AGEP National Research Conference* in Berkeley, California (California Alliance, 2018). The purpose of the conference was sharing findings and insights related to increasing the inclusion of groups historically underrepresented in STEM fields at the graduate, postdoctoral, and faculty levels in STEM disciplines, thereby diversifying the national professoriate. Over two days, alliance representatives both contributed to and learned from sessions focused on the conference theme, *Pathways to a Diverse Professoriate.* Nine representatives from our alliance and its predecessor contributed two of 18 plenary talks and three of 29 posters (California Alliance, 2018).

When the university and evaluation partners reflected on the lessons shared at the conference, they identified a common thread woven throughout many of the talks and posters—that of collaborative and connective practice. Systematically pulling this thread in subsequent years revealed the wide applicability of collaborative practice in funded academic partnerships, from proposal design to project implementation, program evaluation, and the dissemination of findings.

In the following sections, the authors outline applications of collaborative practice across multiple stakeholder groups in the academic ecology of funded partnership projects; summarize the range of benefits conferred by collaborative practice on stakeholders; and highlight evidence that links collaborative practice and positive outcomes related to diversity, equity, and inclusion (DEI) in higher education. The subsequent methods and results sections present our alliance as a case study illustrating the use of the evaluative model over the lifecycle of the funded partnership program.

Collaborative Practice in the Academic Ecology

Collaboration is ubiquitous in human society. When more than one person participates in task completion, the actors (aka stakeholders) must work together in successful ways (aka collaborate). Everyone must participate in collaborative activities as part of life. From an early age, we work together in families, in school, scouts, sport teams, and religious congregations. These collaboration and connection structures are built into our physiology and are fundamental to our psychological identity (Holland, 2020).

Participation in the academy is grounded in collaborative practice, including students and faculty in classes and degree programs, in departments and disciplines, in research and laboratory groups, in mentoring and advising relationships, in campus and community organizations. Contemporary STEM educational frameworks characterize collaboration as a fundamental transdisciplinary skill in education and society (Kelly and Burr, 2019). Partnership and workgroup models span the global workforce in business, industry, government, non-profit, and education sectors. Program sponsors like NSF specifically invest in partnership models like AGEP (NSF, 2016) to achieve national education and workforce goals.

Even though collaboration is a natural part of life, the assumption that collaboration occurs naturally when groups gather may lead partners to minimize the attention it deserves in facilitating partnership function. Effective collaboration does not occur naturally or automatically, it requires intentionality about describing what collaborative practice looks like, how it is implemented, and appropriate outcomes measures. Only in such a context can the benefits of collaborative practice be realized.

As reflected in these examples, stakeholder groups in the academic ecology include: (S)ponsors, whose requirements for partner collaboration and program management drive what (P)artners consider when planning programs, and thus what (A)ssessment and evaluation professionals measure. Findings from program studies form the basis of (R)esearchers' contributions to the academic literature about collaborative practice and its value proposition in the larger academic and global (C)ommunity. The emphasis on multiple stakeholder groups (SPARC) encourages development of collaborative practice across the academic ecology.

Range of Benefits of Collaborative Practice

The model emphasizes evidence-based benefits of collaborative practice across multiple outcome domains: project implementation and performance, academic success and scholarly productivity, psychosocial adjustment, and physical and psychological well-being.

Tools and frameworks for evaluating collaborative practice take a view of optimizing partnership operational performance in achieving stated goals, re-benefits and limitations of collaborative practice in service of project implementation, and performance (Taylor-Powell et al., 1998; Gajda, 2004; Carey et al., 2009; Woodland and Hutton, 2012; Marek et al., 2015). **Figure 1** summarizes common pros and cons of working in collaborative partnerships. The benefits (pros) reflect the idea that collaborative partnerships boost program effectiveness by leveraging resources such as relationships, expertise, funding, and unique capabilities across program partners. Partnerships

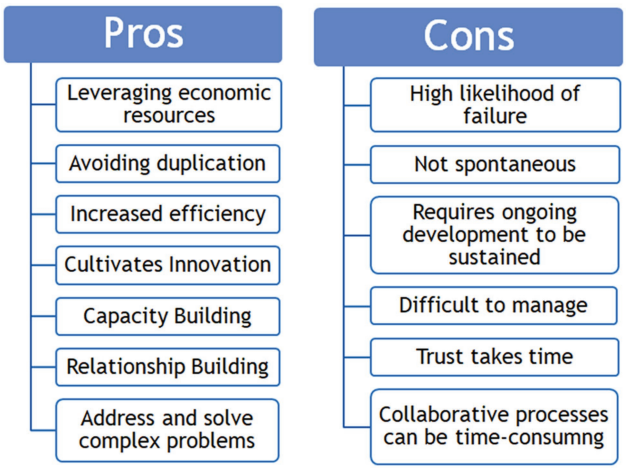

FIGURE 1 | Pros and Cons of Collaborative Practice.

often have further reach with greater impact than partners going it alone. In contrast, the limitations of collaboration center around the challenge and demand of coordination across partners. Any partnership formed must build trusting relationships among the active stakeholders, and this requires extended time spent together. Managing partnerships is difficult and requires considerable sustained effort and interpersonal finesse. Collaborative planning and implementation can be prohibitively time-consuming.

Collaborative practice can also be an integral element of program activities that support the academic success and scholarly productivity, psychosocial adjustment, and physical and psychological well-being of stakeholders participating in the partnership program. Collaborative practice provides important academic benefits "from cradle to career." Collaboration is part of a transdisciplinary skill set that supports academic and workforce performance over the lifespan (along with communication, critical thinking, and creativity; Kelly and Burr, 2019). Many complex technological and scientific advances require interdisciplinary collaboration and sharing knowledge across diverse disciplines. For example, NSF has committed to investing in their 10 Big Ideas,[1] which require collaboration across sectors. Research suggests that measurable positive attitudes and behaviors toward cross-disciplinary and interdisciplinary work are related to engagement in collaborative workgroups (Misra et al., 2015).

Academic scholars rely on both formal and informal channels of learning in the academy. The classroom and coursework constitute official pathways for learning requisite disciplinary information for the degree sought. Unofficial channels reflect information learned through interactions with faculty and peers outside formal learning environments. The information learned through such unofficial channels is referred to as the "hidden curriculum" (Elliot et al., 2016). Collaborative practice structures such as mentoring, short-term embedded practice experiences, writing workgroups, and job coaching can provide support that makes this implicit learning explicit. For example, specifically supporting transitions from doctoral to postdoctoral to early career faculty positions through collaborative practice and mentoring addresses this hidden curriculum, as these transitions often lack formal guidance from the academy (Settles, 2020).

Aside from academic domains, collaborative practice supports the psychosocial and sociocultural adjustment of scholars. Ongoing opportunities to collaborate and connect across diverse communities can promote feelings of belonging and inclusion, as time spent together provides the time and space necessary for trust, group identification, and mutual regard to develop (Komives and Wagner, 2017; Micari and Pazos, 2021). Further, a substantial body of research has demonstrated the profound negative consequences that loneliness and isolation can have on the quality and duration of life as well as the mental health and well-being of citizens across the lifespan (Murthy, 2020). Collaborative practice promotes psychosocial connections that can support coping with feelings of isolation and ostracism in the academy and promote scholar persistence (Kelly et al., 2021).

Murthy (2020) clearly demonstrates how psychosocial connection is directly correlated to well-being and life expectancy. Recent research suggests that participation in the academy, particularly in advanced graduate and faculty roles, is significantly stressful and challenging. Advanced degree programs push students' academic development, but in doing so, they can raise levels of anxiety and depression, particularly near the end of the doctoral program (Bolotnyy et al., 2021). The obvious remedies include connecting scholars with counseling, psychiatric services, support, and recovery groups. Emphasizing activities and discussions about work-life balance, family issues, the pandemic, civil unrest, and wellness habits can provide common experiences among scholars to support their health and resilience (Edwards and Ashkanasy, 2018; Yusuf et al., 2020).

Collaborative Practice Supports Diversification of the Professoriate

Given the goal of our alliance to promote diversification of the professoriate, the model highlights the use of collaborative practice in supporting stakeholders from groups historically underrepresented in STEM fields across these outcome domains. Diversification of the professoriate and national workforce is a government priority. NSF has operationalized its commitment to diversification in its *Broader Impacts* review criteria used by independent review teams to assess every submitted proposal (NSF, 2021c). AGEP alliances strategically focus on the engagement of doctoral, postdoctoral, and early career scholars who represent groups historically underrepresented in STEM fields.[2] AGEP alliances promote DEI in both its structure and function. The use of communities of practice as a structure for learning, sharing, and supporting scholars underlies many alliance strategies (NSF, 2021c).

[1]https://www.nsf.gov/about/congress/reports/nsf_big_ideas.pdf

[2]African Americans, Hispanic Americans, American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders.

DEI in the academy do not happen naturally. Ensuring that all partners are both represented and participating is fundamental for a successful collaborative partnership seeking to broaden diversity in the academy (Pritchett et al., 2021). Stakeholders may require professional development or expert facilitation to plan and implement effective collaborative practice across diverse stakeholders.

A growing body of evidence links collaborative practice and outcomes related to DEI in higher education. For example, students representing groups historically underrepresented in STEM fields are less likely to possess the connections, networks, or mentoring around them to recognize and encourage them (Yeneabat and Butterfield, 2012; Ponjuán, 2013) or to help them navigate the hidden curriculum (Elliot, 2016; Settles, 2020). Engaging scholars in undergraduate research or other collaborative research settings can help prepare them to enter advanced studies (Jones et al., 2010; Cheruvelil et al., 2014; Hernandez et al., 2018).

Mentioned earlier, ongoing opportunities for scholars to collaborate and connect across diverse communities can nurture psychosocial connections and support health and well-being, both of which influence persistence in the academy. This is particularly important for scholars from groups historically underrepresented in STEM fields, who are at elevated risk in these domains due not only to the difficulty of a higher degree program (Bolotnyy et al., 2021), but also to inescapable systemic racism and ostracism within the academy, and prior experiences in society. These experiences elevate loneliness and social pain, impacting health and well-being. These same students are less likely to seek psychological support services or persist with them (Leong and Kalibatseva, 2011), in part due to potential stigma associated with use of such services.

No paper published in 2020 or 2021 is without a reference to the global pandemic and its major psychosocial, economic, public health, political, and higher education impacts (Usher et al., 2020; Cotula, 2021; Jackson, 2021; Khalil et al., 2021; Lynch and Bambra, 2021). Society changed unexpectedly and profoundly in response to the global pandemic. Social distancing, mask-wearing and stay-at home policies subjected everyone to risk from the trauma of forced isolation from others for an extended period. Research has demonstrated the profound consequences this can have on the health and longevity of citizens across the lifespan (Murthy, 2020). National data further confirm that racial minority groups had higher incidence and hospitalization rates relative to their proportions in the population (Stokes et al., 2020). The pandemic has elevated the health risk of racial minorities more than others.

The literature supports the benefits of collaborative practice across the academic ecology of funded partnership programs. By encouraging a broader conceptualization of the potential benefits of collaborative practice, the proposed evaluative model offers stakeholders from similar partnership programs a tool for considering collaborative practice in their own context. Next, in the methods and materials section, authors provide concrete examples of collaborative practice and their measurement using data from a mixed-methods program evaluation of our AGEP alliance over four years.

MATERIALS AND METHODS

The authors served as a program evaluation team, serving primarily as non-participant observers with unique individual positioning. One evaluator came from the lead institution and served as an internal evaluator focused heavily on formative evaluation. The two other evaluators came from the assessment and evaluation group of an external non-profit organization. One external evaluator maintained a primarily administrative and oversight role to ensure evaluation objectivity and contract compliance, while the other external evaluator engaged deeply with the partnership leaders and the internal evaluator to coordinate analysis, reporting, and dissemination of formative and summative evaluation findings. This blended model takes advantage of the increased access to stakeholders by internal evaluators and the requisite need for objectivity satisfied by external evaluators (Patton, 2008).

The lead institution of our AGEP alliance coordinated Institutional Review Board (IRB) approval across the four university partner institutions and the not-for-profit organization of the external evaluation team. Signed informed consent from all program stakeholders (both those receiving programming and those delivering programming) allowed the use of ongoing implementation data collected as part of the project for research and evaluation purposes, such as written reflections, zoom recordings, attendance data, and participant feedback from meetings and events. Specific interview protocols, survey instruments, and other tools such as Individual Development Plans (IDPs) were also submitted for approval, including protocols and instruments used in evaluating collaborative practice. Amendments submitted separately incorporated changes and additional instruments into the original IRB application over the years of the grant.

The program evaluation of our AGEP alliance employed a mixed-method, multi-informant approach to characterize alliance progress in achieving intended outcomes. The evaluation focused on the assessment of collaborative practice across our alliance partners, with stakeholders in the national AGEP community, and in the academic ecology in which they reside.

Stakeholder Groups of Interest

The academic ecology of our alliance, depicted as a set of nested stakeholder groups in **Figure 2**, reflects the stakeholder groups of concern in the proposed evaluative model. The inner four rings are specific to our alliance, while the three outer rings depict the academic ecology that houses our alliance.

At the core of the model are the cohort participants, the primary targets of alliance programming. Since the emphasis of the alliance was on model development, implementation, and study, the funding sponsor limited cohort size. Nine graduate students from identified groups historically underrepresented in STEM fields recruited across four university partners participated for the duration of the program. Requirements for participation included initial status as a dissertator from a recognized minority group with the intention to seek a postdoctoral or faculty position upon completion of the doctoral program. Several dissertators discontinued their participation

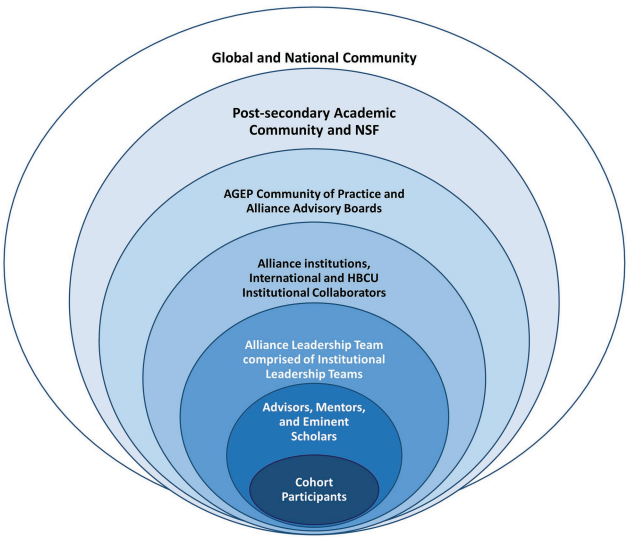

FIGURE 2 | Nested Stakeholder Groups in the AGEP Alliance.

in the program in the first year after deciding to pursue work outside of the professoriate. For each cohort participant, the alliance engaged university faculty to serve in three distinct mentoring roles, represented in the second innermost ring.

The third innermost ring contains the leadership team, currently 32 faculty and staff across alliance partners who provide activity programming and partnership coordination. Each participating university partner has a local team that is part of the alliance leadership team, tasked with specific activities or elements of the program model. The evaluation requested that cohort participants and members of the leadership team participate in data collection on an annual basis. Thus, the evaluation employed a longitudinal, census approach that sampled everyone in the populations of interest. Finally, the fourth innermost ring represents the overall institutional context of our five main alliance partners and the supporting international institutions and Historically Black Colleges and Universities (HBCUs) that our alliance has partnered with for specific program activities.

The three outer rings that surround our AGEP alliance represent the academic ecology in which the alliance is embedded. The third outermost ring includes the national community of AGEP alliances and stakeholders of similar programs, representing the research community most proximal to the alliance stakeholders. The AGEP program is located within NSF's Human Resource Development (HRD) Division of the Education and Human Resources (EHR) Directorate. AGEP's goal is to "increase the number of historically underrepresented minority faculty in STEM…to fund grants that advance and enhance the systemic factors that support equity and inclusion and, consequently, mitigate the systemic inequities in the academic profession and workplace."[3] The community of AGEP alliances connects through annual AGEP national research conferences and other activities relevant to all alliances.

The alliance appointed three advisory boards, one representing stakeholders from the alliance participant cohort, as well as nine subject matter experts from institutions outside of our alliance selected for their research, content, and evaluation expertise in related programs. They provided feedback and professional development to the leadership team and social science research team. The second outermost ring includes the postsecondary education and research academic community at large, with NSF as a major sponsor of research for the STEM disciplines included in this layer. Finally, the outermost ring represents society at large, a reminder that funded programs fulfill national and global needs. In the current context, the need addressed is promoting DEI in the professoriate.

Our AGEP Alliance Model

The goal of our interdisciplinary AGEP alliance is to develop, implement and study a model of STEM doctoral degree completion and the transition to successful postdoctoral fellowships and faculty careers for groups historically underrepresented in STEM. A customary way to depict programs like our alliance is with a logic model, a systematically developed visual representation of a program's underlying assumptions and theoretical framework (W. K. Kellogg Foundation, 2004). Logic models typically delineate the activities of each institutional partner of the alliance (inputs) and connects these activities to their intended outputs (i.e., products of program activities) and outcomes (i.e., specific changes in participants' behavior, knowledge, skills, status, and level of functioning).

The evaluation team developed the alliance logic model (see **Figure 3**) based on program documentation. The logic model maps program elements to three strands of research and evaluation: educational research, social science research, and partnership evaluation. The education research strand is related to the activities offered to stakeholder participants. Local teams responsible for activity development, implementation, and outcomes engage in research to validate observed outputs and outcomes on stakeholder participants. The social science research strand contributes to the larger knowledge base about policies and practices for improving academic outcomes for students representing groups historically underrepresented in STEM fields in higher education. The social science research team examined the relationship between social and physical pain and how this relates to the experiences of students from groups historically underrepresented in STEM fields in the academy.

The evaluation team used the alliance logic model as a basis for designing formative and summative program evaluation. Formative evaluation provides ongoing feedback about alliance functioning in a continuous improvement cycle (during monthly meetings). Summative evaluation focuses on providing credible evidence of program effectiveness in achieving program outcomes (annual reporting). The evaluation strand of the logic model focuses on partnership collaboration, feedback from advisory boards, recruitment and coordinated engagement of cohort participants in program activities, and dissemination across all three research and evaluation strands.

[3]https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5474

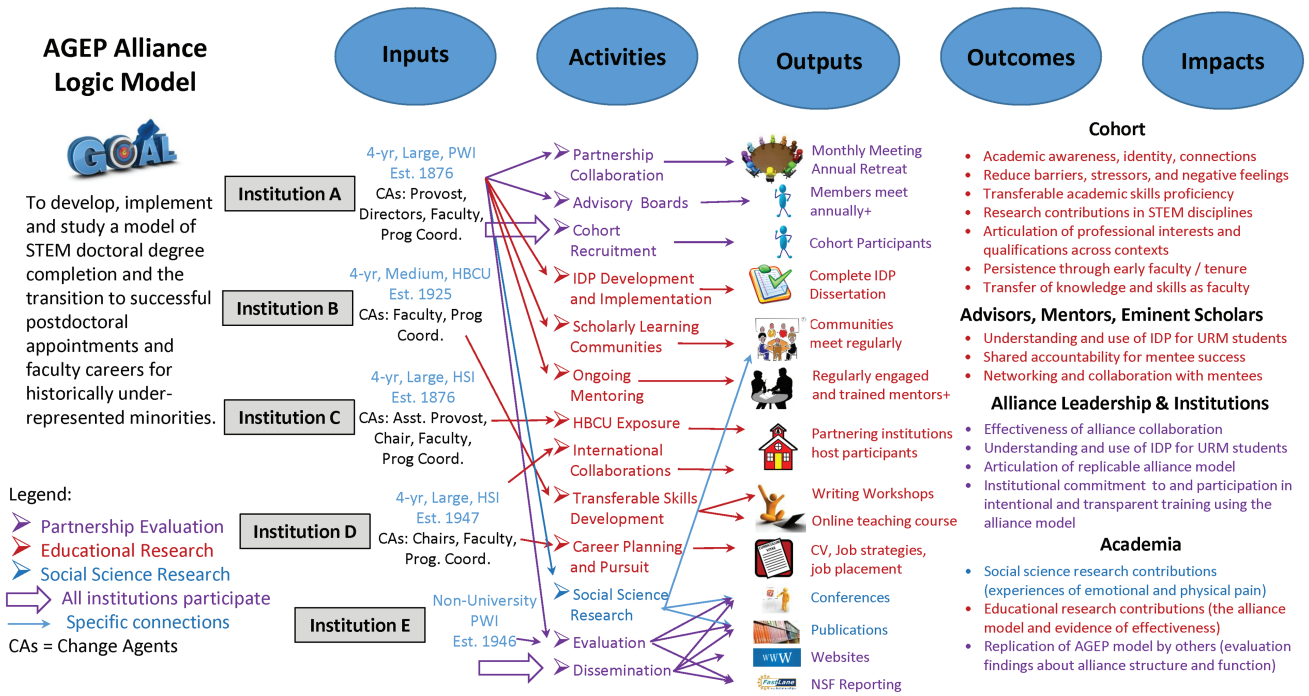

FIGURE 3 | Logic Model for the AGEP Alliance. The logic model displays how the activities of each institutional team lead to outcomes in service of the overall alliance goal.

Logic models not only guide evaluation design but are also instrumental in ensuring stakeholders (inputs) specify what they expect to accomplish (activities and outputs) and how they will know if they did so (outcomes and impacts). Ideally, engaging the leadership team in collaborative discussion around the logic model promotes shared understanding of program goals, roles, and responsibilities, and expected outcomes (Kelly and Burr, 2019). The evaluation team traced the development of shared understanding of the alliance model among the members of the leadership team over time and in response to professional development.

AGEP Community of Practice (COP)

An export from the public funding portal of NSF (2021a) itemized 27 AGEP alliances since 2013 (18 are currently active). Each alliance identified a lead institution for administrative purposes. In total, 22 different institutions served as leads. Five institutions[4] have led consecutive or multiple alliances. Each lead partnered with one or more doctoral institutions, ranging from two or three (20% of alliances) to six or more (35% of alliances), with 50% of alliances having four or five partners. As noted previously, a total of five institutions partnered in our alliance, four doctoral granting institutions in a southern state and an evaluation team contracted from a non-profit government organization in another southern state.

Across these 27 alliances, there are a total of 112 unique institutions partnered in one or more alliances. The authors classified each partner using the Basic Carnegie Classification of Institutions of Higher Education (Indiana University Center for Postsecondary Research, 2021) and designations for Minority Serving Institutions (MSIs; U.S. Department of Education, 2020). All institutions are located within the continental United States. On the map in **Figure 4**, each institution is located as a colored circle representing MSI classification, with lead institutions designated with an '**X**'. Of the 112 institutions, 43 (38%) have an MSI designation. Two-thirds of the partnering institutions have doctoral programs with high or very high research activity. The other third includes schools focused on associate's ($n=8$), baccalaureate ($n=5$), and master's ($n=18$) degree programs, tribal colleges ($n=3$), and a few professional doctoral programs ($n=4$). **Figure 3** (inputs column of the logic model) summarizes the characteristics of the four institutions comprising our AGEP alliance.

The AGEP institutional portfolio constitutes the AGEP community of practice (COP). The existence of the AGEP COP provides opportunities for collaboration beyond a single alliance. Further, a steady stream of AGEP-affiliated events provided regular venues in which collaborative practice across alliances encouraged capacity building around common alliance needs. The evaluation team highlighted professional interactions of our alliance members within the AGEP COP.

Measurement Strategies and Data Sources

The Collaboration Evaluation and Improvement Framework (CEIF; Woodland and Hutton, 2012) informed the program

[4]SUNY at Stony Brook, Texas A&M University, Tuskegee University, University of California-Berkeley, and University of Maryland Baltimore County led multiple AGEP alliance projects.

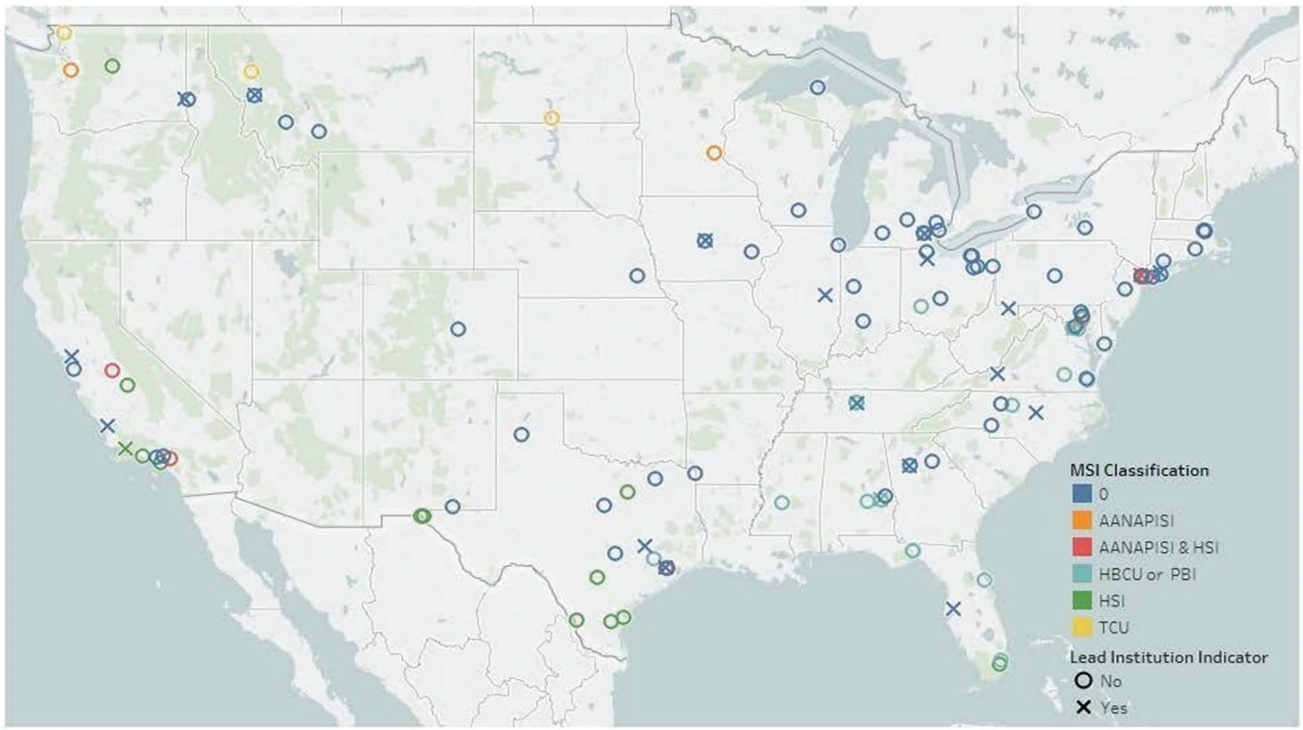

FIGURE 4 | National Map of AGEP Alliance Institutions from 2013-2020. Minority Serving Institutions (MSI Classification) are highlighted in different colors, and the lead institution for each alliance is designated with an X.

evaluation of collaborative practice in our alliance. The CEIF outlines qualitative and quantitative data collection strategies and measurement tools for each of five entry points to collaborative practice in a partnership:

1. operationalize the construct of collaboration—collaborative structures and strategies
2. identify and map communities of practice—interactions among alliance team members
3. monitor stages of development—assemble/form; storm/order; norm/perform; transform/adjourn
4. assess levels of integration—cooperation (sharing), coordination (co-hosting), collaboration (merging)
5. assess cycles of inquiry—data-driven dialog, decision-making, and action

To describe the collaborative practices employed by or engaged in by alliance stakeholders across the five entry points, the evaluation team relied on three sources of data:

1. ongoing program documentation, annual reporting, and dissemination products
2. observation of alliance events with related attendance and feedback data
3. annual assessment of stakeholder knowledge, attitudes, and behaviors in self-report questionnaires and semi-structured interviews

The evaluation team employed strategies to build rigor into all assessment phases: development, acquisition, and analysis. They worked closely together to develop self-report tools and interview protocols based on the CEIF as well as adapt both the number and details of interview questions and self-report instruments each year as collaborative practice evolved across the leadership team and cohort participants.

Following the utility standard of program evaluations [i.e., attention to stakeholders; Joint Committee on Standards for Educational Evaluation (JCSEE), 2018], we considered all individuals targeted by the project evaluation as the sample of our study. Each year during the spring semester, the evaluation team met with each leadership team member and cohort participants engaged in the funded activities of our alliance. Each year, the evaluation team followed similar procedures for scheduling, reminding, providing copies of the questions in advance, so respondents could complete self-report instruments before the interview. During hour-long interviews conducted on a conference telephone line, one evaluator guided questioning using a semi-structured protocol, while another evaluator scribed detailed notes into an electronic template. This resulted in high quality data acquisition of stakeholder responses. Further, only one or two respondents failed to participate in the data collection request each year, yielding a very high response rate (~95%).

Qualitative analysis involved coding responses to interview questions or other narrative sources of information and unitizing of data (Merriam and Tisdell, 2016). The constant-comparative method (Glaser and Strauss, 1999) entailed comparing data to allow themes to emerge. The engagement of the same evaluation team each year, using the same

procedures for coding data and consolidating across respondents, ensured consistency and credibility of the data. Team review of coded data ensured consensus agreement of the final data across the evaluation team. For example, the consistency of answers across respondents and how responses changed over the lifecycle of the project. The next section reviews the interview questions and self-report tools chosen to address each entry point of the CEIF.

Self-Report Instruments and Interview Protocols

Operationalize the Construct of Collaboration

Interview questions addressed the following topics:

1. shared understanding of the alliance goal and logic model across stakeholders
2. activities and structures for successful collaboration, such as regular meetings, location of shared information and resources
3. plans to address turnover in the leadership team, resolve conflict or disagreements
4. opportunities for face-to-face or virtual interactions for building trust among team members
5. working together to disseminate partnership results or outcomes
6. shared decision-making when developing goals/plans.

Identify and Map Communities of Practice

Each year, the evaluation team asked those on the leadership team and in the participant cohort with whom they interacted in a substantive way to identify connections within and across alliance stakeholders using the leadership team, participant cohort, and assigned mentor rosters (fourth year only). Four networking levels classified the number of times individuals were identified as a collaborator. Social network analysis maps created using a social network visualizer (SocNetV-2.4[5]) depict each alliance member as a node at their primary institution and shows connections to those within their institution as well as across institutional boundaries for each year of the partnership. In the fourth year, the evaluation team collected network data in a survey format and included information about the amount of connection time as well as the purpose or content of connections among stakeholders to describe the features of collaborative practice in more detail. The evaluation team requested interviewees to complete the survey in advance of the interview session. While there are multiple metrics of potential use in social network analysis, a detailed treatment is beyond the scope of the model presented here; resources like Taylor et al. (2014) provide a fuller discussion.

Monitor Stages of Development

Each year, the program evaluation team selected interview questions aligned to the stages of partnership development as noted below; see Woodland and Hutton (2012) for sample questions.

1. assemble/form—shared clarity around purpose, structures, strategies, leadership
2. storm/order—urgency, resources, turf, expertise, willingness to take on responsibilities
3. norm/perform—implement established and specific activities to accomplish goal
4. transform/adjourn—data related to goals and outcomes to refine, reconfigure, or dissolve the collaboration

Assess Levels of Integration

All alliance members rated collaborative practice across alliance partners using the Levels of Integration Rubric (LOIR; Woodland and Hutton, 2012). The LOIR lists five categories of collaboration: communication, leadership, members, decision-making, and resources. For each, alliance partners rate from A to E, with A associated with low cooperation (sharing), to medium coordination (co-hosting) at C, and E associated with high collaboration (merging). Interviewees indicated their rubric-based ratings and discussed their reasons during the interview.

Assess Cycles of Inquiry

Ongoing cycles of inquiry include dialog, decision-making, action, and evaluation around a shared purpose based on evidence. The alliance leadership team received feedback about alliance performance from a wide range of sources: formative and summative program evaluation, site visits with NSF staff and AGEP COP experts, advisory board meetings, annual report feedback and partnership negotiations with NSF program officers, and annual alliance-wide meetings. The evaluation team documented how the leadership team responded to and integrated this feedback from the various sources.

Document Analysis

The evaluation team reviewed both solicitation and funding documents from the sponsoring organization, NSF. This included the AGEP solicitation, which funded our alliance (NSF, 2016). Exported public funding data defined the project scope, funding, and duration for each alliance (NSF, 2021a). AGEP community announcement emails kept all partnering institutions informed. Core alliance documents included the funded project proposal, logic model, annual reports, and dissemination products. The project director captured all alliance data on a secure drive accessible only by alliance members, and only after they completed human subjects' certification through CITI.[6]

Event Observation

The evaluation team observed meetings, conferences, and professional development sessions both within our alliance and within the AGEP COP. Notes taken by the evaluators or program director from in-person or zoom sessions served as primary data from these events in addition to attendance data. With the increased use of virtual platforms during mandatory stay at home periods associated with the global pandemic, the capture of additional information related to participation in

[5]https://socnetv.org/

[6]https://about.citiprogram.org/en/homepage/

TABLE 1 | Types of data captured from virtual interfaces.

Virtual data type	Use description
Attendance	Recorded participation by session
Audio/video recording	Captured meeting presentations and discussions
Chat	Captured comments during the live presentations and discussions
Master slide deck	Collected content developed by team members
Online survey software	Collected anonymous pre and post meeting data
Padlet	Collected anonymous responses to open-ended questions on a "wall"

our AGEP alliance annual meetings and workshops became possible. **Table 1** lists the types of data captured from virtual interfaces. Virtual events, often recorded and made available after event completion, increased access to event data beyond the original presentation.

RESULTS

While the CEIF guided evaluation as discussed in the "**Materials and Methods**" section, the CEIF focuses on promoting project implementation and performance through successful collaborative practice among partners. The evaluation team recognized a broader range of benefits of collaborative practice at play across the alliance as well as within the surrounding academic ecology, including specific benefits for scholars representing groups historically underrepresented in STEM fields in the academy. To incorporate these additional elements of collaborative practice, the authors articulate an evaluative model for describing the conceptualization and actualization of collaborative practice across stakeholder groups in the academic ecology.

Dubbed the SPARC model, this acronym emphasizes collaborative practice across the academic ecology of an educational partnership program and demonstrates the unique contributions of each stakeholder group. Shown in **Figure 5**, (S)ponsor requirements for partner collaboration and program management drive what (P)artners consider when planning programs, and thus what (A)ssessment and evaluation professionals measure. Findings from program studies form the basis of (R)esearchers' contributions to the academic literature about collaborative practice and its value proposition in the larger academic and global (C)ommunity. The SPARC model encourages a broader conceptualization of the potential benefits of collaborative practice for stakeholders across multiple outcome domains: project implementation and performance, academic success and scholarly productivity, psychosocial adjustment, and physical and psychological well-being. Of particular emphasis are specific benefits for scholars representing groups historically underrepresented in STEM fields in the academy.

Grounding the evaluation findings in the SPARC model allows a systematic discussion of the role responsibilities of each stakeholder group in the academic ecology, and how they engage in or facilitate collaborative practice. Representative data organized around key analytic themes provide examples of the benefits of collaborative practice in support of alliance and stakeholder success. Each theme summarizes supporting evidence from our alliance program evaluation, detailing the data sources, measurement strategies, and analytic interpretations for each theme. The intention is to illustrate the types of data and insights about collaborative practice resulting from use of the SPARC model rather than attempt a comprehensive presentation of collected evaluation data. A final consideration to keep in mind when reviewing the results is that the evaluation team and evaluation plan evolved over the lifecycle of the partnership as did our leadership team and alliance model, and is still a work in progress.

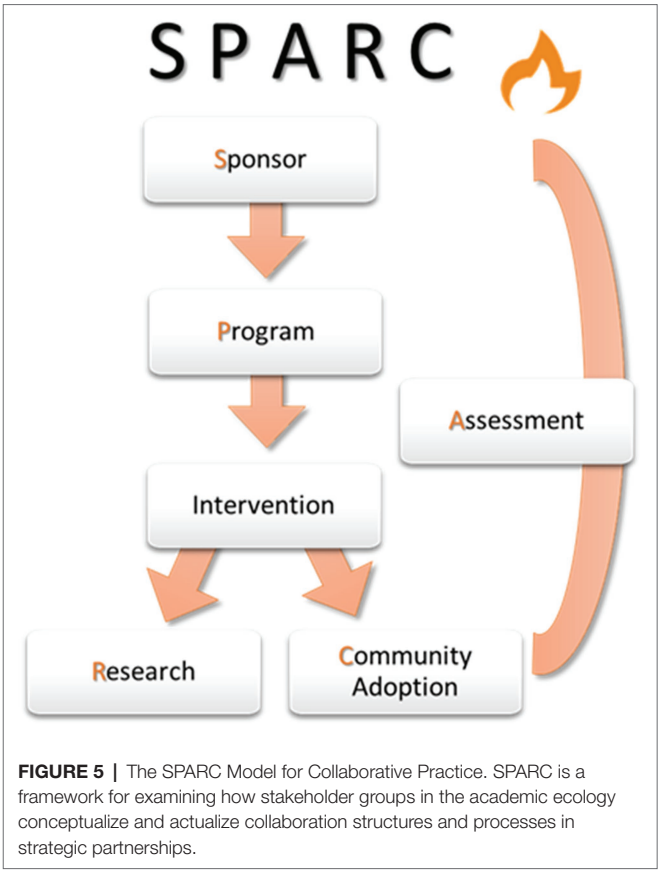

FIGURE 5 | The SPARC Model for Collaborative Practice. SPARC is a framework for examining how stakeholder groups in the academic ecology conceptualize and actualize collaboration structures and processes in strategic partnerships.

Sponsoring Organization (S)

Program officers at the sponsoring organization:

1. specify the details of the solicitation
2. sponsor independent peer review of submitted proposals
3. negotiate the project specifications for award in the form of a cooperative agreement
4. conduct site visits
5. support annual meetings and collaborative opportunities for all award recipients
6. review and approve annual reports

7. release funding increments on behalf of the sponsoring organization

The sponsors of a program influence its structure and function from conception to completion. Sponsor representatives prepare specific funding requests in alignment with policy, plans, and funding allocations, thereby actualizing collaboration requirements for project partners. Proposal review, award negotiations, and reporting requirements for grantees further shape the design and implementation of collaborative practice in funded projects. NSF outlines its policies for sponsored projects in a regularly updated guide to grants (NSF, 2021c).

In proposing partnership projects in response to an NSF program solicitation, the evaluation team examined how program officers or sponsor representatives communicated collaboration requirements or preferences to program partners. Specifically, authors documented the communication of collaboration requirements in the AGEP program solicitations, in award negotiations of our AGEP alliance with the NSF program officer, and in ongoing feedback processes like annual reporting and site visits. Section "**AGEP Community of Practice**" highlights numerous ways NSF program officers regularly engage the AGEP COP in collaborative opportunities such as proposal review, site visit teams, and conference hosting and attendance.

Solicitation Requirements

The evaluation team carefully reviewed the AGEP solicitation (NSF, 2016), which funds our AGEP alliance, for language concerning collaboration and coordination vs. independent activities (Kelly et al., 2020a,b). The solicitation analysis revealed:

Required/Suggested Elements

1. *Partnership requirement.* Must include project partners
2. *Evaluation of collaboration.* Suggests evaluation resources to evaluate collaboration (Korn, 2008)
3. *Definition of Partner Roles.* Define the roles of each partner
4. *Value-Add of Partners to Collaboration.* Prompts for a discussion "why each partnering institution/organization has been selected" as well as "benefits" or "collaborative" contributions
5. *Resources Allocated to Collaboration.* Explicit plan and budget to manage the collaborative aspects of the program
6. *Dissemination to Research Community.* Explicit plan for dissemination of work to the research community

Not Required or Elaborated

1. *Collaboration plan requirement.* Formal collaboration plan
2. *Evaluation of collaboration.* Explicit evaluation of collaborative efforts
3. *Structures for Regular Collaboration/Communication.* Discuss role of collaboration in alliance success or elaborate on structures to use

Analysis of the AGEP solicitation revealed a lack of specificity about articulating collaborative practice at the proposal stage. The requirements do include an explicit plan and budget to manage program collaboration. However, the requirements do not require formal evaluation of collaborative practice or a formal collaboration plan. A potential alliance might not think about the mechanisms of actual collaboration beyond identifying who does what and how the budget supports these roles. Sponsors of such programs should carefully consider how much detail to require in solicitation documents, as the formal requirements will influence how carefully partners plan aspects of the proposed alliance.

Award Negotiation and Annual Continuation

During the funding negotiations, the program officer emphasized collaborative practice in several ways, beginning with creating an explicit alliance structure for equitable engagement across partners. As a result, each institutional partner submitted a collaborative research proposal to lead specific elements of the alliance. Further, each partner appointed a coordinator for their institution to support the alliance while the lead institution appointed an overall alliance director.

An AGEP program officer directed the external evaluation team to prioritize collaborative practice in the evaluation over effectiveness of individual intervention elements. The program officer also suggested an internal evaluator from the lead institution as a member of the leadership team, and that faculty with evaluation expertise serve on the advisory board. Finally, the program officer supported using the American Evaluation Association[7] as a source for relevant expertise. The evaluation team recruited both evaluation experts through their association with AEA. The external evaluators actively participate in AEA and serve leadership roles in the STEM Education and Training Topical Interest Group (TIG).[8] This involvement allowed the external evaluators to quickly locate appropriate evaluation expertise for our alliance.

Ongoing approval of alliance funding was dependent on submitting annual reporting documents as well as participating in site visits guided by NSF staff. For example, in response to a site visit held in year two of our alliance, supplemental support provided for face-to-face annual meetings improved the quality of alliance engagement and collaboration among alliance stakeholders. Increased funding also supported participation of the evaluation team in AGEP COP programming, along with a specific COP dedicated to evaluation capacity building. From our experience as evaluators, the program officers of the AGEP program have directly and deeply engaged with the partners of all 27 alliances that have been funded since 2013. All these actions during the negotiation and continuation discussions represent significant support of collaborative and equitable practice by the program sponsor.

Partners and Participants (P)

Program partners and participants:

1. recruit program partners
2. design, prepare and submit a detailed proposal to the sponsoring organization, including elements related to collaborative practice
3. implement the program with participants recruited from partner institutions

[7]https://www.eval.org/

[8]https://comm.eval.org/stemeducationandtraining/home

4. participate in AGEP COP activities (such as an annual research conference)
5. study and disseminate findings to NSF in an annual report
6. submit presentations and publications to the larger academic community

Program partners plan and implement collaborative practice as part of a funded program, guided both by sponsor requirements and supported by credible research. Planning begins at the proposal phase with the selection of institutional partners and the proposal preparation process used to design the partnership program. One way to infer the value project partners placed on collaborative practice was inclusion in proposal documents and project models. Upon funding, the focus on collaborative practice shifts to how the alliance leadership team works together to launch the partnership, recruit the participant cohort, and implement planned activities of the alliance model over time.

Not only is collaborative practice used by the alliance leadership team to implement partnership activities, once the leadership team recruits the participant cohort, they become actively involved in collaborative practice as part of their alliance participation as scholars from groups historically underrepresented in STEM fields in the academy. The program evaluation focused not only on how collaborative practice improved partnership performance in implementing the model, but also how it promoted academic success and scholarly productivity, psychosocial adjustment, and physical and psychological well-being in the participant cohort.

While the evaluation team examined the role of collaborative practice over the lifecycle of our alliance across all stakeholders, the following two sections will focus on collaborative practice findings relevant to our alliance leadership team during proposal, launch, recruitment, and project implementation phases of the alliance. The implementation discussion also highlights academic and psychosocial benefits of collaborative alliance activities identified by cohort participants. The authors consider this to be one of the most important findings of our alliance evaluation to date.

Collaborative Planning

The alliance team leveraged several collaborative strategies in developing our alliance AGEP proposal. Foremost, the alliance team built our alliance upon an existing AGEP partnership, proposing a new AGEP alliance model for implementation in the same university system. The four university partners came from the prior alliance, as did most of the cohort participants. Selection of the external evaluation team by the AGEP alliance occurred as a direct result of collaborative work in another NSF partnership community, the National Research Traineeship (NRT) program.[9] Representatives from NRT partnerships engaged in a cross-partnership interactive planning activity during an NRT Evaluator's Workshop, which eventually led to the authors joining our AGEP alliance as external evaluators. Evaluators were involved from the initiation of the proposal process, ideal for proper alignment of program and evaluation design (Kelly and Burr, 2019). In these examples, preexisting collaborative connections facilitated the formation of the current alliance.

Facilitated collaborative grant planning and writing commenced several months preceding the proposal deadline. Professional facilitators appointed by the lead institution guided the leadership team in proposal development. With a large leadership team, this was an important aspect of the proposal process. Consultants who can facilitate a collaborative grant-writing process are an asset to any partnership project. Research Development offices are often useful resources for this expertise. There are also tools and protocols designed to facilitate this process. The National Organization of Research and Development Professionals provides information about these types of resources.[10]

Collaborative Implementation

Once funded, our alliance undertook the difficult yet transformative work of evolving collaborative practice across all alliance stakeholders. Using the five entry points of the CEIF framework to explore collaborative practice in our alliance for evaluation purposes, the next section "**Assessment and Evaluation Professionals (A)**" on assessment and evaluation summarizes evidence of the evolution of collaborative practice across the alliance leadership team to facilitate partner equity, improve cohort engagement, and increase the breadth of program dissemination.

In thinking about other benefits of collaborative practice beyond improving partnership performance in meeting stated goals, one event during the third year of our alliance created opportunities to recognize and document benefits of collaborative practice on academic, psychosocial, and well-being outcomes. This event was none other than the coronavirus pandemic that stopped the world in its tracks with citizens quarantined in their homes early in 2020.

The entire AGEP community had to consider changes in program implementation due to national and international restrictions on movement outside the home. Because most alliances have partners separated geographically, virtual technology was already a part of most alliance operations, including ours. Our AGEP alliance adjusted most programming to a purely virtual environment and managed the impact on the grant budget in response to the pandemic. Activities that engaged cohort participants in place-based professional development experiences were most impacted by the restrictions of coronavirus on travel, including institutional visits to international and HBCU destinations. While most work was and continues remotely, it is not possible to fully replace the place-based experiences planned for these activities. The local institutional teams are planning to complete implementation on a delayed timeline.

Considering the importance of face-to-face activities in the development of collaborative groups, the leadership team was particularly concerned about having to conduct the annual

[9]https://beta.nsf.gov/funding/opportunities/national-science-foundation-research-traineeship-program

[10]https://www.nordp.org/resource-links

all-alliance meeting planned for June 2020 using the Zoom platform. The leadership team understood the importance of bringing all alliance partners together and made deliberate efforts to make the virtual experience engaging and meaningful. The engagement in the virtual space was successful—the emotional reaction to the meeting was palpable in the faces, voices, and chat comments of the participants.

The evaluation team took advantage of data provided by the virtual platform to describe what happened (**Table 1**). **Table 2** summarizes attendance and chat narrative that supports the successful engagement of alliance stakeholders. The average number of chats each cohort participant received from attendees about their individual presentations provided direct evidence of the affirmation of cohort participants during the virtual meeting. Some of these messages included offers to connect cohort members to career resources.

Stated outcomes for alliance cohort participants on the logic model (**Figure 3**) include the reduction of barriers, stressors and negative feelings as well as fostering academic identity and connections. Through active engagement in a cohort configuration, alliance participants had opportunities to develop relationships, trust, and a COP among their cohort peers while participating in workshops focused on academic skills development. Regular scholarly learning community (SLC) meetings facilitated ongoing connections among participants and with leadership team faculty during the height of the pandemic. Cohort participants indicated that they continued their own COP outside the alliance (Kelly et al., 2021), and that informal interactions outside of the project were most impactful in building trust and forming bonds. Cohort participants claimed the connections among their cohort peers were essential for their persistence in the academy. The mutual respect, pride, and affection among cohort members provides meaningful and substantive psychosocial support, which promotes both wellness and academic persistence among cohort participants.

Assessment and Evaluation Professionals (A)

The evaluation team:

1. assists in the design of the program during the proposal phase
2. provides expertise in logic and program modeling
3. develops survey and assessment instruments
4. offers experience in human subjects' protections
5. designs formative and summative evaluation plans
6. implements the program evaluation
7. provides formative feedback at monthly leadership meetings
8. provides summative feedback in an annual evaluation report
9. disseminates findings in presentations and publications to the AGEP and academic communities.

As the AEPs for our alliance, the authors chose to make the evolution of collaborative practice the primary focus of annual program evaluation. This was also a recommendation of the NSF program officer during grant negotiations. By highlighting the value of collaborative practice in evaluation findings and recommending actions to improve collaboration practice among stakeholders, AEPs encourage attention to the evolution of collaborative practice across the academic ecology. Findings in the following sections reflect the five entry points of the CEIF (Woodland and Hutton, 2012, summarized in section "Self-report Instruments and Interview Protocols"), and include defining each entry point, identifying key constructs and measurement strategies, and summarizing supporting data drawn from our AGEP alliance.

Operationalize the Construct of Collaboration

Operationalizing collaborative practice refers to identifying collaboration structures and strategies to guide partnership functioning. There is a need to identify what collaborative practice looks like in the context of our AGEP alliance, creating a shared understanding across stakeholder groups. This is related to the need for intentionality in developing an effective partnership discussed in the introduction. Recall that literature supports improving partnership functioning through collaborative practice.

The size of our overall alliance leadership team required explicit attention to coordination and communication strategies, the underpinnings of collaborative practice. Further, the varied sizes of local institutional teams motivated the leadership team to develop additional strategies to ensure the equitable participation of all partners in decision-making and input into administrative alliance discussions. In the first two years of funding, the alliance leadership team applied feedback from evaluators, the advisory board, and during NSF site visits to improve alliance coordination and communication in service of program implementation.

Meeting protocols used the Zoom platform, recorded for asynchronous viewing. Local institutional team meetings typically occurred the week before monthly leadership team meetings engaging all partners in collaborative planning and discussion. Structures to facilitate effective meetings included attendance and roll call strategies to ensure partner input during decision-making discussions, bounding meeting discussions in time with standardized agendas, and providing minutes and materials from each meeting to all attendees.

Each institution designated a project coordinator to facilitate collaborative practice on behalf of the institutional partner. The lead institution appointed the alliance director, who served as the coordination point for alliance operations. A single point of contact for the overall alliance as well as for each partner institution ensured a high degree of coordination. The director launched the use of project management software (Trello), centralized file sharing (dedicated partnership Google drive), and centralized record keeping (master spreadsheet to track activity delivery and attendance).

In annual interviews, leadership team members acknowledged increased alliance coordination over time because of these actions. While all these strategies were helpful, differing levels of experience and comfort with selected technologies across the leadership team resulted in incomplete adoption. While

TABLE 2 | Participation results from virtual annual meeting.

Role Group	Attendees		Participated in chat		Total chats submitted	
	n	%	*n*	%	*n*	%
AGEP cohort	9	100	9	100	141	27
PI/Co-PI	15	100	12	80	94	18
Senior personnel	4	100	4	100	63	12
Support staff	5	100	5	100	62	12
Evaluator	2	100	2	100	27	5
Graduate assistant	2	67	1	50	1	1
Postdoc	1	100	1	100	20	4
Advisor/mentor	12	71	9	75	69	13
Alliance Advisory Board	6	100	4	67	22	4
Social Science Advisory Board	4	80	4	100	14	3
NSF Program Officer	1	100	1	100	3	1
Total	61	93	52	85	516	100

they understood their importance, many leadership team members noted feeling inundated at times with the constant flow of emails and details from the director. These issues are difficult to balance entirely across such a large team. In all, the leadership team made concerted efforts over time to improve collaborative practice across a large team through the strategic coordination of information.

Map Communities of Practice

Mapping communities of practice entails tracking interactions among alliance stakeholders. The activities of our alliance occurred through a network of collaboration. Indeed, the work of most partnership projects occurs at the level of interacting stakeholders across a network of stakeholders. Thus, these connections represent the implementation of the alliance across the academic ecology. Social network analysis and mapping tools effectively model these collaborative networks.

The evaluation team asked each interviewee to identify those with whom they interacted in a substantive way during each year of our alliance. Using these data, analysis examined levels of connection (how many times each alliance member was identified as a collaborator). Connection maps, which represented who is collaborating by connecting two nodes (persons of partnering institutions) in the network with a line, model these connections across all partners (see **Figure 6**).

Four networking levels represented the number of times each partner was named as a collaborator: Very High (being identified 10 or more times), High (six to nine times), Low (four or five times), and Very Low (three times or less). The alliance PI and the alliance director were identified as Very High each year (essential connections). Partners identified as High were activity leads and coordinators who typically collaborated with those on their campus and with a few others across institutions. Individuals identified as Low or Very Low in connections tended to be those who were new to the project or worked primarily within their institution, with fewer connections outside their local team.

Over four years, eight additional leadership team members were identified as Very High. While only one campus had Very High partners in the first year, three campuses had Very High partners in the second and third years of the program, and all four institutional partners had Very High representatives by the fourth year. While three of the four institutions gradually increased networking over the course of the project, one institution showed decreased networking. Interview comments corroborated the network data, as members of the institutional team expressed feeling disconnected from decision-making and activity implementation. In another case, increasing collaboration with partners across institutional teams compensated for the lack of connection experienced with members of the local team. This also promoted increased alignment of alliance activities that provided complementary benefits (job search and preparation activities aligned to skills development activities).

Social network analysis helped identify patterns of collaboration among members of the leadership team over the duration of the grant. The network maps in **Figure 6** illustrate the density of the network connections among team members each grant year. It depicts connections both within and across institutional boundaries. Immediately, it is easy to see that the density of network connections increases over time. Using this network data, the degree of centrality calculation is conceptually like levels of engagement. Over time, centrality spread from one or two members in the first two years to several members by the fourth year. At the beginning of the project, most of the contacts were from the alliance director toward the leadership team members across partnering institutions. From the second year onward, the alliance director becomes the heart of the network (higher degree of centrality). The national evaluation of the NSF AGEP program emphasized the importance of having project directors for alliance stability (American Institutes for Research, 2011).

In particular, the cohort participants indicated how important their relationship with the alliance director was in their project engagement and expressed distress at the turnover in the position in the third and fourth years of the alliance. The turnover of the alliance director role affected participants' experience of project continuity and commitment, and members of the leadership team expressed similar sentiments during interviews.

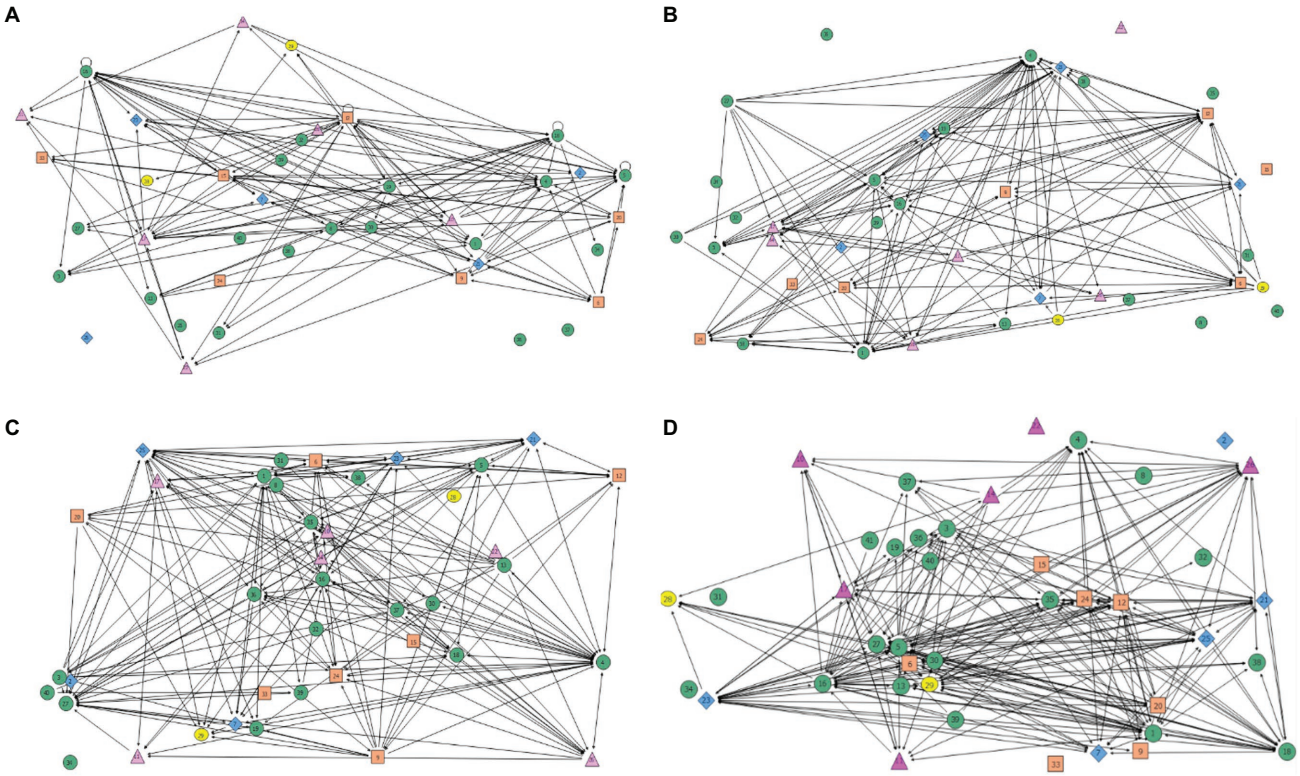

FIGURE 6 | Annual Collaboration Network Diagrams Across AGEP Alliance Institutional Leadership Teams. Each color/shape represents an institutional partner, with individual members designated by random numbers. Panels **(A–D)** show the evolution of connections across the four years of the alliance.

The centrality analysis also indicated that internal and external evaluators increased their centrality over the years, with alliance members seeing evaluators more as team members over time. The overall point is that network analysis provides valuable information about how individual partners collaborate. This is useful both for confirmatory analysis as well as a design tool to look for places to encourage or strengthen connections and monitor network growth in response to programming decisions.

Monitor Stages of Development

As reviewed in section "Self-report Instruments and Interview Protocols," Woodland and Hutton (2012) noted that collaborative teams follow predictable stages of development including: assemble/form, storm/order, norm/perform, and transform/adjourn. The CEIF provides a set of questions addressing the pertinent issues that arise during each stage of development, reflecting the typical progression of a partnership's function over its lifecycle. Questions are both repeated and replaced over time, providing information about developmental changes in partnership functioning. These questions also serve as an important reminder that partnerships should expect to progress through stages of development, each with its setbacks and victories. The progression of our alliance through these stages benchmarks the development of collaborative practice over the lifecycle of the grant.

Proposals identify preliminary levels of collaboration for activities associated with the assemble/form and storm/order stages of development. The assemble/form stage occurred during the first year and the early part of the second year of the funded alliance. As in the discussion about operationalizing collaborative practice, the assemble/form stage of development includes building shared understanding around goals, enacting governance structures, strategies, and leadership.

The program evaluation report articulated the need for shared understanding of the goal of the partnership project and how to conceptualize the alliance model, and a site visit panel provided similar feedback. Shared understanding of the project goal and the alliance model improved over the lifespan of the alliance through alliance wide discussions of stakeholder feedback, with the leadership team members making the shift from an intervention-focused model to an alliance wide partnership model. Answers to annually repeated interview questions about partnership progress toward goals served as data. The similarity of experiences negotiating understanding of the model vs. the intervention shared by many alliance teams suggests this shift is a common event in the developmental trajectory of an AGEP alliance.

The storm/order stage occurred during the first year and continued during the second year of the funded alliance. During this stage, the alliance moves forward with a shared vision, and the business of preparing for activity

implementation begins. Storm/order is a descriptive name for this stage, reflecting the often urgent and sometimes chaotic processes of coordinating timelines for the range of alliance activities and providing a coherent plan for the cohort participants to anticipate. At first, coordination was lacking and cohort participants requested more proactive timelines. Planning for data collection needs from cohort participants lacked coordination across institutional teams. Institutional teams collected information for planning purposes from the participant cohort separately rather than employing a centralized strategy that better controlled the burden on participants. This approach left both the leadership team and the cohort participants with a disconnected view of the overall alliance model. Part of the reason for this disconnection was the partnership structure. A consequence of increasing the equitable engagement of all partners in the alliance model through institution specific roles was a siloing effect, limiting information transfer across activities and increasing the difficulty of alliance coordination across activities.

As practice makes perfect, so did time on task improve coordination among alliance partners. After the ordering phase of a partnership, members proceed to the norm/perform stage. The norm/perform stage began toward the end of the second year and continued through the third and fourth years of the funded alliance. The primary focus is the implementation of planned activities to accomplish outcomes in service of our alliance goal, considered the main operational phase of the funded partnership. During the third year of the alliance, the, the coronavirus pandemic disrupted global operations. As previously discussed in Collaborative Implementation, all alliances had to immediately reassess their implementation plans and associated budget allocations.

Our alliance demonstrated an ability to adjust programming and still provide high quality experiences to alliance stakeholders, such as a highly successful virtual annual meeting. While our alliance completed most planned activities despite the limitations imposed by the pandemic, all the stakeholders remain engaged in completing the remaining activities, including those displaced due to the pandemic. As our alliance enters its fifth and final year, implementation of the project continues, shifting over time as some activities conclude and cohort participants transition into postgraduate and early career faculty roles. The content of alliance activities shifts as well to address the concerns of cohort participants in postdoctoral and faculty roles rather than as dissertators.

The transform/adjourn stage began in the fourth year and is continuing into the fifth and final year of our funded alliance. This stage, referred to as transform/adjourn, reflects the transition of the primary focus of the partnership from project implementation to reporting, dissemination, and sustainability. While our alliance has engaged in dissemination activities throughout our alliance lifecycle, it is of particular focus toward the end of a partnership. Given the purpose of federal funding agencies to share and replicate best practices, our AGEP alliance developed a formal dissemination plan. This plan involves a constellation of venues, from peer-reviewed journals to conferences and communities of practice in research, education, evaluation, and broadening participation.

Our alliance is currently developing web pages to showcase our scholarly contributions to a public readership. Leadership team members are also developing a virtual toolkit to share best practices based on our alliance model more broadly. As a result of reliance on the virtual mode of content delivery during the coronavirus pandemic, our alliance utilized a range of virtual tools to increase engagement and enhance program delivery on digital conferencing platforms like Zoom. The toolkit will showcase this repertoire of virtual tools. While the pandemic profoundly disrupted global society and higher education, it also provided a space for new knowledge to arise, and the emphasis on virtual technology as a tool to combat isolation and oppression is one example.

Assess Levels of Integration

The CEIF suggests an important feature of a partnership is the integration of activities across partners (Woodland and Hutton, 2012). Integration exists as a continuum that ranges from lower to higher levels of integration. At the lower end, partners simply share information or resources in a cooperative fashion. In the middle, partners coordinate more closely to accomplish the goals of the partnership, a co-hosting arrangement. At the high end, collaboration requires an effortful, yet beneficial, merging of mission, materials, and processes. An important clarification is that optimal levels of integration will depend upon the needs of the partnership, and integration may vary across functional domains.

Each year, the evaluation team used the LOIR to assess and describe the functioning of the strategic partnership. The levels of integration range from cooperation (sharing) to coordination (co-hosting) to collaboration (merging) using a grading scale of A (lowest) to E (highest). Each leadership team rated integration each year across five functional domains: communication, leadership, members, decision-making, and resources.

Figure 7 illustrates findings from four of the five domains across four years of the funded alliance. Alliance members rarely selected rubric scores of A and B, indicating that for collaborative constructs under consideration, alliance members established relationships that went beyond simply sharing to co-hosting and collaboration, reflecting more integrated partnering. Ratings in **Figure 7D** show that ratings of decision-making varied over the first three years, but converged to ratings D and E in the fourth year, reflecting a more consistent perception of collaboration.

Regarding the resources domain, recall that grant negotiations with the program officer resulted in independent budgets allocated to each institution based on assigned activities. This reflects a sharing arrangement, which is at the lower end of the integration rubric. Leadership team members consistently reported difficulty in applying the rubric to the resources domain, and many chose not to answer because integration did not seem to apply as the budgets were independent. Taken in sum, data from the LOIR reflected changes in the perceptions of integration over time and domain in response to programmatic decisions and progress.

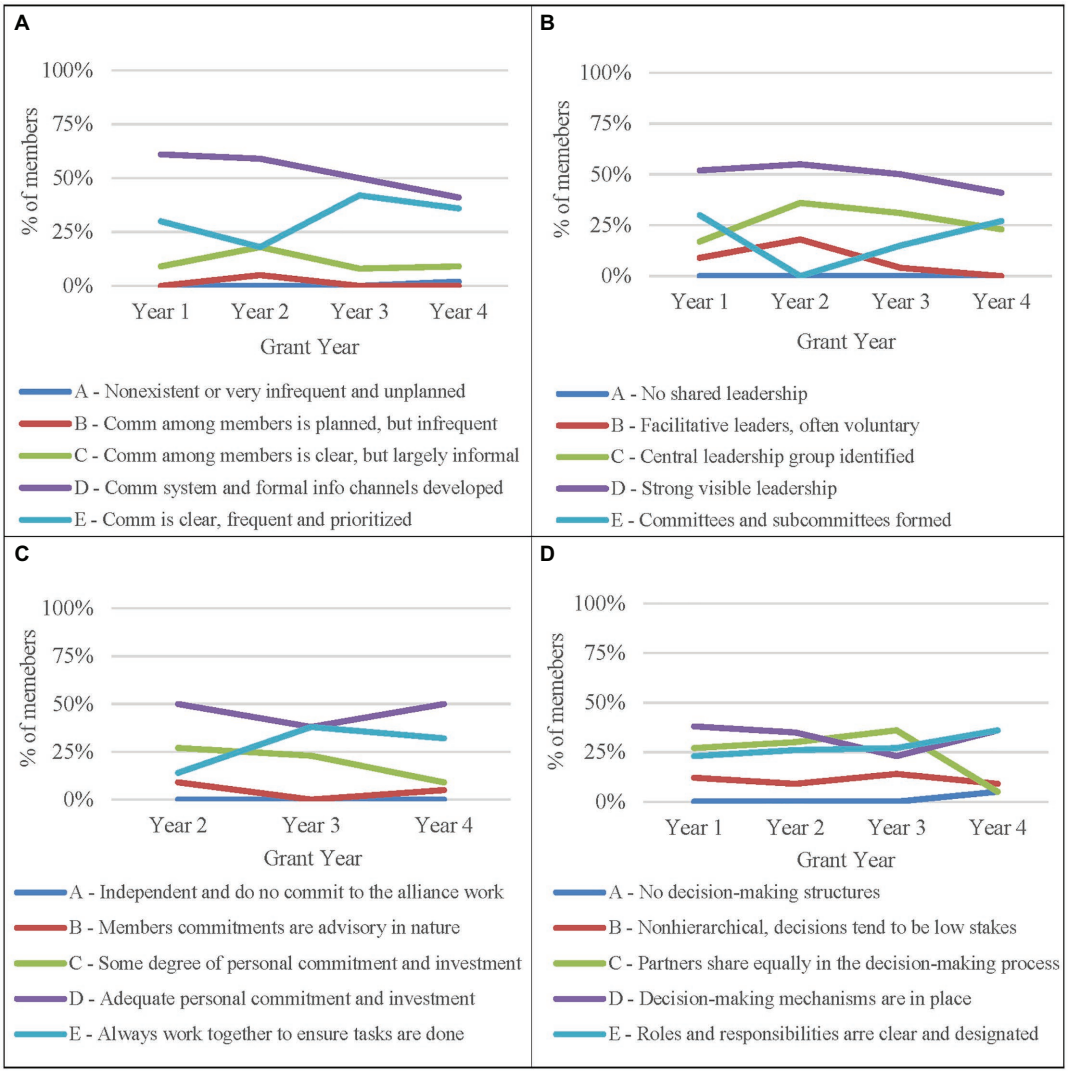

FIGURE 7 | Annual Levels of Organizational Integration for Communication, Leadership, Members, and Decision-Making.

Assess Cycles of Inquiry

The final CEIF entry point, assessing cycles of inquiry, focuses on how partners engage in data-driven dialog, decision-making, and action. As partnerships proceed through stages of development, how do stakeholders negotiate change? Change is expected and important in a partnership project. NSF has a section in annual reporting that specifically addresses changes in scope, budget, or implementation that occur during the lifecycle of a funded project.[11]

Using a feedback response cycle (**Figure 8**), the evaluation team examined how the alliance leadership team engaged in seeking feedback and implementing changes in alliance function. Sources of feedback, or inputs into the feedback cycle, were numerous. These inputs included annual evaluation and reporting requirements, alliance annual meetings, site visits and negotiations with NSF, and annual advisory board meetings. Faculty experts served on advisory boards, one to advise our overall alliance model, and another focused on advising the social science research component of our alliance. Composition of the advisory boards was part of initial grant negotiations with the program officer to ensure a proper range of expertise among members in advising our alliance.

The alliance leadership team was not only open to receiving feedback, but actively sought it. An important development was establishing advisory boards to represent the cohort participants. Seeking feedback on behalf of the cohort participants regarding the content and direction of alliance activities became increasingly important over the lifecycle of the grant. This was in part due to increasing needs for customized and just in time support as cohort participants' trajectories to the professoriate tended to diverge over time.

With so many sources of feedback, a systematic approach for responding to and incorporating recommended changes

[11]https://www.research.gov/research-web/content/aboutprojectreports

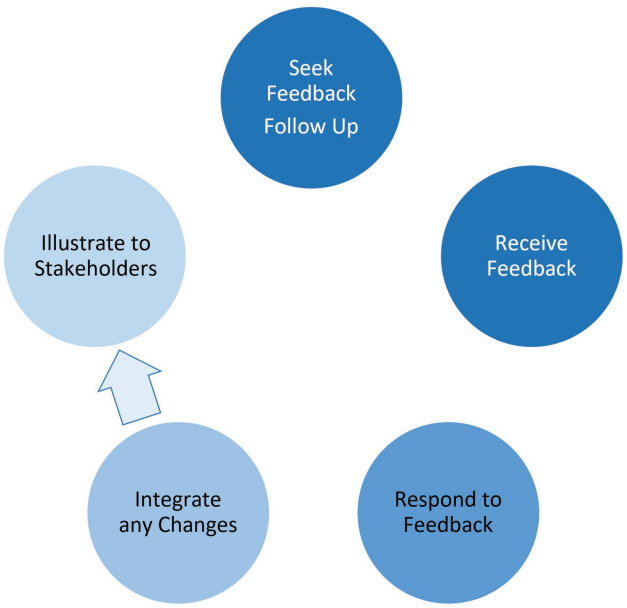

FIGURE 8 | Feedback Response Cycle for Managing Change in the AGEP Alliance. The lighter circles illustrate incomplete attention to bringing evidence of change back to stakeholders.

improves the potential for feedback to serve its purpose in improving alliance function. One approach in response to feedback from advisory board members was to organize the feedback in structured response documents that integrated the feedback and leadership team responses in a two-column format. This approach engaged leadership team members in dialog about how to address given feedback on a point-by-point basis.

The next step in the response cycle was for the leadership team to implement these responses or suggested solutions. An analysis of responses to advisory board feedback provided in the first two years of the program suggested that alliance members were least able to implement feedback in relation to improving model development, and better at creating collaboration and connection among alliance partners and cohort participants, connecting social science research to cohort members, and adopting specific dissemination plans for research.

During the virtual annual meeting held in June 2020, an advisory board member expressed interest in seeing how the leadership team incorporated previous feedback provided by the board. This comment revealed a gap in the feedback response cycle of illustrating the results of feedback, which brings the feedback process full circle to follow up in seeking continued feedback. Further, integrating and tracking feedback across sources and over time would provide a visible and coherent approach to engaging in meaningful cycles of inquiry, driving the improvement process.

Researchers in Academia (R)

Program and evaluation stakeholders:

1. have a reciprocal relationship to the academic research base
2. use the research base to design project elements, best practices, measure outcomes
3. learn about and contribute findings to the research base:
   a. AGEP sponsored conferences, webinars, and workshops
   b. aligned conferences and communities of practice
   c. publications in education, evaluation, and social science research journals

The introduction began with a discussion based on prior research of the benefits and burdens of collaborative practice. The academic research base is a product of prevailing scientific practice and the national and global intellectual climate regarding the value of collaborative practice. Stakeholders engage in reciprocal relationships with the research base on collaborative practice, both relying on it to inform their practice and shaping it with the results of that practice—the goal of the academic enterprise. For example, this current paper is a carefully considered contribution to collaboration research informed by the academic research base. For our alliance to progress beyond localized impacts of implemented activities, our leadership team must promote systematic engagement with the research community beyond our alliance. The dissemination of alliance findings to the larger academic community is an expectation for all AGEP alliances.

While the peer-reviewed literature is the gold standard of academic research, it is but one of a set of practices that can effectively disseminate findings and best practices to communities of interested researchers and practitioners. The following two sections are particularly important in the collaborative practice discussion, as they illustrate two structures with potential for widespread impact across the academic ecology. These are collaborative writing and dissemination practices across stakeholders as well as the engagement of our alliance stakeholders in a robust community of practice with the entire community of AGEP alliances.

Collaborative Dissemination

NSF program officers review alliance progress disseminating results from the development, implementation, and study of our AGEP alliance model as part of the annual reporting process. As part of grant negotiations with the program officer, the leadership team generated a detailed dissemination plan for education, evaluation, and social science research presentations and publications over the lifecycle of our funded alliance. The timeline itemized the title, research questions, first author, other authors, type of product (Conference, Journal, Instrument), and submission date.

While the need for dissemination support to fulfill the promised timeline was not evident during proposal development, it became so over the alliance lifecycle. Consider the requirements to successfully publish in peer review journals: both NSF and the partnering institutions require IRB approval for instrument selection, development, and acquisition procedures to collect data from human subjects. Limited capacity for consistent coordination of the alliance IRB application and amendments in the local team at the lead institution shifted the burden to the internal evaluator. This highlights the need to ensure the appropriate assignment of IRB responsibility and maintenance as part of the leadership team's management responsibilities, particularly when management requires coordination across

multiple university partners. Based on feedback from cohort participants, more careful coordination of data collection needs reduces the number of times cohort participants are asked to respond to queries and provides a comfortable time period in which to respond. Minimizing burden on cohort participants is particularly important in alliances with a large leadership team and requires considerable coordination.

A consequence of the evaluation team's focus on collaborative practice was limited capacity to generate data for the education research included in each institution's dissemination plan. The primary responsibility for instrument design, data collection, analysis, and dissemination of education research shifted to local institutional team members. The shift impacted some institutional teams more than others. A number of leadership team members were simply not familiar with research methods employed in education and social science research and required interdisciplinary collaboration with leadership team members who were. In particular, the evaluation team and faculty from the lead institution's teaching center for excellence assisted institutional teams with dissemination products. The leadership team also sought input on dissemination strategies during advisory board meetings, conferences, and site visits.

To provide more direct support of stakeholders to achieve planned dissemination products, the evaluation team identified several strategies that successfully engaged alliance stakeholders in collaborative writing practices. These practices support scholarly productivity in team environments. A brief discussion of each collaborative practice follows, with each representing a different stakeholder team:

1. dissemination product teams
2. toolkit working group
3. synchronous writing circles

Dissemination product teams worked with a dissemination support consultant using virtual, shared, and synchronous spaces to prepare products to submit for publication and presentation. The consultant developed a needs assessment to review product status and initiate a work plan based on a collaborative approach to academic writing (Belcher, 2019). In the current context, the core structural practices to support dissemination teams are backward planning from identified product and submission requirements, writing with consistent focus on the argument the product is making, and working from a structured outline of the content using an accurately formatted draft document. The core behavioral strategies that build successful writing practices are the same as those that build successful habits: do not do it alone, do it daily, and do it in manageable pieces.

The toolkit working group assists leadership and institutional teams in sharing the alliance model with others in a public, accessible, durable, and virtual space. The toolkit development process employs a working group model organized around a charge. Shared interactive templates and drafted examples using accessible technology tools guided the structure and content of alliance activities and assisted institutional teams in gathering and presenting relevant details in the toolkit. The working group continues to draft the templates and examples with feedback from the leadership team during monthly meetings. This type of structure guarantees a consistent, accessible, and thorough description of alliance activities. The team is committed to employing technologies that are interactive and entice users to want to know more.

A final example engaged cohort participants in synchronous writing circles, a uniquely structured approach in which participants generated relevant academic content simultaneously during weekly virtual sessions lasting around one hour. During the spring of the fourth year, the lead faculty of the job search and preparation activity engaged cohort participants on specific job support activities such as research proposals or academic portfolios. A typical session would be to define the writing activity (write a specific aims section of a grant proposal) for 5–15 minutes, each circle participant works on their own writing for 30–45 minutes but remains active on the call or webinar, and each participant shares out about progress made for the final 5–15 minutes.

During the annual meeting held in July 2021, the activity team lead described the development and function of the circles. The cohort participants indicated their experience in these collaborative writing sessions as particularly helpful because being part of weekly sessions guaranteed hours of writing productivity on something relevant; each person was doing something similar but customized to their particular research interests. The common experience reinforced motivation and commitment, and the meeting structure helped create writing as a repeatable, accessible practice. A recent article in the Chronicle of Higher Education highlights a group that used a collaborative writing retreat to complete an edited collection volume about the origins of modern food habits.[12] The most important lessons in these dissemination examples are recognizing that writing does not have to be solitary, and in fact should not be. Further, providing more direct support of planned dissemination products through dedicated personnel and collaborative writing practices are effective ways to increase scholarly productivity in alliance stakeholders.

AGEP Community of Practice

The mechanisms NSF program officers employed to engage the AGEP COP are worthy of emulation by other sponsoring programs desiring facilitated collaborative practice among a set of funded projects with similar goals. Our alliance took advantage of most if not all the AGEP COP offerings. NSF engages AGEP community members in a variety of activities including proposal review and site visit teams. Participating in these activities has been a valuable professional development opportunity for members of our alliance.

The AGEP program also supports conference hosting and attendance (e.g., the Boston AGEP National Research Conference (NRC);[13] Boston University, 2021). Indeed, an NRC conference served as the catalyst for this paper and the others included

[12]https://www.chronicle.com/article/lessons-for-academics-from-a-weekend-writing-retreat?cid2=gen_login_refresh&cid=gen_sign_in

[13]https://live.bu.edu/agep/

in this special journal issue focused on diversifying the STEM professoriate (California Alliance, 2018). Our alliance has been an active participant in annual AGEP NRCs, sharing research and insights with the larger AGEP community. For example, our alliance shared an abbreviated version of our successful June 2020 annual alliance meeting with the AGEP COP during a workshop offered at the November 2020 NRC (Morris et al., 2020).

The AGEP program invested in building capacity in evaluation practices as demonstrated by their support of an Evaluation Capacity Building Conference[14] (ECBC; Education Development Center (EDC), 2021) and building collaborative practice through their INCLUDES coordination hub[15] (NSF, 2021b). The evaluation team started exploring the evolution of the SPARC model beyond the borders of our alliance to a focus on collaborative practice as reflected at the AGEP community level to develop shared conceptualizations and assessments of collaborative practice across alliances (Kelly et al., 2020b). They also sponsored a discussion at an ECBC webinar at the invitation of the team at EDC, engaging AGEP evaluators in a discussion and reflection about the evaluation of collaboration in their alliances (Kelly, 2021). Leveraging results across alliances allows stronger inferences about the impact of collaborative practice on stakeholders across the academic ecology and can build a shared understanding across the AGEP portfolio of 122 unique institutions of higher education. The critical point of these dissemination activities is to highlight the opportunities provided to work with the larger AGEP COP and how these opportunities enrich the research community dedicated to diversifying the professoriate.

Community and Society at Large (C)

The entire academic ecology benefits when successful partnership projects:

1. support DEI in higher education and in the resulting STEM workforce
2. respond to contextual events in flexible and adaptable ways
3. expand knowledge, practices, and opportunities to benefit from collaborative practice in the partnership over time
4. encourage the transfer of best practices in collaborative practice to other partnerships and stakeholders to increase broader impacts
5. collaborate with other partnerships and stakeholders to expand research on collaborative practice generated by the AGEP COP

The larger academic and global (C)ommunity dictates the value of collaborative practice across stakeholders in the academic ecology. The value of collaborative practice is reflected in stakeholder perceptions of the positive impact of collaboration on project outcomes and by popular "demand" or adoption by others. In keeping with the focus of this special issue, the authors focus on the implications of the SPARC model for supporting DEI in higher education and pathways leading to diversification of the professoriate. The evaluation team of our alliance identified four collaborative practices that show promise for advancing DEI in higher education: advocacy roles for SPARC stakeholders, focus on well-being of academy scholars, virtual technologies to promote inclusive and equitable practices, and safe spaces for discussions about institutional racism and related topics.

The SPARC model emphasizes the role that AEPs can serve to facilitate the use of collaborative practice and its afforded benefits. It also emphasizes that all stakeholders in the AGEP ecology share responsibility for conceptualizing and actualizing collaborative practice. Stakeholders have power to influence their context—to use available avenues of expression to support the value of collaborative practice in service of DEI in the academy. Recent policy from AEA suggests that credible evaluation requires explicitly addressing DEI in the implementing context. In other words, evaluators are ethically obligated to advocate for social justice and cultural responsiveness in all evaluation activities.[16]

The pandemic provides a unique opportunity for research, as evidence continues to accumulate about how our thoughts, behaviors, leisure, work, and relationship with technology has changed. NSF issued a Dear Colleague Letter inviting the research community to think about critical research to capture during the pandemic period.[17] Taking to heart the lessons learned during this unique time in history confirms the primary need to attend to the well-being of scholars from groups historically underrepresented in STEM fields in the academy, particularly in times of challenge. The medium of collaborative practice is one pathway to support well-being and academic success. Examples from our alliance were the virtual annual meeting and the monthly meetings of the SLC during the forced isolation period.

Due to the reliance on virtual meeting tools during the period of forced isolation, the evaluation team is studying the impact of technological tools used by alliances to promote inclusive and equitable practices in virtual spaces. The success of the annual meeting suggested that specific efforts to increase engagement through interactive tools can have positive results. Virtual technologies can also orchestrate interactions that ensure all participants engage in the content and provide feedback, an empowerment evaluation approach (Fetterman et al., 2017). A recent article suggested that remote learning can be used in similar ways to displace the roles of power and privilege that dominate the traditional classroom experience by decentralizing the teacher in learning, giving the power of engagement to the learners, increasing accessibility of information across multiple modalities, and employing equitable participation strategies to include everyone's views.[18] Both synchronous and asynchronous opportunities to view content across multiple

[14]https://agep-ecbc.edc.org/
[15]https://www.includesnetwork.org/home
[16]https://www.eval.org/About/About-AEA/Mission-Vision-Values
[17]https://www.nsf.gov/pubs/2020/nsf20052/nsf20052.jsp
[18]https://www.edsurge.com/news/2021-09-06-how-remote-learning-subverts-power-and-privilege-in-higher-education

modalities increases stakeholder access to information in ways most useful to them. The toolkit our alliance is developing will include a section that details interactive and inclusive technologies used by alliance stakeholders in providing alliance content to cohort participants or other alliance stakeholders.

The national dialog surrounding systemic racism and police brutality exploded upon the death of George Floyd by convicted felon Derek Chauvin. This incident, along with similar victims of police homicides, fueled the Black Lives Matter protest movement across the nation. Events such as the dispute at University of North Carolina in Chapel Hill over granting tenure to *1,619 Project* creator Nikole Hannah-Jones[19] and recent legislation forbidding discussion of critical race theory in public schools[20] further underline the urgency of our work to engage higher education in the challenge of achieving DEI across the academic ecology. As researchers concerned with DEI in the academy, it is critical to have forums to safely discuss these issues. From the perspective of the authors, the AGEP COP was not only a safe space in which to have an authentic dialog about these concerns, but also a community which considers this dialog an essential part of institutional change in higher education.

DISCUSSION

The goal of this method paper is to demonstrate the application of an evaluative model that spotlights collaborative practice across stakeholder groups in funded academic partnership programs. While this story reflects the perspective of our AGEP alliance, it mirrors the stories of other AGEP alliances. As such, it has relevance for the entire AGEP community and related STEM education partnership programs funded by NSF or other government sponsors.

The evaluation team summarized best practices and lessons learned for each SPARC stakeholder group into a reflection tool, the *SPARC Model Checklist for Collaborative Practice*. While targeted toward AEPs, other alliance stakeholders will find the checklist of value in their own collaborative practice. Given the goal of our alliance to promote diversification of the professoriate, the model highlights the benefits of collaborative practice in supporting stakeholders from groups historically underrepresented in STEM fields across outcome domains: partnership project implementation and performance, academic success and scholarly productivity, psychosocial adjustment, and physical and psychological well-being. The next section summarizes the content of the checklist. A full copy is available online.

SPARC Model

(S)ponsor

Sponsor requirements for partner collaboration and program management drive what Partners consider when planning programs. When seeking funding support through a sponsored program, consider how expectations for collaborative practice are negotiated and communicated throughout the period of support.

- Does the solicitation include language about collaboration?
- During award negotiations:
    - Is there a focus on collaborative practice?
    - Does the sponsor require an evaluation team and advisory board?
    - Does the sponsor require separate applications from each institution?
- Is there a community of practice promoted by the sponsor?

(P)rogram

Program partners and participants must necessarily work together to propose, develop, implement, and study the alliance model for diversifying the professoriate. Consider how partners and participants incorporated collaborative practice in the procurement and execution of the alliance program.

- Was the program planned collaboratively?
    - Has the program team leveraged prior collaborations?
    - Did the program team engage evaluators and advisory boards during planning?
    - Did the program team engage grant writers to facilitate writing the proposal?
- Is the program implemented collaboratively?
    - Has the program team organized itself to respond effectively to disruptions?
    - Is technology intentionally incorporated to facilitate collaboration?
    - Are annual meetings or retreats planned intentionally to facilitate connection and collaboration?
- Have the participants in the program self-organized to collaborate?

(A)ssessment and Evaluation Professionals

Evaluators have a unique opportunity to promote collaborative practice by structuring evaluation explicitly around it. They can promote equity in collaboration to ensure equal representation of views. They can regularly spotlight collaborative practices they observe and support team dissemination activities (e.g., promoting sharing of data, collaborative tools, and studies across alliances). Based on the adoption of the CEIF (Woodland and Hutton, 2012) as a framework for evaluating collaborative practice within the alliance, the following questions align to the five entry points identified on the CEIF.

[19]https://www.npr.org/2021/06/30/1011880598/after-contentious-debate-unc-grants-tenure-to-nikole-hannah-jones

[20]https://www.brookings.edu/blog/fixgov/2021/07/02/why-are-states-banning-critical-race-theory/

- Has your project team addressed how to operationalize collaborative practice?
    - Does the project team have a shared understanding of the program's goals?
    - Has the project team created well-defined and documented structures and procedures for collaborative practice?
    - Has the project team provided communities of practice for cohort participants?
- Are you tracking participants' and the team's engagement in the program's communities of practice?
    - How engaged are team members (i.e., number of members they engage with)?
    - Do team members' connection patterns within and across institutions change over time?
    - Is there an evaluation team with internal, external, and advisory board components?
    - Is there a program director or coordinator who has primary responsibility for alliance management?
- Are you adjusting the content of your annual assessments to align with your program team's status as they move through the stages of partnership development?
    - Forming: Are team members committed to a shared goal? Relationships established?
    - Norming: Have team members determined decision-making? Clarifying structures and processes?
    - Performing: Is the team focused on implementation? With minimal oversight?
    - Transforming: Is the team focused on dissemination and next steps for the partnership?
- Are you assessing the program team's levels of integration?
    - Are levels of integration consistent across stakeholders? Across institutions?
    - Do levels of integration change over time? For which categories?
    - Do levels of integration reflect desired levels of sharing, co-hosting, or collaboration? Do they suggest any issues in need of attention?
- Are you assessing the program team's cycles of inquiry?
    - Does the leadership team receive feedback from multiple sources (such as Advisory Boards, site visits, annual evaluation reports)?
    - Is the leadership team responsive to feedback in a concrete way?
    - Do team members share consistent opinions about how well their institutional team collaborates around data driven decision-making? How about the overall alliance team?

(R)esearchers

In the case of our AGEP alliance, we systemically contribute to the national conversation about the role of collaboration in partnership programs like AGEP through systematic dissemination. Based on our alliance work, consider the following questions about collaborative practice for alliances when thinking about research and dissemination.

- Does the program team use the academic research base to support their planning of collaborative practice?
- Does the program team have specific dissemination plans to share their alliance research or collaborative practice?
    - Do any team members require support for social science or education research?
    - Is there a team member with a clear responsibility for IRB coordination across institutions?
- Are team members engaging in group writing, coordinated workgroups, or other models of collaborative dissemination?
    - Would team members benefit from professional development in collaborative dissemination practices?
    - Would team members benefit from expert coaching or writing support?
- Do team members actively participate in the AGEP COP?
    - Do team members regularly share alliance work with the AGEP COP?
    - Have team members engaged in any collaborative work with other AGEP alliances?

(C)ommunity

The unprecedented health crisis and civil unrest of the past two years has forever altered the face of our national and global society. AGEP alliances occur within this context, and thus must remain responsive to the evolving conditions in which a program finds itself. Consider the following questions about being prepared for the future.

- Have alliance members considered how to promote the use of collaborative practice more broadly in diversifying the professoriate in their own role?
- Are there contingency plans in the case of disruptions to planned activities?
- Are mechanisms ensuring the well-being of all cohort participants in place?
- Are there safe spaces for the open discussion of concerns and solutions regarding DEI in the academy?

CONCLUSION

The evaluation team of our AGEP alliance recognized the increasing value of collaborative practice in the design, implementation, evaluation, and dissemination of findings in the partnership over time. Authors operationalized the SPARC model with a checklist to assist program stakeholders in designing for and assessing collaborative practice in support of project goals in funded academic partnership projects, emphasizing the contributions of collaborative practice in promoting diversification of the professoriate.

Before concluding, a word from our authors. During our work on the AGEP alliance, we were cognizant of the transformational contributions of this moment in time and reflective practice in creating the SPARC model of collaboration. The combination of a unique point in history with being intentional about learning from the experience created a mindfulness that guided us to important insights about collaborative practice. Engaging in reflective practice helps your brain make sense of the value of something to you and how you will use it (Bransford et al., 2000). Thus, our most important advice in conclusion is to be mindful and observant of the role of collaborative practice and how to structure it in a way that offers value to all group members.

Both a strength and a limitation of the SPARC model presented here is its "*post hoc*" rather than *a-priori* design, an emergent phenomenon that compelled our attention as we hope it will compel yours. As such, it should be considered an initial model, based on a strong yet small set of data. As evaluators, we evolved our approach to collaborative practice and its assessment over the years of the alliance, and this will certainly continue in the last year of the program. Regardless of its rigor in this initial form, it does provoke a rich discussion about collaborative practice that can have immense value for enhancing programs that promote diversification of the professoriate.

An additional limitation is the extent of the body of work reviewed here. The work presented is based on annual interviewing of around 30 people per year, in addition to attendance and observations of meetings and professional development that require considerable time for data collection and analysis. Further, evaluators must have the capacity to conduct the qualitative research and data analysis described. Application of the framework requires flexibility of the evaluator to design evaluation questions based on the collaboration development stages. The authors have decades of combined experience in evaluation work of this nature. Also, alliance members or grant recipients must be willing to invest time to participate in these interviews and be comfortable sharing their views about the project with the evaluators.

A current focus of the evaluation team is exploring ways to leverage common results across alliances. When attending NRC conferences, it is quite common to hear a presenter echo something the evaluation team has observed in our alliance. If there were systematic efforts to build on these common findings, the work of the AGEP COP could take a new direction. In the results, we discussed initial work to create a way to characterize collaborative practice across alliances for the sake of comparing alliance practices more directly (Kelly et al., 2020b); foundations already exist for this future work.

The results outline an emergent model of collaborative practice across key stakeholder groups in the academic ecology of a funded alliance. This alliance is part of the AGEP program in NSF, a sponsored program focused on increasing the diversity of the professoriate. The SPARC model encourages a broader conceptualization of the potential benefits of collaborative practice because it extends beyond alliance boundaries and demonstrates what each stakeholder group uniquely contributes to collaborative practice in the academic ecology. Collaborative practice is a key transdisciplinary skill set (Kelly and Burr, 2019), worthy of substantial investment.

> "The ability to collaborate on both a large and small scale is one of the core requisites of post-modern society … in short, without collaborative skills and relationships it is not possible to learn and to continue to learn as much as you need in order to be an agent for social improvement." (Fullan, 1994, pp. 17–18).

DATA AVAILABILITY STATEMENT

Due to confidentiality concerns and limitations of sample size, the datasets presented in this article are not publicly available. Requests for data or further details should be directed to Theresa Murphrey, t-murphrey@tamu.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Texas A&M University TAMU 1186 | College Station, TX 77843 Tel. 979.458.4067 | Fax. 979-862-3176, https://vpr.tamu.edu/human-research-protection-program/. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Signed informed consent from all program stakeholders (both those receiving programming and those delivering programming) allowed the use of ongoing implementation data collected as part of the project for research and evaluation purposes. Specific instruments were also submitted for approval, including protocols and instruments used in evaluating collaborative practice.

AUTHOR CONTRIBUTIONS

EB, KK: method conceptualization. EB, KK, TM, and TK: instrument development. EB, KK, and TM: data collection. EB, KK, TM, and TK: analysis and interpretation of results. EB, KK, TM, and TK: draft manuscript preparation. All authors contributed to the article and approved the submitted version.

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A Research Publication and Grant Preparation Program for Native American Faculty in STEM: Implementation of the Six R's Indigenous Framework

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Faculty members in science, technology, engineering, and mathematics (STEM) disciplines are typically expected to pursue grant funding and publish to support their research or teaching agendas. Providing effective professional development programs on grant preparation and management and on research publications is crucial. This study shares the design and implementation of such a program for Native STEM faculty (NAF-STEM) from two tribal colleges and one public, non-tribal, Ph.D. granting institution during a 3-year period. The overall development and implementation of the program is centered on the six R's Indigenous framework – Respect, Relationship, Representation, Relevance, Responsibility, and Reciprocity. The role of NAF-STEM and their interactions with the program, as members of the community formed by their participation, impacted the program. Their practices and the program co-emerged over time, each providing structure and meaning for the other. Through such reciprocity, NAF-STEM and the program research team continually refined the program through their mutual engagement. They took on the shared responsibility of the program while they participated in and shaped its practices. The process and results of formative and summative assessment and the impact of COVID-19 on the program are reported. Results of the program offer lessons on the implementation of six R's framework in professional development at institutions of higher education.

Keywords: indigenous research methodologies, professional development (PD), tribal college and university, institution of higher education, culturally responsive

INTRODUCTION

The need for a culturally responsive and effective professional development (PD) program to support Native American Faculty in Science, Technology, Engineering, and Mathematics (NAF-STEM) was identified through research into the experiences of Native American students in the

field of natural resources and the critical contributions of Native American faculty to the success of Native American students (e.g., Aragon, 2002; Tippeconnic Fox, 2008; Gervais et al., 2016; Page-Reeves et al., 2018). A team assembled to create, implement, and study a model to support the career satisfaction and success of NAF-STEM, and to advance knowledge about issues impacting their career progression in STEM fields. Two Tribal Colleges and Universities (TCUs) and one predominantly white institution (PWI) with Native American and non-Native team members, formed the Willow Alliance, funded by the National Science Foundation.

The research team consists of 20 researchers. Ten of the team members are enrolled members of seven Tribal Nations; two are Asian and eight are non-Native. Four members of the team led the development and implementation of the Research Publication and Grant Preparation (RPGP) Program and are the first authors of this article. Three are Native, one is Asian. Between the two coauthors, one is Native, the other is White. The personal and professional lived experiences of the Native American team members contributed an additional layer of richness and perspective to the Willow project.

One of the project founders is a member of the Hidatsa tribe, who are also known as People of the Willows because historically, they lived along the river where willows were abundant. As the project was conceptualized, the vision of NAF-STEM as being similar to willows developed: a group of people who are thriving and play a critical role in their ecosystem. Willows represent flexibility and adaptation – not only to survive, but to thrive in some of the most challenging conditions and environments. The branches symbolize structure and a sense of responsibility. The roots symbolize being grounded and nurturing. The leaves symbolize nature and growth. Native Americans also use willows as a traditional medicine and willows are widely utilized in natural resources restoration for stream stabilization. The vision of the project was to create a model that supports NAF-STEM to become like the willows: abundant, contributing to a more diverse and enriched ecosystem, and a medicine for our people.

The research team developed a Willow model with three interconnected components to support NAF-STEM: Indigenous mentoring program (branches), institutional support program (roots), and research publication and grant preparation program (RPGP, leaves). The creation process of the model was Native American-led and was guided by specific tenets of Indigenous research methodologies (IRM), drawing upon Respect, Relationship, Representation, Relevance, Responsibility, and Reciprocity, our six R's framework. In this article, we share the work on the RPGP component of the Willow model.

The definition of American Indian and Alaska Native varies across United States federal agencies and at different times in history. In this article, we use Native American, American Indian, American Indian and Alaska Native, Native, and Indigenous interchangeably. We are aware of the variation among the 500+ tribal nations in the United States and respect the differences in their traditions, cultures, languages, and worldviews. Here, we seek to look at Native American faculty broadly, focusing on commonalities among these groups.

A Brief Description on the History and Contexts of Tribal Colleges and Universities

The first Tribal College was established by the Navajo Nation in 1969 to provide culturally sensitive, place-based higher education to Native Americans. As of the American Indian Higher Education Consortium [AIHEC] (2021) reports there are 37 Tribal Colleges and Universities (TCUs) in the United States, spanning 16 states and providing rigorous education to predominantly Native American students. Chartered by their respective Tribal councils, TCUs tend to be community hubs centered on the economic and cultural needs of their students (St. Pierre, 1998; Page, 2017).

Tribal Colleges and Universities are classified separately from other institutions of higher education, which fall under several familiar categories, such as Doctoral Universities and Baccalaureate Colleges (Indiana University Center for Postsecondary Research, 2021). According to an Introduction to Tribal Colleges from AIHEC (1999), most TCUs have small student populations; most are remotely located on reservations with limited access to other colleges; all began as 2-year colleges, and all have open admission policies. AIHEC also indicates that most TCUs are teaching institutions and do not offer tenure or have an instructional ranking system. The student body at TCUs consists primarily of Native American (about 89%) students (cited by Voorhees, 2003, using IPEDS Fall 2000 Enrollment Survey) with enrollment typically ranging from a few hundred to a couple thousand students.

Demographics of Native Faculty at Tribal Colleges and Universities and Non-Tribal Colleges and Universities

In 2018, in higher education institutions nationwide, less than 1% of faculty were Native American (Institute of Education Sciences, U.S. Department of Education, and National Center for Education Statistics (NCES), 2020). Among TCUs in 2014, 33% of faculty were Native American, 82% had a Master's degree or higher, and 68% were full-time (Al-Asfour, 2014). TCUs draw strength from their reliance on cultural scholars to lead courses centered on the delivery of cultural knowledge and/or language. Thus 11% of faculty, staff, and administrators are listed as experts in their field with no degree (AIHEC and Systemic Research, Inc., 2008).

A 2008 AIHEC report indicates that many faculty members at TCUs commit a high level of effort to student support services and few faculty receive release time, which means they have less time to develop research products (e.g., publications, books, presentations).

Role of Native American Faculty at Tribal Colleges and Universities and Non-Tribal Colleges and Universities

Tribal Colleges and University faculty are paid less than faculty at PWIs (average $18,000 less), but TCU faculty, especially American Indian faculty, have a strong sense of obligation and commitment to Native communities (Voorhees, 2004). Further,

Native American faculty at TCUs share many core values with their Native counterparts at non-TCUs, including a desire to *give back* to their community (Page-Reeves et al., 2019). In a 2014 study, Yeager found that racial minorities tend to persist at higher rates when they have a more "self-transcendent" view of tedious academic activities (Yeager et al., 2014). Many Native Americans hold such a view, being motivated by family and a strong sense of giving back (Guillory, 2008; Guillory and Wolverton, 2008). This self-transcendent view often goes a step further – to a sense of duty to their families and communities (Al-Asfour, 2014; Page-Reeves et al., 2019).

Pursuing grant funding is a common expectation of faculty in STEM disciplines. Providing effective PD programs on grant preparation and management can help advance their careers. However, institutional contexts and culture are important factors that support or constrain faculty research activities (Zimbler, 2001). In this study, the Willow PD program aimed to support NAF-STEM at two TCUs and one public Ph.D. granting PWI, taking into account the participants' needs and their institutions.

THE SIX R's INDIGENOUS FRAMEWORK

The overall design of the RPGP is centered on the six R's framework for Indigenous research: Respect, Relationship, Representation, Relevance, Responsibility, and Reciprocity. The ideology behind the six R's has been put into practice in Indigenous communities and elsewhere for generations. They came into the practice fairly recently and not all at the same time.

Three decades ago, Verna J. Kirkness and Ray Barnhardt laid the groundwork stressing the need to incorporate into higher education systems, The Four R's: Respect, Relevance, Reciprocity, and Responsibility (1991). The authors presented American Indian students' perspectives that differed from mainstream institutions and characterized ways programming transforms education (Thorne, 2019). Over time, the fifth R for relationship came into play (Harris and Wasilewski, 2004; Wilson, 2008; Styres and Zinga, 2013; Cull et al., 2014; Tessaro et al., 2018).

Tessaro et al. (2018) expounded upon "The Five R's for *Indigenizing* Online Learning," examining how a Canadian First Nations course for school principals was centered around the Five R's. Representation was the sixth R to be included. Representation of Indigenous communities has been a struggle since colonization, and the ability to "represent ourselves" is seen as a fundamental right (Smith, 2012). Kovach (2010) stresses the importance of including Indigenous voice and representation within research, using conversation as a means for gathering knowledge through the relational process of story-telling.

Stemming from Indigenous worldviews, the six R's honor Indigenous knowledge systems and support cultural integrity. Below we describe the six R's in more detail. They do not stand alone, they complement one another. They are connected, intertwined, and overlap. The six R's are core values woven throughout our work that together provide a holistic structure guiding this study.

Relationship requires attention and effort to build and maintain (Brayboy and Maughan, 2009; Brayboy et al., 2012). *"Relationship is the kinship obligation"* (Cajete, 2000; Harris and Wasilewski, 2004). Respect, relevance, reciprocity, and responsibility are expressed through relationship (Brayboy et al., 2012; Styres and Zinga, 2013). Relationship is reciprocal and respectful (Kirkness and Barnhardt, 1991). We recognize building trust and good relationships with our participants is fundamental.

Respect is recognition of a community's cultural standards and openness to learning (Carjuzaa and Fenimore-Smith, 2010). We recognize and respect the "mutually empowering" aspect of the relationship between individuals and the group (Hampton, 1988; Kirkness and Barnhardt, 1991). Taking the time and making the time to build relationships demonstrates respect for Indigenous values and the community as a whole (Brayboy et al., 2012; Windchief et al., 2017). Truly respecting our participants involves learning who they are: their identities, culture, values, and stage in their professions, all of which impact how we develop, shape, and change our PD program.

Responsibility is all-inclusive, recognizing our connections to Indigenous communities and our desire to continually develop sustainable, supportive relationships with them (Cull et al., 2014). "*Responsibility is the community obligation*" (Harris and Wasilewski, 2004). It is our responsibility to our participants to develop this program to support their professional career progression; their institutions (e.g., when faculty grow and succeed, their students and the institution also grow and benefit from each other); their/our communities; and to support their individual understanding of and definition/s of success. Rather than developing the program FOR participants, it is our responsibility to co-create the PD program WITH participants.

Representation allows the community to identify what is relevant. The participants' unique knowledge traditions are represented in new contexts through their participation. The Willow team allows representation of Native participants and provides space to have their voices heard. Our NAF-STEM participants' input supports the direction of the PD program.

Relevance values Indigenous knowledge, involves Indigenous communities, and ensures that programs, services, and education for Indigenous peoples are responsive to the needs they *themselves* have identified (Cull et al., 2014). We ensure that our PD is relevant to our participants' individual and institutional contexts and goals. Inclusion of their voices and insights make the research and program relevant.

Reciprocity is respectful knowledge sharing between people participating as both student and teacher, across disciplines, throughout the full educational process (Brayboy et al., 2012; Cull et al., 2014). *"Reciprocity is the cyclical obligation"* (Harris and Wasilewski, 2004). Reciprocity plays a critical role in participants' lives and "unifying cultural construct" (Guillory, 2008; Page-Reeves et al., 2019). It is important that the PD program is mutually beneficial to our participants and the program team. We learn from each other and continuously co-construct the program together.

PROFESSIONAL DEVELOPMENT PROGRAM – RESEARCH PUBLICATION AND GRANT PREPARATION

Background of the Professional Development Participants

The RPGP had eight NAF-STEM participants (four female, four male). Their home institutions are in the Northern Great Plains. Four participants are from two different TCUs and four participants are from one state-funded 4-year PWI.

Overview of Research Publication and Grant Preparation

Figure 1 illustrates how the six R's serve as the overarching framework, which surround our work and encompass all other elements of the RPGP. From inclusion to integration of Indigenous perspectives and approaches, NAF-STEM are *represented* at the center of our continued journey.

The circles illustrate our ongoing relationship building with each other, our communities, our environments and beyond. Through our collaboration, we recognize and understand that our shared knowledge unites us, providing a cohesive Indigenous voice for PD in higher education, and elevating our Indigenous communities and institutions. In this realm, we are able to shift institutional approaches away from *merely tolerating* Indigenous knowledge(s) "to one where Indigenous knowledge(s) are embraced as part of the institutional fabric" (Pidgeon, 2016).

The RPGP was designed as a 1-year program that offered three components to Willow NAF-STEM participants (highlighted in yellow text in **Figure 1**). They could participate in one or more components of the program.

Component 1: A grant proposal preparation program. If a participant chose to join this component, the expected outcome was that, by the end of the 1-year program, the participant would complete a review-ready proposal for an external funding source as a PI or a collaborative proposal as PI or Co-PI.

We offered two mechanisms to support participants to achieve this goal: a Grant Writing Series (GWS) and Collaborative Writing and Support (CWS). The GWS offered four, 90-min sessions to collaboratively explore different aspects of writing grant proposals. All sessions were in person and online. The

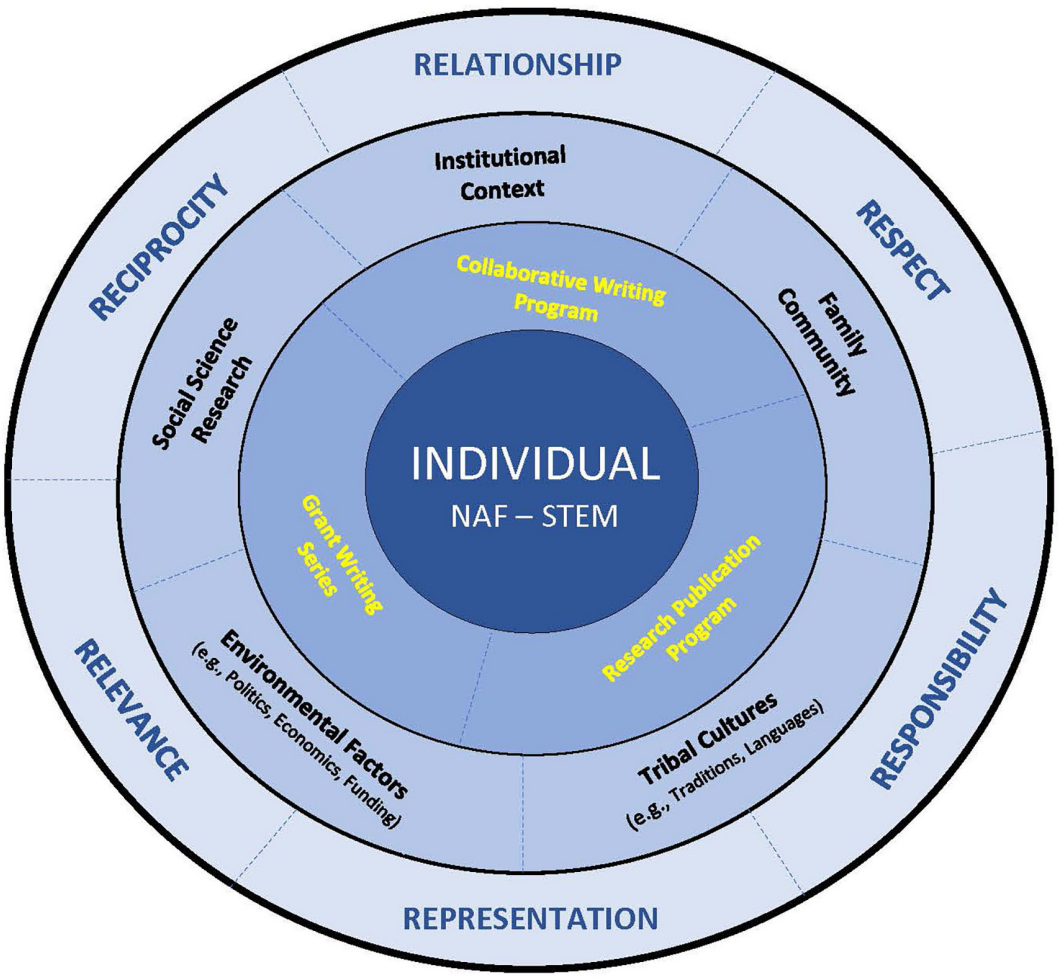

FIGURE 1 | Six R's indigenous framework for RPGP.

TABLE 1 | Timeline of the RPGP program.

Task	Timeline
Develop materials for GWS and relationship building	Summer (Year 1)
Pilot the GWS	Fall semester (Year 1, in person among faculty at the non-TCU institution)
Adapt the materials for the GWS	Spring semester (Year 1)
GWS 1	May (Year 2, in person at the same non-TCU institution and online)
GWS 2, GWS 3	Summer Workshop (Year 2, in person at one of the partner TCUs and online)
GWS 4	September (Year 2, in person at the non-TCU and online)
CWS (weekly)	October through June (Year 2, held weekly in person and online); A subgroup of the CWS extended their meetings into Year 3 due to COVID-19 pandemic and all meetings were online
Reflection	Summer Workshop (Years 3 and 4, originally planned at the other partner TCU, but was moved online due to COVID-19 pandemic)

CWS was based on a best practice in grant writing, i.e., to have periodic reserved writing time with peers for accountability and support (Young et al., 2016). Participants had the option of meeting together as a large group or in subgroups for the 90–120 min CWS sessions where they received support from the team.

Component 2: A research publication program. The expected outcome was that the participant would complete a submit-ready, peer-reviewed journal article, conference proceeding, or book chapter with the participant serving as a major contributor (e.g., lead, second, or third author). NAF-STEM who chose this option participated in at least two of the four GWS sessions in option 1. Each individual worked with the research team to determine the time for regular Collaborative Writing and Support (CWS) based on availability, location, and format. The research team worked with individual participants at the frequency they wanted.

Component 3: A collaborative writing program (CWP) among participants on their experiences as Native faculty and researchers. The expected outcome was a submit-ready manuscript co-authored by participants for a journal or alternative destination determined by authors. The Willow team facilitated regular CWS meetings for participants who chose to work on the manuscript.

Calendar Schedule of the Research Publication and Grant Preparation

Table 1 demonstrates the timeline and tasks of the RPGP. Due to the COVID-19 pandemic, the development and implementation of the program lasted over 3 years.

Implementation of Research Publication and Grant Preparation

Figure 2 demonstrates the five key elements of the development process of RPGP under the guidance of six R's. The circular connection (green arrows in **Figure 2**) indicates the interactive and iterative nature among all the elements.

The five elements from **Figure 2** are described below. Additional detail on how the six R's were necessary for program adaptation is described in the section "Discussion" of this article.

Relationship Building With Fellows

Relationships were fostered through face-to-face interactions at group sessions, one-on-one correspondence (phone, email, Slack messages), and through an open-door policy. Ongoing interactions helped our team to further understand participants' individual contexts in relation to proposal writing and grant management.

Understanding Institutional Context

Tribal Colleges and University context and participants' needs differ from public state-funded institutions. TCUs tend to be very student-focused and encourage their faculty to embody this in their day-to-day work. At many public state-funded institutions, faculty are expected to perform research and are sometimes afforded resources (e.g., time, proposal writing assistance, databases) to accommodate this. This difference means that the number and types of proposals that a faculty member submits depends upon their institutional context.

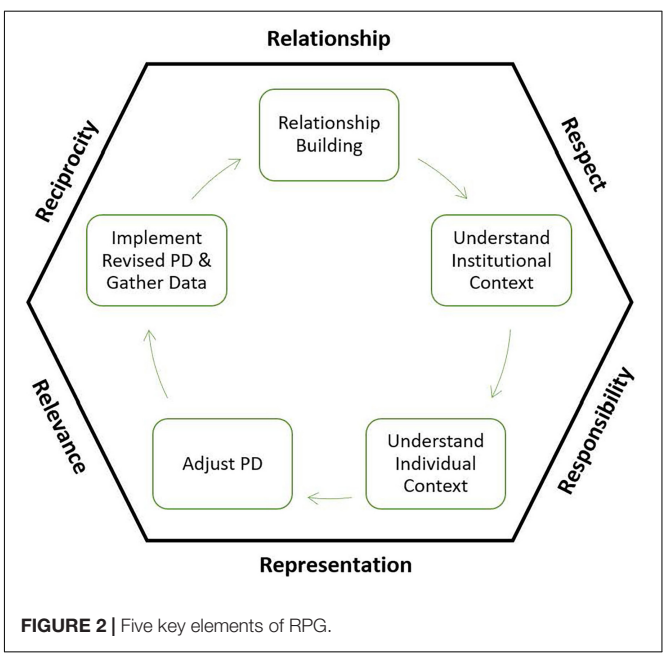

FIGURE 2 | Five key elements of RPG.

Understanding Individual Context

Participants had various degrees of grant writing and management experience. Those with more experience became peer mentors for others. This informed our decision to adapt the program to engage the senior faculty in discussions during the GWS sessions.

Other "intersectional" traits for participants included tribal cultures and traditions, family composition and status (e.g., single parent, foster parent), individual professional status, and environmental factors such as a global pandemic.

Adjusting Professional Development

The understanding of individual context led us to realize that some participants prefer to publish their scholarly work, rather than securing grants due to institutional and individual factors. Many faculty in our program opted to focus on publishing their work to strengthen their research agenda. This resulted in further adaptation of our PD program by adding Component 2 – Research Publications.

Through our reciprocal relationships and respectful listening, we learned that several participants desired to share their lived experiences as Native faculty in TCU and non-TCU settings to (a) support Native communities to inspire more students into STEM fields and become faculty and (b) help the broader audience in higher education to better understand the strengths/challenges for Native STEM faculty and provide suggestions on support. This resulted in adding Component 3 – the Collaborative Writing Program.

Implementing Revised Professional Development and Gathering Data

Over the period of the project, we revised the initial grant writing and management program to better meet the needs of our participants. We implemented our professional development plan, gathered data, and made adjustments (as described above). This process resulted in the final program, where participants were allowed to choose the component(s) that best suited their personal and professional goals: Component 1: Grant Writing Series; Component 2: Research Publications; Component 3: Collaborative Writing Program.

Program Assessment

The program effectiveness was assessed through formative and summative assessments. The formative assessments included: participation rates in the program and conversations between external evaluators and participants at biannual gatherings and summer retreats for feedback.

Summative assessments include: (a) final outcomes from the RPGP, that is, number of proposals submitted and awarded for Component 1; number of publications submitted and accepted for publication for Component 2; number of publications or presentations for Component 3; (b) findings from informal focus group with participants at the end of the program.

RESULTS

In this section we present the formative and summative assessment results of the RPGP. We then share the results on the program effectiveness from our participants' perspective. We also address how the COVID-19 pandemic impacted the RPGP and our response to it.

Results From Program Assessment

Results from Component 1 GWS: Among the eight NAF-STEM, the numbers of participants in GWS sessions 1–4 are 3, 8, 8, and 5 (note that participants only need to attend two of the four GWS sessions). One of the TCU NAF-STEM participants chose to further develop and submit a proposal in collaboration with a faculty member at the state institution to start a new graduate program at the TCU. The proposal was selected for funding.

Results from Component 2 Research Publication: Two NAF-STEM chose to participate in this component working at their own pace. Based on one participant's writing log, he used 15 writing sessions, ranging from 1 to 5 h long, to work on a manuscript. The manuscript has been published in a refereed journal in his field. The other participant published one book chapter.

Results from Component 3 CWP: Five participants collaborated with three research team members on this component. This component was extended from a 1-year program to a 20-month period due to the COVID-19 pandemic. The group had a total of 38 1-h gatherings to work on the writing project. The participants gave a presentation followed by question-and-answers with about 50 participants at a national conference for Native American and Chicano/Hispanic students. A manuscript authored by the four participants and three team members on how Native American faculty navigate academia is currently being revised for its second submission to a peer review journal.

Results on Program Effectiveness Through the Lens of the Participants

Regarding the effectiveness of the program, we learned that participants appreciated the opportunity to get to know one another and share their stories. They felt that the work in RPGP was meaningful and gave them the ability to reclaim knowledge in an Indigenous context. These conversations also allowed Indigenous knowledge to expand beyond the TCUs and into other institutions, where the conversation on cultural change was brought to a wider audience. Others felt that the program could have been improved by offering a less time-consuming option. Some participants with ample grant writing, management, and research publication experiences indicated that they did not learn new skills through the program, and the RPGP could have benefited from an even deeper contextual understanding of where participants are, both in terms of career trajectory and institution type.

We also asked participants to posit what a similar program might look like if it were implemented solely at a TCU or solely at a PWI. One participant indicated that many TCUs

do not ask that their faculty write proposals, but rather hire grant writers to support institutional-level proposals. There is no pressure from the institution for the NAF-STEM to pursue individual research funding. Taking this comment into account, we might avoid proposal writing for PD at TCUs altogether, potentially replacing it with advice for seeking or working with a professional grant writer (depending on the needs of the individual TCU faculty). Because NAF tend to have a self-transcendent approach to their work, broadening the definition of knowledge production beyond research publications and into creative scholarship would be beneficial. Including creative dissemination products (e.g., documentary, film, podcasts) would be useful in a classroom and in the community, therefore reciprocating the NAF's impact beyond their own research and career and into their community.

Impact of COVID-19 Pandemic

The COVID-19 pandemic challenged the implementation of the RPGP by limiting interaction among participants. The collaborative writing sessions and annual workshops were shifted from in-person to abbreviated remote formats, limiting interactions and reducing opportunities that could potentially lead to publication.

Additionally, Native American (NA) communities experienced the pandemic in especially devastating ways. In the United States the COVID-19 mortality rate was 2.5 times higher among NA than it was among non-Hispanic whites (Akee and Reber, 2021). These high rates were also reflected in the states where our faculty participants' home institutions are located. For instance, in Montana, NAs account for roughly 7% of the population, but accounted for 32% of COVID-19 deaths (Montana Department of Public Health and Human Services [DPHHS], 2020-2021). The drastic disparity in the COVID-19 death rate added strain to our NA participants, several of whom experienced personal loss during the pandemic, as well as impacts to productivity that are impossible to measure.

We responded with flexible timelines to complete the RPGP and added a weekly "wellness check-in" for our team and NAF-STEM to provide support to each other. We purchased technology and provided financial support to alleviate some of the added pressure on participants.

DISCUSSION

In this section, we discuss the findings of the study through the conceptual lens of six R's. We conclude with reflections on lessons learned and recommendations for researchers and administrators in institutions of higher education.

The Strengths of Incorporating the Six R's Indigenous Framework

Incorporating the six R's (Relationship, Respect, Responsibility, Reciprocity, Representation, and Relevance) into the RPGP served two purposes. When working in systems that value non-Indigenous processes, it was important for the Willow team to *remain grounded* in the Indigenous six R's framework. Using the six R's framework also provided the Willow team with a *system of accountability* aligned with Indigenous practices.

Many of the ways the six R's guided the process were complex and integrated. In this section, we discuss the development and implementation of the RPGP and the holistic strengths of the six R's, which are congruent with Indigenous Research Methodologies (IRM).

The connections and overlapping of the six R's is important. Highlighting how they are represented and connected to each other in the Willow project is integral to understanding the process. The first of the six R's recognized in this process is **Representation. Representation** existed at the beginning, with its development by several Native American team members leading the RPGP and elevating Native perspectives. NAF shared narratives throughout, contributing to important national conversations on using IRM in science communities with their shared work. Having a shared identity with NAF-STEM, Willow team members as a whole carried a sense of **Responsibility** with **Reciprocity** in RPGP development. This sense of **Responsibility** is represented by Willow team leader's responsiveness to NAF-STEM needs, while simultaneously NAF-STEM reciprocated responsiveness to the needs of their campus community. The responsiveness of the modifications are connected to **Relationship, Respect,** and **Reciprocity**.

The Willow team facilitators entered into **Relationship**s with NAF-STEM using a **Respect**ful **Reciprocal** approach. As participants began to express needs and interests to modify the structure of the RPGP, the Willow team **Respect**ed their requests to make modifications. Because of the **Respect** given to NAF-STEM, they were open to **Reciprocate** and express what their hopes were for the program.

As a result, a new option, the Collaborative Writing Project (CWP), was developed and took on a different, less hierarchical structure. All participants, whether they were Willow team or NAF-STEM, held equal influence. In this collective approach, as NAF-STEM felt compelled to direct the conversations, Willow rotated leadership of meetings and sections.

As the CWP was developed, NAF-STEM identified **Relevant** needs at each of their institutions. They were given opportunities to tell their stories – stories about themselves, their students, their experiences, and their communities. This meaningful and sustainable engagement with the Indigenous community is **Relevance** (Cull et al., 2014; Stanton et al., 2019). **Responsibility** contributed to the Willow team's support in adjusting to this new structure that would meet the needs of their respective campuses. **Reciprocity** was practiced in the knowledge-sharing that happened among the group and in the value of meeting the needs of NAF-STEM, who in turn felt compelled to give back to their students, campuses and communities.

A strong sense of community was formed and close **Relationships** were made among Willow participants with implementation of the six R's. The participants' shared identity allowed an openness to be responsive and flexible, share their work with each other and the wider audience, and learn about each other. Shared identity and experiences enhanced focus on culture and language.

Building **Relationship**s with TCUs and communities is crucial to better understanding Native scholars' perspectives and interest

in program components that support student involvement and are meaningful to the TCU community. The opportunity to successfully co-develop and implement the RPGP with NAF-STEM was possible because of the six R's framework.

Limitations, Lessons Learned and Reflections

The development of a model by this project has not been done with the intention of creating a copy-paste program that can be replicated across institution types and populations. As the program evolved, it became apparent that the standard goal of a repeatable PD was not going to be one of our outcomes. Our results demonstrate the critical importance of assessing and engaging participants in the development stages and program delivery to better meet their unique needs. Similar to traditional knowledge systems, NAF-STEM needs are unique and context-dependent, which makes exact replication illogical and undesirable, especially for dissimilar populations. A model approach would be thoughtful engagement and respectful listening for participants to identify strategies and supports best suited to their specific needs and desires – with implementation of the six R's throughout.

To appreciate the TCUs NAF-STEM's efforts in our program, we originally planned to pay for a course teaching release, so that they would have time to participate. We quickly realized that our TCU partner institutions are geographically located in rural areas and the number of faculty in STEM is very small. It is extremely difficult to hire qualified instructors to teach their courses. Willow changed the compensation plan to summer salary, travel funds, and seed funding.

We are grateful that our NAF at the TCUs participated in our program in ADDITION to their heavy teaching loads and service requirements. Building a trustworthy relationship with participants takes time and it cannot be done through a one-time survey or meeting. A wide variety of flexible communication options with NAF-STEM is needed to suit individual preferences. PD activities must be carefully planned and continually adapted to the unique and individual needs and responsibilities of participants.

Contributions to Professional Development Field

The RPGP expands on existing models of PD. For example, J. M. Frantz's approach to providing research and writing support for a group of health professionals used "academics' needs as a departure point for designing activities that support them throughout the process" (Frantz, 2012, p. 122). Bali and Caines (2018) describe faculty programs based on transformative learning and heutagogy that respect individuals' priorities, reward PD, promote self reflection, and support access (through technology in their case). RPGP was reconfigured to address faculty priorities, offered a stipend for participation, provided both time and topics that allowed for self reflection and used various formats. It met all of Bali and Caines' goals while also introducing the six R's framework, critical to making it relevant to NAF-STEM. Our work of incorporating current best practices in the context of the six R's contributes to the field of participatory PD with a specific lens on Indigenous scholars.

Conclusion

This article shared the iterative development and implementation of the RPGP, a PD program to support NAF-STEM at two TCUs and one PWI. The RPGP offered a set of evolving options for participants that allowed for professional outcomes, such as a grant proposal, book chapter, and article submissions, as well as contributions to participants' communities through a TCU graduate program proposal, a presentation, and an article on NAF navigating academia. Future iterations could have an even broader definition of professional products and could reduce or remove the grant writing components for participants from TCUs. Feedback from participants emphasized that the RPGP allowed them to reclaim knowledge in an Indigenous context.

The six R's Indigenous framework (Respect, Relationship, Representation, Relevance, Responsibility, and Reciprocity) guided the RPGP team to emphasize Native perspectives, respond to participants' needs and contexts, and support participants' desires to give back to their communities. Native communities have had the experiences of western researchers and large institutions conducting research on Native communities with unethical approaches and without truly building long-lasting, reciprocal relationships or understanding the contexts of Indigenous cultures, traditions, needs, and ideologies. We hope this example of adaptive program development helps researchers better understand the importance of learning and applying the six R's Indigenous framework when working with tribal communities and Native peoples.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the IRB at University of Montana, Salish Kootenai College, and Sitting Bull College. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

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ORIGINAL RESEARCH
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Critical Incidents for Hispanic Students on the Path to the STEM Doctorate

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Hispanics are grossly underrepresented in the receipt of STEM Ph.Ds. The National Science Foundation (NSF) Science and Engineering Indicators (Trapani and Hale, 2019) suggest that only 7.8% of S and E doctoral recipients are Hispanic while their representation in the population is more than twice that, and that figure goes even higher if restricted to those within the college-age range. To address this gap, the NSF has awarded a grant (the Hispanic Alliance for Graduate Education and the Professoriate, H-AGEP) to the City College of New York and the University of Texas at El Paso to work with Hispanic STEM doctoral students to provide teaching training and preparation for academic positions so they can become role models for Hispanic community college undergraduates. In working to understand the career-decision making of our Fellows, in-depth interviews were conducted (n = 13) to understand what put them on the path to defy the odds and become a STEM doctoral recipient. Interview results suggest that isolated, critical incidents and chance events were responsible for a number of our students entering into doctoral programs. This research suggests that for some Hispanic STEM doctoral students the experience of chance events meant the path to a STEM doctorate was not assured from a young age and further, that the provision of "planned" critical incidents may support an increase in Hispanic STEM doctoral enrollment.

Keywords: Hispanic, STEM, doctorate, graduate, career decision making, Latinx

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INTRODUCTION

Hispanics are grossly underrepresented in the receipt of STEM Ph.Ds. The National Science Foundation (NSF) Science and Engineering Indicators (Trapani and Hale, 2019) suggest that only 7.8% of S and E doctoral recipients are Hispanic while their representation in the population is more than twice that, and that figure goes even higher if restricted to those within the college-age range. The underrepresentation of Hispanics with Ph.Ds. in STEM fields raises questions as to why this occurs. The career path to a Ph.D. in STEM can be considered to have three parts: the development of an interest in STEM, education in STEM, and the decision to engage in a career in STEM. The objective of this research is to illuminate the first two parts of this pathway among Hispanic STEM doctoral students. As part of an NSF funded grant (the Hispanic Alliance for Graduate Education and the Professoriate, H-AGEP) the City College of New York and the University of Texas at El Paso have worked with Hispanic STEM doctoral students to provide preparation for possible academic careers, particularly at community colleges. In-depth interviews were conducted with all participants in the first two cohorts (n = 13) to document how they developed their interest in STEM and came to study at the Ph.D. level.

Interview results suggested that isolated, critical incidents and chance events were responsible for a number of our students becoming engaged with STEM and ultimately entering into doctoral programs. These seemingly chance events suggest that the path for many Hispanic STEM doctoral students is not one that is assured from a young age. Hispanic student participation in STEM activities and attainment of STEM degrees may increase with more "planned" critical incidents that would support their pursuit of STEM career pathways.

LITERATURE REVIEW

Hispanic Representation in STEM

The United States Census Bureau reported that in August of 2012, Hispanics had become the "nation's largest ethnic or racial minority" during the 2011 calendar year (U.S. Census Bureau [USCB], 2012), reaching 16.7% of the total population. This growth was expected to continue and researchers project that by 2060 Hispanics will make up 30% of the United States population, having increased from 55 to 119 million persons (Colby and Ortman, 2015), reaching minority majority status along the way (Colby and Ortman, 2015; Preuss et al., 2019).

As the Hispanic population continues to expand nationally, their presence in higher education has also been noted. For example, the National Center for Education Statistics [NCES] (2018) reported that in 2016, Hispanics made up 3.2 million, or 18.9%, of all undergraduate student enrollees. As the number of Hispanic students in higher education has increased, so has their share of all degrees earned. The number of associate degrees earned by Hispanic students increased by 10 percentage points (from 10 to 20 percent) between 2000–01 and 2015–16; the count of bachelor's degrees earned has also doubled, increasing by 6 percentage points (from 6 to 13 percent) between 2000–01 and 2015–16 (National Center for Education Statistics [NCES], 2018).

An educated Latino community equates to greater economic opportunities for Hispanics and the greater society at large (Nora and Crisp, 2009). However, as Garza et al. (2019, p. 2) noted, "while we have experienced an increase in educational attainment, the growth in higher education completion rates has not kept up with the growth of the Hispanic population, which can have a negative effect on the future of the community as well as the future of our nation." Within higher education, Hispanics are overrepresented in the attainment of associate degrees but have lower attainment of undergraduate or graduate degrees, particularly in STEM fields. According to the National Center for Science and Engineering Statistics, Hispanics are one of three racial and ethnic groups underrepresented in STEM (Linley and George-Jackson, 2013). NSF's 2018 Science and Engineering Labor Force report states "Overall, Hispanics accounted for 6% of employment in S and E (science and engineering) occupations, which is lower than their share of the United States population age 21 and older (15%)." The statistics are even worse for females: in 2015, Hispanic women made up 1.8% of the United States S and E workforce, despite representing 7.5% of the United States residential population aged 21 or older (National Science Foundation [NSF], 2018). These circumstances led Sharkawy (2015) to characterize the limited presence of degreed Hispanics and members of other minority groups in the STEM workforce as "one of the most challenging problems for science education researchers and policymakers."

The problem of underrepresentation of race/ethnic minorities in STEM is particularly evident at the doctoral level. This issue is magnified by the fact that in comparison with all other STEM doctoral students, completion rates of racial/ethnic minority students tend to be lower and attrition rates tend to be higher (Sowell et al., 2015). For example, time-to-degree, or the length of time it takes to complete the degree, is an issue of concern among a wide range of stakeholders in graduate education (Bell, 2010). According to a study of under-represented minority (URM) STEM students in 21 doctoral programs, Sowell et al. (2015) found that the median doctoral time-to-degree for Hispanic students was 64 months. In terms of attrition, one-half of engineering, mathematics, and physical sciences URM students who withdrew from their doctoral studies did so in 21 months (Sowell et al., 2015).

The attrition of underrepresented minority scientists in their journey from the dreams of youthful scientific exuberance to an impactful research career should alarm us all (Fadeyi et al., 2020). This poses an urgent threat to scientific innovation by missing out on diverse minds and talent, and simultaneously exposes several ugly cracks in the American developmental journey of a scientist (Stanford, 2020). The professoriate in particular plays a critical role in dispensing knowledge to URM STEM students through course instruction, advancing the field through research, and mentorship. Like all sectors of the workforce, the professoriate should resemble the country's demographics. Unfortunately, this is far from the case in most STEM departments nationwide. As a result, talented faculty from URM groups remain a poorly tapped resource (Fadeyi et al., 2020). The poor representation of underrepresented minority (URM) faculty in academia also results in little to no role models for undergraduate students of color, which may negatively impact their aspirations, persistence, sense of belonging in undergraduate school, consideration of graduate school, or entrance into the STEM workforce (Jacobi, 1991).

Barriers and Supports for Hispanic Students in STEM

A number of research endeavors have focused on understanding the barriers and supports to Hispanic engagement and retention in STEM degrees and careers. Studies have largely focused on factors located within the relationships students have with family and faculty, individual factors, and institutional factors. A closer examination of each factor demonstrates different aspects of the individual experience and suggests that for Hispanic students, multiple aspects are interwoven and determine whether the student will engage and persist in STEM studies and careers.

Relationships

Across multiple research studies there is evidence that the relationship Hispanic STEM students have are pivotal in entering and persisting in STEM. Families and faculty members are critical to engaging and supporting Hispanic students in STEM careers. The presence or absence of these supportive relationships has been found to be critical to many Hispanic STEM students.

Families

Family plays a central role in many Hispanics' lives so it is unsurprising that the research found multiple ways in which families influence the career trajectory of their children. Family influence ranged from students being encouraged to persist when experiencing obstacles, to focus on their coursework and attend college, while also providing emotional and financial support (Banda, 2012; Peralta et al., 2013; Carrandi Molina, 2016). In rich qualitative interviews, Contreras Aguirre et al. (2020) collected data on how students found parental support to be crucial, particularly when they doubted their abilities in school. In a case study of ten undergraduate senior year Hispanic students enrolled in STEM majors, Contreras noted that "the encouragement and support parents provided to their daughters' influence(d) their major choices and persistence in STEM fields" (p.137). Students voiced how parents had encouraged them to attend college, offered emotional support when they were stressed by their academic work, increased their self-confidence and belief in their ability to do the work, and shared their pride in their children. As one participant noted, "I think they've always been very supportive, they always said, whatever you want to do we're going to support you. . . I know that whatever I do they are proud of me" (p.140).

Faculty

A further relationship variable found in the Contreras Aguirre et al. (2020) case-studies was the report by students of the importance of their relationships with faculty. Students indicated faculty provided them encouragement to continue onto graduate studies with them, to come to them with questions or requests for recommendations, provided interview tips, and motivated students to stay in difficult classes.

In a different case study research, Sangiago (2012) aimed to understand the unique experience of low-income Hispanic students in STEM at an HSI. Student responses included many who shared that they did not have an adult at the institution that they felt provided access to "support, social capital, or guidance" (p. 141). Those students who indicated positive relationships with faculty noted that the key benefits of those relationships were the provision by their mentor of "an extensive network, knowledge, and resources to connect them with high-impact programs and resources, such as summer research, academic support, and mentoring experiences" (p.142).

Faculty relationships can be even more important at the intense doctoral level of study. To prepare Hispanic STEM majors to enter doctoral programs, the Ronald E. McNair Post Baccalaureate Achievement Program has been successful with a program focused on faculty mentoring and academic preparation activities offered to students in their junior and senior years, providing additional evidence of the potential for faculty relationships to support Hispanic STEM graduate pathways (Fifolt et al., 2014).

Institutional Factors

Studies on Hispanic success in STEM tend to focus most frequently on research concerning institutional and individual impacts that hinder or support minority student success in STEM. Institutional impacts look to understand the factors at universities that either promote or inhibit URM success in STEM. A number of researchers have looked across multiple studies to try to find consistent impact factors that could then guide universities in developing programs and actions that positively impact Hispanic participation in STEM.

In a review of 59 studies on what institutional factors could support academic success in Hispanic college students, Winterer et al. (2020) found eight factors that influence success, listed in order by those with the greatest number of studies supporting the factors. The factors identified were "peer interactions, cultural climate, advising, coursework articulation, academic integration, support services, asset-based factors, and outreach" (p. 8). Of these factors, peer interactions and individual student-based assets are less able to be influenced by the institution. However, the other six factors are largely within institutional control. Cultural climate includes the diversity of the faculty and students and the support and resources available for students from diverse backgrounds and identities. Advising was shown to have either a positive or negative impact based on how it was received by the student and based on a positive correlation with frequency and quality. Academic integration looked at the student involvement with external academic parts of the college, showing a positive correlation with student involvement in "study groups, learning communities, social contact with instructors, meeting with academic advisors, and academic conversations with instructors" (p.13). Students suggested that the availability of tutoring centers and computer labs and similar support services is additionally important to them. For community college students, coursework articulation that ensures students are able to transfer their credits to a 4-year institution, while important, did not come up in the studies as strongly impacting student success as the other elements.

In a second study that looked at summarizing findings from multiple articles, Martin et al. (2019) looked at 74 studies that considered how to improve pathways of success for Hispanic students. Positive outcomes were found for a number of institutional practices, including "mentoring, counseling, advising, study groups, tutoring, scholarships, orientations, career services, undergraduate research, articulation agreements, and transfer programs" (p. 3). However, the authors concluded none of the interventions had enough support to recommend wider adoption.

While the degree of support is uneven for the multiple interventions suggested in the reviews of the literature, the three areas advocated by the Hispanic Association of Colleges and Universities [HACU] (2020) task force have been frequently supported in research articles. The HACU formed a task force to create recommendations that would increase the participation and success of Hispanic students in STEM. For the community college and university level they recommended that there be "effective articulation programs, stronger laboratory STEM. . . (and) expanded undergraduate research opportunities" (p.13). Increasing articulation programs to keep 2-year STEM graduates from being discouraged or financially unable to complete a bachelor's degree is essential and is supported in the literature

(Jackson et al., 2013; Boatman and Soliz, 2018; Martin et al., 2019; Taylor, 2019; D'Amico et al., 2021).

Similarly, the recommendation to encourage institutions to use research and project-based experiences as a means to increase URM engagement in STEM has also been well-supported in the literature (Hackler, 2011; Slovacek et al., 2012; Foertsch, 2019; Jin et al., 2019; Ing et al., 2021).

Individual Factors

A number of studies have focused on factors within the individual to explain Hispanic student retention and progress on a STEM pathway. Some of the newer research studies examining these individual-focused factors take an asset-based approach and suggest that Hispanic students possess traits, experiences, or abilities that support their STEM trajectories (Gallard et al., 2016). Other studies focus on more of a deficit approach such as inadequate academic preparation. Individual factors that have been studied include; number and level of science and math coursework (Wang, 2012; Borman et al., 2017), SAT and ACT math scores (Crisp et al., 2009), achievement in middle school and high school (Borrego et al., 2018), levels of self-efficacy (Wang, 2012; Borrego et al., 2018), persistence, networking, and race (Frett, 2018), gender stereotypes (Cunningham, 2017), exposure to math and science Wang, 2012), gender and ethnicity (Borrego et al., 2018), personality type, and genuine interest in the field.

A growing number of scholars critique much of the research and institutional approaches to URM student retention in STEM that uses a deficit model that locates the problem within the student rather than the institution (Harper, 2010; Valencia, 2010; Martin et al., 2019). The adoption of the Community Cultural Wealth model (Yosso, 2005) is an attempt to resituate how we conceptualize URM student success in higher education. In talking about cultural capital there are two distinct types discussed in the literature. Cultural capital is seen as that knowledge and experience that is generally available to majority members of the population with middle or high SES incomes. A newer form of cultural capital that is considered is Yosso's (2005) Community Cultural Wealth (CCW) model. Yosso's model focuses on "the forms of capital that draw on knowledge students of color bring with them from their homes and communities (Yosso, 2005, p.69)."

More recent studies have begun to use Yosso's lens to consider how these types of knowledge and experiences found in URM communities provide resistance to oppression and resilience, allowing URMs to persist and thrive in STEM pathways. Drawing on two previous research studies, the authors Rincón and Rodriguez (2021) summarized the six forms of CCW as seen in Hispanic students pursuing STEM pathways. The forms of CCW they documented are; aspirational capital (hopes for STEM future), familial capital, linguistic capital, resistance capital (challenging inequality through oppositional behavior), and social capital (leveraging networks) thus providing support for Yosso's theory of CCW.

In a phenomenological study that involved interviewing 16 STEM major Hispanic students, results further supported Yosso's notion of the importance of Community Capital Wealth (CCW) (Rincón et al., 2020). In this research they found that second-generation college students had access to both traditional cultural capital and CCW, while first-generation college students only have access to CCW. The second- gen students spoke of the additional need to navigate between these two forms of capital.

In a third studying looking at CCW among URMs at a Primarily White Institution (PWI), Chavez (2018) found that "aspirational, familial, navigational, and resistant capital" (p. 141) were the most often used forms of Yosso's CCW among her research participants. Students indicated that they used their navigational and resistant capital to deal with "instances in which participants described their response to a discouraging event or what their experience was like as a Hispanic STEM major, involved the feeling of being underprepared for STEM college courses, and the culture shock of attending a predominantly White university" (p 144). Students reported that their classmate(s) had come from well-resourced schools with AP courses in addition to having greater financial resources available to support themselves. Hispanic students used their CCW to deal with these challenges and were able to persevere and remain on a STEM pathway. The two approaches to cultural capital are useful as they both offer means of supporting students in STEM success.

Next Research

Despite the many studies that have outlined the basic contours of barriers and supports for Hispanic participation and success in STEM, there remain calls for additional research. Crisp and Nora (2012) noted the need for deeper research into the "socio-cultural variables influencing Hispanic students' decisions to major and persist in STEM (p.12)." Winterer et al. (2020) suggest that key barriers and supports have been clearly identified, however, there is a need for research that emphasizes how "institutional policies, practices, and programs" are experienced by individual students (p.20). Qualitative research with deep rich narratives is well suited to gain that greater degree of description of participant experiences.

BACKGROUND

The City College of New York (CUNY) and the University of Texas at El Paso (UTEP) were awarded a 5-year grant (H-AGEP) to develop a model program for preparing Hispanic STEM doctoral students to teach at 2-year colleges. The grant program includes three main components; teaching training, undergraduate mentoring, and workshops for professional development.

The teaching training program involves seven modules related to undergraduate STEM teaching and learning (CIRTL) which leads to Fellows creating a STEM course syllabus, lesson plan, teaching, philosophy, and diversity statements by the end of the semester. At the same time, Fellows participate in a practicum at a local community college where they are paired with a CC mentor from a similar background and major. The fellow initially observes their mentor but eventually teaches at least twice in that CC classroom, though some students have taught more frequently. The Fellows are provided continual feedback and

mentoring from their CC mentor. Fellows also have a chance to work more closely with CC students by partnering with them to conduct research. Further, Fellows are provided a range of professional development workshops to support additional skills such as preparing for academic interviews and grant writing. Fellows also participate in evaluation and research activities as well as retreats and networking events throughout their participation in the H-AGEP program.

RESEARCH METHODS

The research being conducted as part of this NSF-funded grant seeks to understand how H-AGEP Fellows make career decisions, particularly to understand the paths these Fellows took to be in a STEM doctoral program, on the cusp of successful graduation. Social cognitive career theory (SCCT), developed by Lent et al. (1994), was the theoretical framework used in the development of semi-structured interview questions used to gather qualitative data about Fellow's career decision-making. SCCT looks to explain three aspects of career decision making: (1) how individuals develop their academic and career interests; (2) how individuals make educational and career decisions; (3) how individuals attain academic and career success. This lens was useful in addressing the following research questions in our study:

Research Question 1: How did Fellows develop an initial interest in STEM?

Research Question 2: How did Fellows end up in STEM Ph.D. programs?

Study Design

This study used a qualitative research design based on a grounded theory approach developed by Glaser and Strauss (1967), whereby researchers were interested in exploring a social construct from the perspective of the individuals being studied. In this research, we were particularly interested in learning about the career decision-making processes of Hispanic STEM doctoral students and how these influence their decisions to pursue academic careers. The findings generated seek to add rich descriptions of participants experiences and perceptions of their experiences.

The NSF's Alliances for Graduate Education and the Professoriate (AGEP) program contributes to the National Science Foundation's objective to foster the growth of a more capable and diverse research workforce (National Science Foundation [NSF], 2018). Through this solicitation, the NSF seeks to build on prior AGEP work, and other research and literature concerning racial and ethnic equity, to address the AGEP program goal to increase the number of historically underrepresented minority faculty in STEM. Furthering the AGEP goal requires advancing knowledge about new academic STEM career pathway models (Alliances for Graduate Education and the Professoriate [AGEP], 2021). The use of the term "historically underrepresented minority" reflects language from Congress, and in the context of the AGEP program, the AGEP populations are defined as STEM doctoral candidates, postdoctoral scholars, and faculty who are African Americans, Hispanic Americans, American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders. At the graduate student level, only doctoral candidates are included because they have greater potential to enter a faculty position within the project duration time frame. Therefore, in terms of participant recruitment for this study, a non-probabilistic, purposive sampling approach was used, as only H-AGEP participants were selected according to predetermined criteria (Hispanic STEM doctoral students) relevant to our research objective related to the analysis of career decision-making.

Participants

Participants in this study consisted of thirteen Hispanic STEM doctoral students from both the first and second cohort of the H-AGEP NSF-funded grant. The demographic characteristics of these participants, referred to as H-AGEP Fellows, are shown in **Table 1**.

Participants represent a range of Hispanic subgroup identities. Seven H-AGEP Fellows are from Mexican backgrounds and the other six are from Colombia (2), Ecuador (1), Peru (1), and Puerto Rico (2). A third of the Fellows (4) attended non-United States institutions as undergraduates. Of the nine who attended United States institutions, four received Pell grants and five did not. Six of these students had attended a 2-year college at some point in their academic journey. Most students were not first-generation college students (9), though four were. Students represented a range of STEM majors with a heavier emphasis in engineering (Electrical Engineering-2, Mechanical Engineering- 2, Civil Engineering-2, Environmental Science and Engineering-1), followed by Earth and Environment majors (Earth and Oceanographic Sciences -1, Environmental sciences -2, and Ecology and Evolutionary Biology-1) in addition to three students majoring in Biological Sciences.

Fellows were initially recruited to this grant by H-AGEP Alliance members. These grant team members are faculty at CCNY and UTEP who teach in STEM fields. To qualify to be a Fellow, Hispanic STEM students had to have completed all of their doctoral coursework, be at the dissertating stage, have advisor permission, and have an openness to completing the components of the program. At the time interviews were conducted, these Hispanic doctoral STEM students were in

TABLE 1 | Demographic characteristics of H-AGEP fellows (N = 13).

Gender	Hispanic Sub-Group	1st Gen/2nd Gen	Major
Male	Mexican	2nd Gen	Civil Engineering
Male	Mexican	2nd Gen	Electrical Engineering
Male	Colombian	2nd Gen	Electrical Engineering
Male	Colombian	2nd Gen	Mechanical Engineering
Male	Ecuadorian	1st Gen	Environmental Sciences
Male	Puerto Rican	2nd Gen	Mechanical Engineering
Female	Peruvian	2nd Gen	Biology
Female	Puerto Rican	2nd Gen	Oceanographic Sciences
Female	Mexican	2nd Gen	Environmental Sciences
Female	Mexican	2nd Gen	Biology
Female	Mexican	1st Gen	Biology
Female	Mexican	1st Gen	Ecology/Biology
Female	Mexican	1st Gen	Civil Engineering

the mid-phase of their program, where most had taken their comprehensive exams and had, or were in the process of, defending their dissertation proposal.

Interviews

Prior to initiating interviews with the H-AGEP Fellows, the lead researcher developed interview questions using a SCCT lens that sought to elicit aspects of Fellow's career decision-making processes. Interview questions were centered around six key areas thought to influence career decision-making: (a) the development of STEM interest at home and at school; (b) interactions within K-12 and higher education systems around their STEM interest and developing STEM identity; (c) experiences in their doctoral program; (d) impacts of Hispanic and gender identities; (e) influences of geographic mobility; and (f) Fellow's experiences in the H-AGEP program. Interview questions were semi-structured to allow for both formal and informal discussions about each topic or to expand onto a related topic.

H-AGEP Fellows were contacted by the Graduate Student Research Assistant in late 2019 to inform them of the purpose of the study and to obtain their written consent for participation. Students were assured that participation was voluntary, confidential, and that they could choose to stop the interview at any time. IRB approval was granted from the lead author's institution (University of Massachusetts at Amherst) as well as from the partner institutions (UTEP and CCNY). Interviews were conducted by the Research Lead and the Research Assistant in January and February 2020 either in person or by the Zoom online platform depending on convenience for the student. A semi-structured interview protocol was used to ensure that all students were asked the same questions, though Fellows were able to digress from the questions and add material not requested. Interviews lasted anywhere from 50 to 90 min and were recorded and then transcribed for accuracy.

Data Analysis

Interviews were recorded on the Zoom platform and later transcribed by Rev.com. Once the transcriptions were completed, data was downloaded onto the MAXQDA qualitative and mixed methods data analysis software program. A grounded theory methodological approach was used to identify themes related to Fellow's development and support of their STEM interests and how these experiences affected their decision to pursue a Ph.D. in STEM.

Grounded theory refers to a set of systematic inductive methods for conducting qualitative research aimed toward theory development (Given, 2008). A grounded theory approach was chosen because it (a) provides explicit, sequential guidelines for conducting qualitative research; (b) offers specific strategies for handling the analytic phases of inquiry; (c) streamlines and integrates data collection and analysis; (d) advances conceptual analysis of qualitative data; and (e) legitimizes qualitative research as scientific inquiry (Given, 2008).

Data analysis was an iterative process whereby each researcher collected and analyzed the interview data and used inductive reasoning to create codes as each transcript was read. For each interview, the researchers recorded new codes developed and noted code characteristics, including the code name, code definition, type of code (inductive or deductive), any notes about the new code (e.g., clarity of the issue, completeness of the code definition). New codes were generated and grouped within the following categories: development of STEM interests in k-12 schools, development of STEM interests outside of school, undergraduate experiences, pursuit of graduate degree, mentorship experiences, impacts of gender and/or ethnic identity, and H-AGEP experiences. Documentation of code development and iterative refinement of codes continued for each interview individually until all thirteen interviews were reviewed and the codebook was complete. Areas of disagreement were discussed and reconciled so that there was agreement on all codes and coding. After two transcripts there was sufficient consistency for the two coders to work independently. As new codes emerged the coders met to discuss and work backward to see if they applied to any previously coded transcripts. After all the transcripts were coded, a review of the codes was pursued to develop initial themes which were used to answer our research questions.

Using a grounded theory approach, conducting a rigorous data analysis generally results in the identification of all available codes relevant to the research inquiry. Achieving this end point is often referred to as saturation, where no additional issues or insights emerge from the data and all relevant conceptual themes have been identified, explored, and exhausted (Hennink et al., 2017). This signals that conceptual categories are "saturated," and the emerging theme, or theory, is comprehensive and credible. Sample sizes recommended for qualitative research vary, but previous studies have found that saturation, based on the extent of theme development and theme importance in the data, can be achieved at twelve interviews (Guest et al., 2006; Hennink et al., 2017). Therefore, our dataset of thirteen interviews was considered sufficient for pursuing our research objectives.

RESULTS

Results were analyzed to see what themes developed surrounding each of the research questions. In response to the first research question, *how did Fellows develop an initial interest in STEM,* we found five distinct areas of influence in how Fellows developed their initial interest in STEM. The respondents overwhelmingly indicated interest development at an early age. The key areas noted by participants included: the influence of parents as teachers, engagement with family construction companies, the outdoors, access to taking things apart, and access to books. Through these varied activities we found that the Fellows developed a passion for STEM.

Parents as Teachers

A number of Fellows discussed how their parents acted as teachers and increased their knowledge, skill, and interest in STEM. However, these parents were not acting in traditional teaching with lecture modes with large groups of students but instead were engaging their children in hands-on science or individualized tutoring in mathematics.

- One Fellow noted, "My mom, she's actually very good at it, and she was the one." You know like when you have the breaks, she was always like, okay, let's go further. Let's take it a little bit. So, she was teaching me (math) so that when I was going to the next year, I was ready. And I never had an issue, never fought with her because of that. I liked it.
- Since I was little, my mom's a science teacher. So, I grew up with science lessons if I wanted to or not. So, I grew up with learning science and doing science projects always. For me it was doing experiments at home, so she would bring stuff that she would teach in the class and then do it at home with me. And, when I was younger, I would go to class with her. So, I grew up dissecting stuff in her classroom.

Construction Companies

Other Fellows discussed going to work with parents or other family members who owned or were involved in construction companies. Through their family connections they built informal networks that provided access to experiences others without those connections would not have. Authentic engineering experiences in the world intrigued our students as they participated in these family business activities.

- One of my uncles is an electrical engineer and my dad is an architect. He had a construction company, and so since I was a little kid, I was around them. I always liked that. I liked building and doing. . . we would always be doing projects at home. We had a pretty big house and land, so we were always building stuff there. Then with my uncle, we would do some electrical work, but that was when I was older, in middle school. That's where I got shocked few times, helping there.
- Before high school. I have an uncle, well, it's not really a direct uncle, but he's part of the family and he has a business. He sells materials for construction. And I think that was something that when I talked to him, I got interested in civil engineering especially. . ., when I was in high school, I had to do some service hours, so I decided to do my hours with my uncle. I was able to go to different construction sites and talk to people at different projects and talk to those guys and see how they were doing it, and what is what they were doing. And so, I was able to go to their field and interact with people and talk to them. . . and just from that experience I was like, "Oh yeah, I think this is something that I enjoy and I like."

Outdoors

Other Fellows were drawn into STEM through their experiences with the outdoors, an opportunity provided by their families. The Fellows' experiences in nature varied but they all spoke of how this had connected them to STEM in a deep way.

- When I was a child, I always used to go to my grandparents' farm. They have a pair of forests and pair of farms there. That's the way I remember I like nature. I always see how life moved when I was there. So, I was interested how this happens, why this happens. This was at age 6–8 years old.
- So, I actually always loved being in nature. I think the thing is, my parents always loved to be outdoors. We'll go camping or having a picnic in the river. And in (country name redacted), it's very easy to go just from the beach to the mountains, so it was always at that time when I was young, I was very privileged. We had the opportunity to travel also to the countryside. And then I think when I was in school, I remember I really loved my natural science class. And I remember when I was a kid, I wanted to be maybe a geographer or, I always dreamed about traveling to new places. And being like an explorer, right?
- My family is really outdoorsy. We go camping a lot. Go hiking a lot. We were always looking at animals and plants and rocks and stuff like that. It was just really having a childhood where we were outdoors a lot and going hiking and going all over the place.

Taking Things Apart

For some Fellows their interest was sparked by curiosity about how things worked and the occasional opportunity to pull things apart and see. Families that provided these opportunities to their children stimulated and supported their child's deep interest in STEM.

- So, I liked to be fixing things, moving things, see how they work when I just take apart some equipment and put it back together.
- Maybe when I was 10 years old, and I had my first video game console and it got me curious about electronics. . . a curiosity of understanding how they worked.

Books

For some Fellows, literature was the key introduction to a love for STEM. Through the pages of books provided by parents they became drawn into STEM. Parents were also seen as instrumental in providing additional materials and experiences stimulated with literature.

- I was very young, I would say. So, even in elementary school, I guess. I was interested in like space. . . Kind of always had a fascination with it (since) third grade. I think I did read children's books but space oriented. And then I feel like my parents would try. (Parents took her to space observatory and Cape Canaveral as child).
- I wanted to do airplanes. I remember it developed because my parents had. if you remember the almanacs, if you remember those books, my parents had that and I remember looking, just flipping through one of them and I saw a picture of helicopter and that's where I remember that first bird. And I remember I turned the pages very slowly in that section. And so that's where my interests were, and then I didn't really pursue kind of at that time the whole idea of STEM, it was not in my verbiage. But I knew I wanted to do something with science and math, I knew I liked it.

Varied

A few of our students had unique triggers for the passion for STEM. In one case it was their AP classes, in another their love

of bridges, and lastly a family illness. These triggers had the same impact as the previously listed categories in that Fellows reported these events was where their desire to pursue STEM originated.

- HS CLASSES: It was the classes that I was taking. So, I had the AP courses, so all the biology (*sic*) and chemistry courses were a little advanced so I that's why I wanted to learn it because I really enjoyed it more than math. And. . . all of the science fairs, I really liked the science fairs.
- BRIDGES As a child (I was) in love with bridges. Later realized that meant engineering and since (I) liked math (I) wanted to do something with bridges.
- FAMILY ILLNESS. . . (my) grandma got diagnosed with breast cancer when I was very young and that changed my perspective on medicine. So that's when I wanted to become a doctor.

Both researchers noted that when the interviewees discussed their pathways to STEM, we heard a passion for STEM. Students appeared emotionally motivated by the intrinsic joy they received from engaging with STEM. These early life activities appear to have ignited an interest in STEM that has continued into their doctoral programs. In discussing their academic choices and journey, students all seemed to assume they would pursue a bachelor degree in STEM. They did not hold the same assumption, however, when the transition was to doctoral studies.

Research question two, *how did Fellows end up in STEM Ph.D. programs,* provided insight into how Hispanic students with a demonstrated interest in STEM described their individual journeys from a student with a passion for STEM to being doctoral candidates in STEM. Five emergent themes that influenced their pursuit of a Ph.D. included; chance encounters with peers, issues of employment, interactions with professors, coursework, and self-initiation.

Chance Encounters With Peers

More advanced peers in their doctoral program provided Fellows with cultural capital through the information they provided about the doctoral process or which professors to seek out. Peers who were similar in age or ethnicity to the Fellow were particularly valued.

- One of the reasons I decided to do a Ph.D. is because when I joined this lab as a graduate student, my advisor had a Ph.D. student who was Peruvian so we kind of had a good connection right there. A doctorate honestly back then sounded out of reach for me, I hadn't even considered it but after meeting this guy, I kind of identify (with him) and basically, I thought that I could do it as well because I saw a lot of similarities. He did his undergrad back home, he came here (to the United States) for grad school, he's been in the lab so having that connection with him and also having similar backgrounds pretty much brought the idea closer to me, into consideration.
- And when I would go to get help with homework from his TA, who was a Chinese student, an international student, I was asking him about the Ph.D. and things like that, and it was like, "Oh wait, you're getting paid to do this? You're getting your tuition taken care of?" And then I literally asked him, "so you're saying that I can say that I want to do a Ph.D. and I don't want to pay for it and I could be arrogant about it?" And he's like, "yeah, yeah, you can, you can get paid to go to school." I'm like, "what?"
- So, I didn't interact with anyone, not even the professors, but one professor, I think it was almost when I was finishing my senior year (of the undergraduate), Dr B. my advisor, well one friend recommended me to go talk to him to start doing research. I talked to him and he offered me (a research position) to start as a volunteer. And again, everything changed after that because I got more involved.

In one case a student finds that seeing another Hispanic student doing doctoral work provided him with the self-confidence to recognize he is also capable of doing that. Another student found that doctoral studies would not be the financial struggle they envisioned and was thus something they could consider. And lastly, through a peer pointing them to a professor that would provide research opportunities for undergraduates, a student became involved with a professor who would further support him into pursuing doctoral studies.

Employment

For some students, transitional points in employment offered them the opportunity to consider applying to school. Students at these transitional points seemed equally happy to continue working or return to school to obtain a masters and doctoral degree-.

- The engineering students here take an exam at the end of their careers called the FE from the. . . engineering. So, my first step was to sign up for that exam. . . so I did (the) exam, I passed and my plan was after the exam, look for job or apply to school. And I was working, so in the meantime I was applying for school for the masters and I waited until I had my certification from the exam to apply for engineering jobs. But I guess maybe since I started the application process for school earlier maybe I got a response sooner. So, I was testing my options and I guess I got the response from the graduate schools first before I was able to find a job.
- That's a little. I guess it was. I didn't plan for it. Honestly, I never thought of. I mean, I maybe had slight idea of applying for a (graduate degree). It wasn't in my first option. But then I was working in (foreign country) for a company, then they had some changes there. . . my contract was up and they told me that I have to wait to renew the contract. Again, I had thought about the Ph.D., and then at that point I was like, "You know what, I'm thinking this might be a good opportunity to pursue it," and then I applied, and I got accepted.

Professors

Professors were key to some students in the networking they provided, and in others, in the critical cultural information about the Ph.D. process that was provided. In the first example, the seamless transition from one advisor to another at a different

institution was facilitated by the networking of the first professor for her students. In the second example a student gained critical knowledge, that while not deployed immediately, in the end served to lead the student to entering a STEM doctoral program.

- My undergrad advisor knew my current advisor M. And so, she knew she was looking for students, so that's kind of how. And then I stayed with M through the Ph.D. program.
- There was a professor here, her name was Dr. X.. . . But at that point in time I didn't know what to do (at end of BA) and since my parents didn't go to college, I didn't know that there was anything other than a bachelor's degree. So, she was really nice and she took an hour and a half just explaining to me that there is a Master's program, there's a Ph.D. program. I later took up a job at (retail job), and I was up for a promotion because I was the only employee who had six of six standards. And when I got my promotion, it was 65 cents so I said, "You guys can't just add 65 cents." The very next day I called in sick, I applied. . . I came here, I found out I only had a week to turn everything in (for Ph.D. application). But I wouldn't have known about a Ph.D. program if it wasn't for Dr. X, and that's because she took the time to tell me. In my science courses there was never people saying, "There's much more than just a bachelor's degree, you can do science research, or you can do this, or you can do that."

Coursework

For one student, an exciting experience in a community college biology class engaged them so much with biology that from that experience, they started on the path to the Ph.D.

- Taking a class at CC. I took my intro to biology courses there. Which I had put off, because I didn't like. I almost failed biology in high school. And I really hated it. That's one of the reasons why I took biology at CC, because they said it was easier. And I had a really good professor that made me like biology. For sure taking that course with that professor that I had at CC (led to entering doctoral program). Because I thought to myself, "If only my high school teacher was like that, then maybe I would have decided a long time ago that this is what I wanted to do. And I wouldn't have wasted so much time doing other stuff."

Self-Initiated

A number of students indicated that they were their own motivator to pursue a Ph.D. One student decided that his home country did not offer the resources to pursue the type of doctoral work he was interested in. A second student indicated their desire to learn propelled them back into academia.

- When I was getting my undergrad, I got involved with some research. But we didn't have enough instruments so that we can fully do research. And that's when I decided to relocate to the United States I always wanted to go for higher education, but at that point I wanted to go for a Master's. I actually wanted research, and I knew that going toward higher education probably will get me to that point. And then I came to the United States, and I got into a master's program. While I was doing the master's program, I was actually able to do research (that led to pursuing the Ph.D.).
- I moved to NYC and after completing my undergraduate degree and I decided to apply for a graduate degree. I was not pushed by a person. I would describe it as, "Because I like to learn more things."

Additional Finding

While this study looked at critical incidents on the path to the STEM doctorate, we also found an unexpected finding that may provide further corroboration of the Sowell et al. (2015) study results. As of year four, all of the Fellows are persisting toward their doctoral degree or have graduated. Three of the four critical factors that were found as central to URM student persistence to degree are central parts of this grant program; financial support, mentoring/advising, and peer group support.

Students are provided a stipend for participating in the program and additional funds when they participate in the teaching practicum in a partnering community college. Additional funds are made available for those Fellows who provide research mentoring to undergraduates and for conference travel expenses.

The development of a strong mentorship and networking program to support Fellows during their transition to academic careers in community colleges and in their professional lives is another key pillar of this intervention. Mentorship is provided by grant faculty, the Fellow's dissertation advisors and community college faculty. All work in concert to ensure that the Fellows are supported in gaining the skills needed for transitioning successfully to a career and while in the program.

Finally, Fellows often described the social support they received from the frequent interactions with their peers within and across the two lead institutions. The social support and extended peer network developed over the course of the program—as Fellows graduated and a new cohort was welcomed—provided Fellows with role models of successful URM STEM peers that they may not have otherwise seen in their programs or at their institutions. The connections established between the Fellows reinforced to them the similarities in the challenges URM STEM doctoral students face as they contemplate pursuing academic careers, while also reinforcing the values these Hispanic Fellows prioritized in being role models for the next generation of Hispanic, URM undergraduates.

DISCUSSION

Research has shown that Hispanic students are interested in STEM majors and careers at the same level as White students. However, many fewer Hispanics end up graduating with STEM degrees and this is especially so at the doctoral level where only three percent of STEM doctorates are awarded to Hispanics (U.S. Department of Education [USDE], 2012). It raises the obvious question of what happens between the development of interest in a STEM major and degree attainment. This research is unique in looking in particular at the varied pathways to the doctorate

in STEM. In reviewing the data, it appears that while there are commonalities in how the Hispanic students surveyed developed their STEM interests, there was a wide range of non-structured, random events leading to Hispanic STEM student participation in doctoral programs.

Consistent with prior researchers (Banda, 2012; Peralta et al., 2013; Carrandi Molina, 2016), we found that family support was instrumental in students engaging and continuing in STEM pathways. Similarly, we found agreement with Contreras Aguirre et al.'s (2020) work that found that positive relationships with faculty could similarly support students on their STEM pathway. While prior research studies have indicated the importance of faculty mentoring and contact with instructors (Martin et al., 2019; Winterer et al., 2020) and we found that was an important factor for some of our Fellows, the presence of such a supportive faculty member was inconsistently present for our students and instead they more often relied on families, peers, and the cultural capital (or CCW) they brought with them to succeed.

While family support and CCW were critical to participants developing a passion for STEM at a young age and leading to student enrollment in STEM baccalaureate programs, the CCW they developed then did not include gains in CCW that would support entry into doctoral programs. As a result, while all our students spoke of their early goals of pursuing STEM bachelor's degrees, the doctorate was not assumed by our Fellows. The decision to pursue a doctorate seemed to require the majority of students to engage with faculty or peers in such a way that then the path opened up to them. In looking at this doctoral engagement process, we found that there seemed to be critical chance incidents that occurred and ended with students entering doctoral programs. We define *critical incidents* as something that happens that leads to a bifurcation in the direction of the Fellow's career path, and with them pursuing a path that was less likely or not available prior to the critical event.

- Example: Professor X met with a Fellow for 90 min to explain the structure of advanced study (BA - > Masters- > Ph.D.) Later, this knowledge allowed the Fellow to pursue the path to the Ph.D.

Further, these critical incidents often occurred by chance and were not planned or part of a structured event. These were not events experienced by all undergraduate STEM majors.

- Example: A number of Fellows by chance were in labs when a peer, with critical knowledge or serving as a role model, was present.

The probability of the occurrence of these critical events, that led our Fellows to doctoral programs, are a concern as there is a strong element of uncertainty to these chance events. This leads to the question of how many more Hispanic students might have continued on the path to a doctorate if they had experienced these types of events. It also suggests that the critical cultural knowledge that was represented in these events may be essential to disseminate to all Hispanic STEM undergraduates and other students underrepresented in STEM. Institutions that wish to increase Hispanics in STEM graduate work may want to consider how to institutionalize the sharing of cultural capital about STEM pathways in programmatic rather than provisional ways.

These research results do not appear to support the idea seen in many K-12 interventions that STEM programs, offered in varied amounts across school systems and within local communities, are the primary catalyst for students developing a passion for STEM. Instead, we found that families that respond to their child's interests and support that development is what was effective with our participants in putting them on a direct path to STEM careers.

Future research is needed to understand the parenting practices that have so frequently been seen in our Hispanic Fellows' experiences. Is it possible to share those practices within different types of URM communities? Additionally, research on creating effective interventions that explore sharing key cultural knowledge about the graduate school pathways to STEM with Hispanic undergraduates is also desirable. This research demonstrates that, as others have found, cultural capital is of great importance in Hispanic student academic engagement. We did not collect data on CCW but it would be worthwhile in the future to see how CCW provides the cultural capital beneficial for student success beyond attainment of the bachelor's degree.

Limitations

As with any case study our findings are limited by the small size of our sample. Our findings cannot be generalized to other Hispanic doctoral STEM students or other URM students pursuing doctoral degrees. We will be repeating this study with the next two cohorts and look to see whether future data supports our initial findings or whether new themes are identified that influence career decision-making. Additionally, we may not be able to draw conclusions about the STEM pathways for all Hispanic students, particularly for those that do not have and will never have an interest in graduate studies. There may be differences in motivation and curiosity, that our Fellows showed an abundance of, and that make them more likely to wish to engage in doctoral studies where they can continue to think and explore ideas and questions. However, identifying children with a passion for STEM may be a useful first step in finding and supporting future STEM college graduates.

CONCLUSION

This research has found that Hispanic families and the manner in which they engaged their children in STEM activities or supported their child's interests was uniquely effective in leading to doctoral Fellows with self-motivation to pursue their passion—STEM. Additionally, the importance of critical cultural knowledge about the academic process of graduate school should not be assumed to be known or available to many Hispanic undergraduate students. Without this knowledge, even Hispanic

students who have a passion for STEM may be lost to engagement in graduate STEM pathways.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available due to restrictions in the submitted IRB. Requests to access the dataset should be directed to DH, dmhorton@umass.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved in an IRB submitted at the University of Massachusetts, Amherst. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DH developed the interview protocol with suggestions and revisions by IT-C. DH applied for and received IRB approval. DH and IT-C each conducted half of the interviews and each coded 3/4 of the interviews in a qualitative data software. DH themed the results and reviewed with IT-C for suggestions and revisions. DH wrote the article with input from IT-C. Both authors contributed to the article and approved the submitted version.

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Developing a State University System Model to Diversify Faculty in the Biomedical Sciences

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Amid increasing demands from students and the public, universities have recently reinvigorated their efforts to increase the number of faculty from underrepresented populations. Although a myriad of piecemeal programs targeting individual recruitment and development have been piloted at several institutions, overall growth in faculty diversity remains almost negligible and highly localized. To bring about genuine change, we hypothesize a consortia approach that links individuals to hiring opportunities within a state university system might be more effective. Here we present a case study describing the progress of the NSF-funded Alliances for Graduate Education and the Professoriate (AGEP) PROMISE Academy Alliance, a consortium within the University System of Maryland (USM) collaborating to develop, implement, self-study, evaluate, and disseminate a unique postdoc-to-faculty conversion model in the biomedical sciences. The initiative centers on diversifying faculty across five institutions in the USM, including teaching-focused institutions, comprehensive universities, research institutions, and professional schools. Components of this approach include (1) enhanced recruiting and hiring practices to attract outstanding postdoctoral scholars from underrepresented backgrounds, (2) multi-institutional networking and professional development, and (3) facilitated processes to transition (or "convert") postdocs into tenure-track positions at their postdoctoral institution or another institution in the state system. This model is distinct from more deficit-based approaches because it goes beyond focusing on building the individual's skills to enter the professoriate. This program restructures the traditionally short-term nature of postdoctoral employment and incorporates a pathway to a tenure-track professorship at the same institution or within the same statewide system where the postdoc is trained. This multi-institutional model leverages collaboration and distinct institutional strengths to create cross-institutional support, advocacy, and policy. Importantly, it uses a decentralized financial structure that makes this approach distinctly

replicable. Recognizing the immediate need for more collaborative approaches to diversify faculty and a lack of literature about such approaches, this case study describes the development of, and potential benefits of, a state university system, as well as the qualitative lessons learned from self-study, internal evaluation, external evaluation, and NSF site visits. The AGEP PROMISE Academy can serve as a model for replication at other university systems hoping to diversify their faculty.

Keywords: faculty diversity, biomedical sciences, postdoc, AGEP, state university system

INTRODUCTION

Increasing faculty diversity has important implications for maintaining and growing U.S. competitiveness in innovation, the knowledge and science economy, and broadly equipping the 21st-century workforce. The compelling need for more innovative approaches to diversify faculty is clear by the changing demographics of the student body and the ensuing racial and ethnic imbalance. While the national percentage of underrepresented minority college students (undergraduate and graduate students combined) has risen to nearly 50%, the percentage of underrepresented minority faculty remains below 30% (Finkelstein et al., 2016; Snyder et al., 2018; Espinosa et al., 2019; Brown, 2021), and the percentage of tenure-track minority faculty remains even lower at 22% (NCES, 2018). The benefits of a more diverse faculty extend to all students (Stout et al., 2018). For students from traditionally underrepresented racial and ethnic groups, having faculty role models from similar backgrounds sends a powerful message of support and belonging (Jayakumar et al., 2009; Cole and Griffin, 2013; Shin et al., 2016; Griffin, 2020), and students from majority backgrounds gain by experiencing broader pedagogical perspectives (Umbach, 2006) and countering stereotypes to reduce bias (Gocłowska and Crisp, 2013). For these reasons and many others, successful initiatives to increase the number of faculty from underrepresented backgrounds are critical.

The academy has been discussing strategies to improve racial equity for decades, but progress has been incremental and slow (Snyder et al., 2018). Unfortunately, there are still many structural barriers that impede excellent underrepresented STEM postdoctoral scholars from being recruited, retained, and promoted into faculty positions. Because postdoctoral training is the gateway to a tenure-track position in the biomedical sciences, the structural barriers to accessing employment at this level help to maintain the stark racial and ethnic disparities in outcomes at the faculty level. For example, lack of access to opportunities to learn about academic careers (Gibbs et al., 2015) or to obtain professional and social supports (Layton et al., 2016) as well as clearly documented racial bias in postdoctoral (Eaton et al., 2020) and faculty search processes (White-Lewis, 2020) prevent entry into faculty positions. Beyond recruitment and hiring, other structural barriers can include a toxic department culture (Cole and Hassel, 2017; Dutt-Ballerstadt, 2020), or a culture of "niceness" that centers on conflict avoidance (Liera, 2020), a disproportionate workload (Peek et al., 2013; Jimenez et al., 2019; O'Meara et al., 2019; Dutt-Ballerstadt, 2020; Flaherty, 2020) and lack of attention to the importance of sense of belonging (Gibbs et al., 2015) which contributes to the failure of institutions to retain scholars of color in the academy. When recruited and hired in low numbers, biomedical faculty from underrepresented backgrounds are often socially isolated and less likely to find connections of shared experiences (Misra et al., 2021) and thus find themselves with limited mental and emotional support when they most need it.

One potential avenue to securing more diverse faculty is to recruit more underrepresented postdoctoral scholars. In the laboratory sciences and a growing number of other disciplines, postdoctoral appointments (where scholars work on the research of a faculty member) are an expectation prior to securing a tenure-track position. These appointments are typically 2–3 years long, but a recent *Nature* survey of postdoctoral scholars found that 48% of respondents had been working as a postdoc for more than 3 years, with 30% of respondents having already completed two or three positions before their current postdoctoral appointment (Woolston, 2020a). Academic careers are the top choice of postdoctoral scholars, with over half of biomedical postdocs ranking faculty positions as their intended career, but interest in pursuing academia typically decreases between years one and three of a postdoc, particularly for underrepresented minorities and women (Lambert et al., 2020; Woolston, 2020b). There is justification for the noted pessimism and anxiety documented in postdoctoral surveys: only 15–20% of postdocs actually do transition to tenure-track positions (Kahn and Ginther, 2017; McConnell et al., 2018). The postdoc-to-faculty transition has been recognized as one of two key junctures where underrepresented minorities divert from their goals of becoming faculty (Meyers et al., 2018) and financial security, responsibility to family, and lower sense of belonging and self-efficacy seem highly influential in the departure of female and underrepresented scholars (Lambert et al., 2020). However, few interventions focus on this critical period or the barriers presented by traditional postdoctoral positions.

Institutional efforts have been tried. For example, prestigious, postdoctoral fellowships, designed specifically for scholars from underrepresented backgrounds, are growing in number, attempting to attract more scholars from the doctorate into pre-faculty roles. Despite documented successes of these programs (Holtzclaw et al., 2005; Faupel-Badger and Miklos, 2016; Eisen and Eaton, 2017) they do not address transitional barriers head on. A promising intervention is the postdoctoral conversion model, where scholars from underrepresented backgrounds are

recruited into postdoctoral positions that come with a direct pathway to "convert" to the tenure-track at their fellowship institution (Culpepper et al., 2021). Because this reduces a barrier to the professoriate position and provides financial security, it stands a chance of making a significant difference in enhancing racial equity. Conversion models, however, are being implemented at only 38 institutions nationally (Culpepper et al., 2021) out of over 5,000 colleges and universities, making any potential progress slow and localized to individual departments or institutions.

Scaling up conversion models to the university system may be a way to accelerate their potential. Dr. Kimberly Griffin, author of *Redoubling Our Efforts: How Institutions Can Affect Faculty Diversity*, is "increasingly convinced that collaborative efforts were the key to real gains in faculty diversity across higher education… group efforts might happen not just across disciplines, with the help of disciplinary organizations, but also in other configurations—such as across a state university system" (Flaherty, 2016). While some university systems have strategic plans for increasing the number of faculty from underrepresented backgrounds, commitment statements, or even "action plans," rarely accompany any tangible steps being taken to combat this problem meaningfully. In fact, the only pre-existing exemplar of a system-wide approach is the University of California system's President's Postdoctoral Fellowship Program, established in 1984 to "encourage outstanding minority Ph.D. recipients to pursue academic careers at the University of California." Not only does it supply funded postdoctoral positions, in 2003, it began incentivizing the tenure-track hire of these scholars by providing 5 years of salary support and start-up funds. This program has been incredibly successful, with over 260 hires of minority scholars into tenure-track positions since the financial incentives were established (Lawson, 2020). However, no research has been published about the establishment, evolution, or efficacy of this model, and the centralized funding approach used by the University of California system (facilitating initiatives where funds can be dispensed to institutions within the system easily) is uncommon among state university systems, and thus has not been replicated.

On the other side of the country, within the University System of Maryland (USM), a new state system approach is being developed that could have greater scalability because it operates in the context of a more traditional university system, with institutional budgets set by the state and extremely limited funds for centralized initiatives. In this article, we describe the current progress of Maryland's NSF-funded Alliances for Graduate Education and the Professoriate (AGEP) PROMISE Academy Alliance, a five-institution consortium (out of 12 institutions that comprise the USM) developing a model to increase the number of tenure-track underrepresented faculty in the biomedical sciences. Building on successful lessons of other postdoctoral programs aimed at supporting the success of underrepresented scholars, the AGEP PROMISE Academy Alliance seeks to recruit, onboard, develop, and mentor postdoctoral fellows to be prepared for the tenure-track. Uniquely, this program includes overt intention and concrete support to transition postdoctoral fellows into tenure-track faculty positions, either at their postdoctoral institution *or at another institution within the university system*. This disrupts the traditional short-term timeframe of a postdoc and hopefully some of the subsequent insecurity and anxiety that accompanies standard postdoctoral fellowships (Postdoctoral training: time for change, 2011; Milojević et al., 2018; Woolston, 2020a). The stress of this insecurity is especially daunting for scholars with children or those hoping to have children (De Welde and Laursen, 2011; Woolston, 2020a), putting women from underrepresented backgrounds at a particular intersectional disadvantage. The AGEP PROMISE Academy also provides fellows the benefit of networking and learning about different types of institutions, something frequently absent from a postdoctoral fellowship, and provides potential hiring institutions with a supply of highly qualified, vetted, and trained scholars as potential colleagues.

Below, we present a case study of this novel intervention, describing the key programmatic elements of the AGEP PROMISE Academy Alliance model along with qualitative data assembled from focus groups, document analysis, meeting observations and interviews, collected through self-study as well as internal evaluation, external evaluation, and multiple NSF site visits. This article summarizes many of the facilitators and hindrances observed and reported by evaluators to provide insight into the development of both a state system alliance and as well as a unique fellowship program for underrepresented postdocs. While data on the impact of the model is limited (due to being just 3 years into implementation), robust data has been collected about the *process* of developing this multi-level collaborative intervention. Considering the dearth of literature on system approaches to faculty diversity and the high interest of institutions and systems to make more substantive progress, we include discussion of barriers to developing state system alliances, successes that can be and have been measured during development, and practical lessons learned in our effort to increase the hiring and retention of faculty from underrepresented populations in five institutions within one university system.

CONTEXT AND BACKGROUND

The AGEP Promise Academy Alliance has a focus on diversifying the faculty in biomedical sciences and includes five institutions within the USM: two research-intensive campuses [the University of Maryland College Park (UMCP), and the University of Maryland Baltimore County (UMBC)], two comprehensive teaching-focused universities (Salisbury University, SU, and Towson University, TU), and a research-intensive professional school (University of Maryland Baltimore, UMB). The research-intensive campuses and the professional school (UMCP, UMBC, and UMB) had a history of working together to provide support and programming for underrepresented graduate students in STEM through previous NSF AGEP awards, and that relationship served as a strong foundation on which to build a system-wide model geared at the next stage of the professoriate career path: the postdoctoral position. The alliance is building a model that uses enhanced recruiting and hiring

practices to attract outstanding postdoctoral scholars (Fellows), provides a multi-institutional professional development plan (leveraging distinct strengths of institutions within the alliance), and creates facilitated conversion processes to transition postdocs into tenure-track positions at their postdoctoral institution or another institution in the statewide system. The alliance provides a unique development program (the AGEP PROMISE Academy) for Fellows by leveraging the strengths and differences of all partner institutions. The model includes two conversion pathways: (1) the Predetermined pathway supports a Fellow through the program with the expectation to convert the Fellow into a faculty position at the same institution where the postdoctoral fellowship is completed, and (2) the Flexible pathway supports a Fellow to investigate and connect with other institutions within the university system with aims of transitioning the Fellow into a tenure-track faculty position. The AGEP PROMISE Academy supports postdoctoral scholars as they prepare to enter tenure-track faculty positions after experiences with career- and skill-building professional development, dedicated mentoring and networking, and opportunities to showcase their research at other USM campuses. As all institutions had strong biomedical programs, including behavioral and cognitive sciences, the model places an emphasis on diversifying faculty in the biomedical sciences. The alliance is funded by the NSF and is in the beginning of year four of the five-year grant period.

The USM consists of 12 Institutions, three Centers, and one System Office, spread across the state, and serves over 170,000 students. Geographically, Maryland is small, with most university system institutions within easy driving distance from one another. While operating under the umbrella of the university system, each institution is autonomous, with separate presidents, provosts, and budgets. Collectively, these independent leaders unite to formulate common strategies and policies for the entire system. The unique individuality of institutions is a strength to our system and the inherent diversity this individuality brings allows for successful collaborations. Diversity and inclusion have been at the forefront of Maryland's university system and on individual campuses. A recent example of this dedication was shown when UMCP, recently announced a $40 M investment to promote efforts to attract, hire, and support more faculty from diverse backgrounds. Many USM institutions have official diversity, equity, and inclusion offices and officers, all of which provide support and assistance for increasing and supporting diversity initiatives.

A NEW MODEL FOR FACULTY DIVERSIFICATION

The State University System Approach: A Multi-Level Collaboration

The goal of Maryland's AGEP PROMISE Academy Alliance is to develop, implement, self-study, evaluate, and disseminate (DISED) a state system alliance model to increase the number of tenure-track faculty from underrepresented (as defined by the National Science Foundation)[1] backgrounds in the biomedical sciences within the system. The work of this project is three-pronged: (1) we are generating a postdoctoral program and experience (the AGEP PROMISE Academy) that includes recruitment, selection, mentorship, professional development, and conversion into tenure-track positions (at the fellowship institution or another institution with state university system); (2) we are creating, assessing and evolving the structures needed for a system-wide project to operate; and (3) simultaneously, an arm of our alliance is conducting significant research on bias in faculty search processes (creating the "R" in what the NSF refers to as DISED+R). This article focuses on the first two prongs of the project, as the research component is parallel to, and not an assessment of, the first two prongs. This work is shaped considerably around the five pillars of Collective Impact Strategy (CIS; Kania and Kramer, 2011): building a common vision, using agreed-upon metrics of evaluation, facilitating mutually reinforcing activities, encouraging continuous communication, and establishing a strong backbone of dedicated staff to ensure the sustainability of the project. These pillars will be referred to throughout this article.

The programmatic experience created for postdoctoral scholars from underrepresented backgrounds, the AGEP PROMISE Academy, was conceived from recruitment, onboarding, and professional development to conversion to a tenure-track position (see **Figure 1**). A broad team of over 35 individuals across alliance institutions (including provosts, deans, directors, staff, and faculty) collaborated to create this program at a kick-off retreat in the first year of the project. The details and merits of the programming will be discussed later in this section. Our model for diversification within a state university system centers the AGEP PROMISE Academy program, but also emphasizes the continuous interaction and influence between the Alliance, the individual institutions within the Alliance, and the university system office (see **Figure 2**). As an Alliance, we created the model and program communally and have together developed protocols, guidelines, and tools to facilitate implementation of the program across the Alliance. However, we continuously learn from and leverage institutional expertise, and also execute elements of our model and program through complementary institutional processes (**Figure 2**). For example, our model has been informed heavily by institutional programs at the UMBC to diversify the faculty through postdoctoral recruitment and conversion into the tenure-track. The Provost's Fellowship for Faculty Diversity has operated for 10 years, with over 50% of the postdoctoral participants staying on as UMBC faculty. A more recent adaptation of this program, the Pre-Professoriate program at UMBC, addressed many of the ways to make this program more effective in the laboratory sciences, and the administrators of these programs are active members of the Alliance team, ensuring we incorporate lessons learned from these initiatives. Another example of the interplay between the Alliance level and Institutional level of the model is the process

[1]The NSF defines underrepresented minorities in STEM as African Americans, Hispanic Americans, American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders.

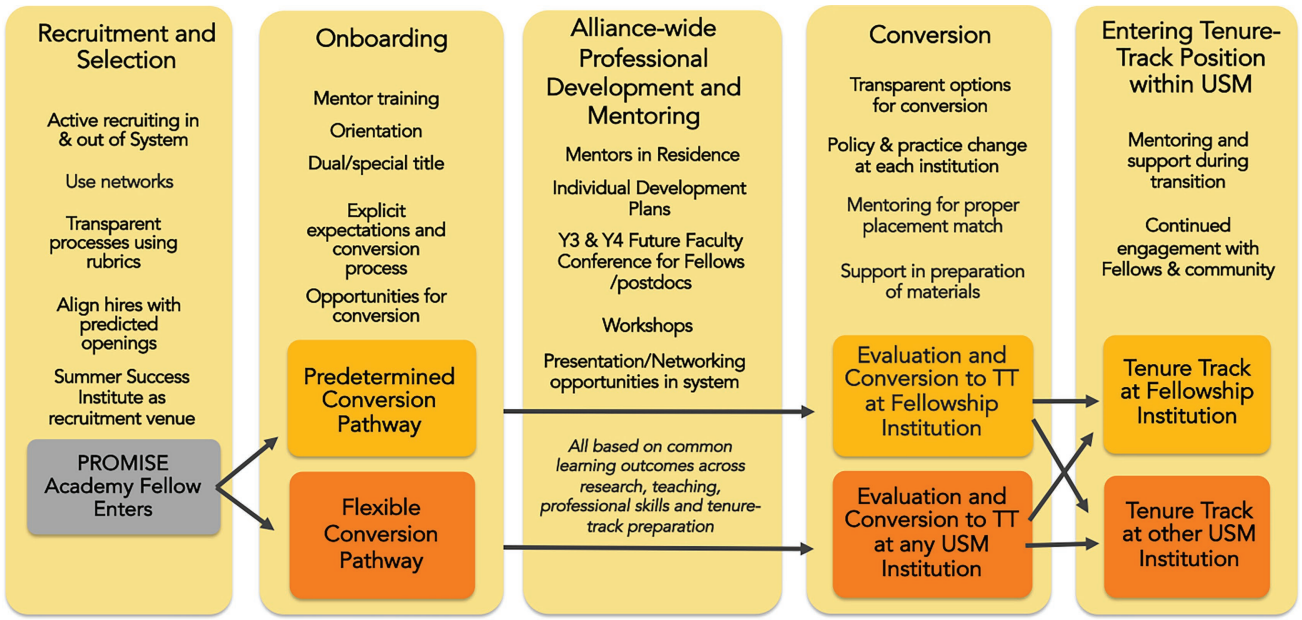

FIGURE 1 | Components of the Alliances for Graduate Education and the Professoriate (AGEP) PROMISE Academy, a program to recruit, onboard, professionally develop, and convert biomedical postdocs from underrepresented backgrounds into tenure-track faculty positions, either at their fellowship institution (Predetermined pathway) or at another institution within the state university system (Flexible pathway).

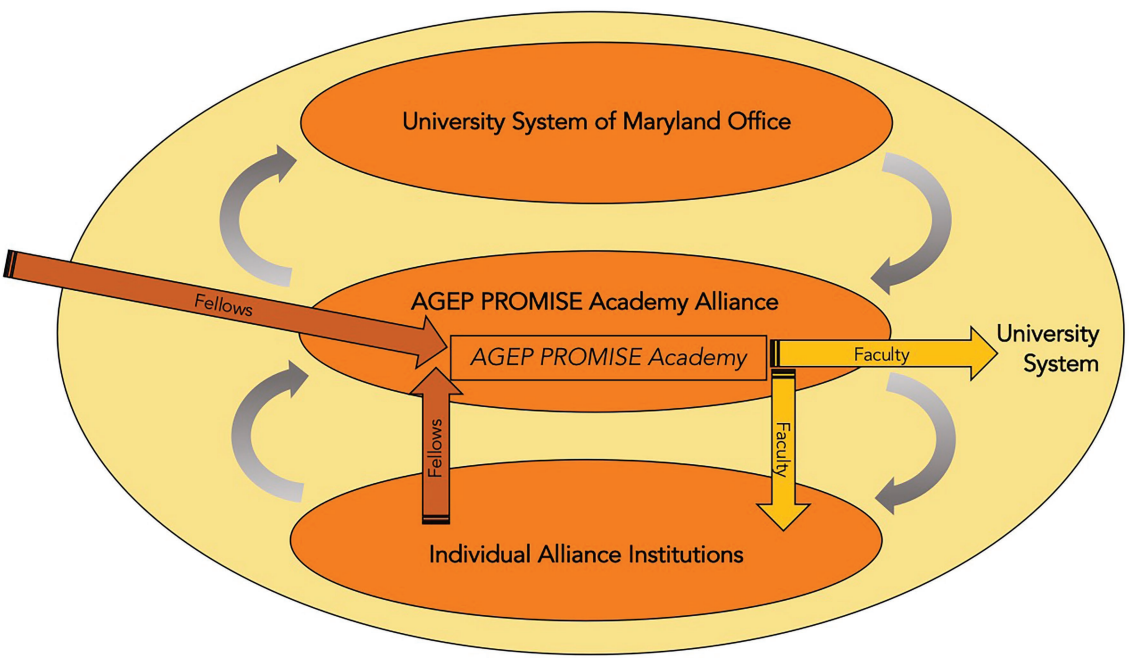

FIGURE 2 | Conceptual model of interaction (gray arrows) between University System of Maryland's System Office, AGEP PROMISE Academy Alliance, and the individual AGEP PROMISE Academy Alliance institutions. AGEP PROMISE Academy Fellows enter the program (rust arrows) from institutions within the Alliance, within the university system, or from external institutions and move into tenure track faculty positions (gold arrows) following the Predetermined pathway to a position at their home Alliance institution or the Flexible pathway to a position at a different Alliance institution or other USM institution.

of finding and hiring Fellows. The recruitment and hiring of Fellows occur independently on individual campuses since funding for the fellowship comes from the institutions. But guidelines for recruitment of Fellows were developed by the Alliance leadership team for use across the Alliance institutions, and include sample job ad language, rubrics, and recruitment

strategies.[2] The Alliance team realized such guidance was necessary, since institutional processes can vary widely, and the Fellows hired are not traditional postdocs but tenure-track faculty-to-be. Using a national search process that is similar to that of a faculty search would build departmental buy-in for future conversion at the institution or another university system institution. The recruitment process has some shared components which the Alliance hopes to strengthen over time (for example, using shared recruitment venues like the annual Summer Success Institute conference for underrepresented graduate students and postdocs in STEM). New Fellows are onboarded with a combination of Alliance activities (e.g., one-on-one welcome and skills assessment[3] with the director, Orientation with all Fellows) and institutional activities such as campus orientations, meetings with their mentors and department chairs, and the development of individual development plans (IDP) with their primary faculty mentor.

Similarly, our model's success hinges on a reciprocal interplay between the Alliance and the USM system office (**Figure 2**). The Alliance encourages System change by participating in System-level committees that can influence structural changes that facilitate hiring of Fellows at institutions throughout the system, as well as influence policies to reduce bias and increase diversity (e.g., Appointment, Promotion and Tenure policy committee). In turn, the Alliance receives support from the System by being given platforms for dissemination (e.g., Academic Affairs meetings) and technological support. Most notably, at the request of the Alliance, the USM Information Technology unit is building out a database of USM postdoctoral scholars and academic opportunities (e.g., guest lectureships, adjunct teaching positions, and faculty openings) within the system. This database, modeled in part after the Big 10 Alliance's Professorial Advancement Initiative postdoctoral directory,[4] enhances the Alliance's ability to connect Fellows with opportunities across the system and also vice versa, provides a mechanism for departments to learn about postdoctoral talent that already exists within the system and could bring additional diversity to their institution. We have been grateful to have incredible buy-in and support from the USM system office, and they have allowed us access to numerous system-wide meetings to describe our efforts, build relationships, and begin the process of forging policies and practices that will be critical to the success of the project.

Participation in the project is expected at all levels throughout the period of NSF funding and beyond. Some of the major activities of each level across the early, middle, and later years of the 5-year AGEP grant are captured in **Figure 3**. While the Alliance is committed to continuous DISED+R, the most notable development and implementation activities included creating the AGEP PROMISE Academy program and directing the execution of that program, including the cohort building, professional development, and conversion pathways to tenure-track faculty positions. The institutions recruit, hire, onboard and mentor the Fellows, but also host Fellows from other institutions for seminars and guest lectureships to consider them for faculty lines. In addition, institutions examine their own departmental "readiness" for supporting the success of additional faculty from minoritized backgrounds and consider their own institutional structural changes (more of this is discussed in Overcoming Barriers and Measuring Success, below). The USM office administrators promote the Alliance throughout the university system and facilitate engagement with non-Alliance institutions, encourage broad adoption of Alliance practices, and support infrastructure and policy changes that can institutionalize the Alliance model at the system level.

The AGEP PROMISE Academy: Our Programmatic Core

At the center of our state system model is the postdoctoral experience in the AGEP PROMISE Academy (**Figure 1**). This two-year fellowship is designed to prepare the Fellow for the tenure-track, preparing them to successfully convert into a tenure-track line at their fellowship institution or at a campus within the university system.

Building a sense of community and a network across campuses is a cornerstone of our AGEP PROMISE Academy. Fellows attend monthly virtual meetings with the other Fellows and the program director to help provide an external safe space to share concerns and successes, troubleshoot barriers that arise, and to build a sense of community among these underrepresented scholars who may not have frequent access to a group of other racial minorities in a similar position. Lambert et al. (2020) recommends this type of cohort and structured programming for underrepresented minority postdoctoral scholars and cites the success of institutional efforts that leverage cohorts to find community (Eisen and Eaton, 2017). In addition to monthly meetings of the Fellows, the Fellows attend regular professional development activities led by Alliance institutions. To help guide the professional development that we offer to our Fellows, we worked with current and former Fellows (now faculty) and Alliance team members to develop a set of common learning outcomes[5] that aligned with their experience as well as the National Postdoctoral Association's Core Competencies[6] that build a Fellow's skills to enter the professoriate. We developed and implemented a skills assessment with our Fellows upon entering our program and at checkpoints during their fellowship. But mentorship of the Fellows and use of the skills assessment in an IDP occurs on the individual campuses with designated faculty mentors. A distinguishing feature of our model is that we provide a multi-institutional professional development plan that includes workshops leveraging the distinct strengths of institutions within the university system alliance. For example, the regional comprehensive institutions (TU and SU) provide pedagogical

[2]https://theagepromiseacademy.com/wp-content/uploads/2021/10/Guidance-for-Recruitment-and-Selection-of-APAA-Fellows.pdf

[3]https://theagepromiseacademy.com/wp-content/uploads/2021/10/APAA-CLO-SKills-Assessment-Revised.pdf

[4]https://btaa-pai.btaa.org/pai

[5]https://theagepromiseacademy.com/wp-content/uploads/2021/10/APAA-CLOS-and-Expectations_20210803.pdf

[6]https://www.nationalpostdoc.org/page/CoreCompetencies

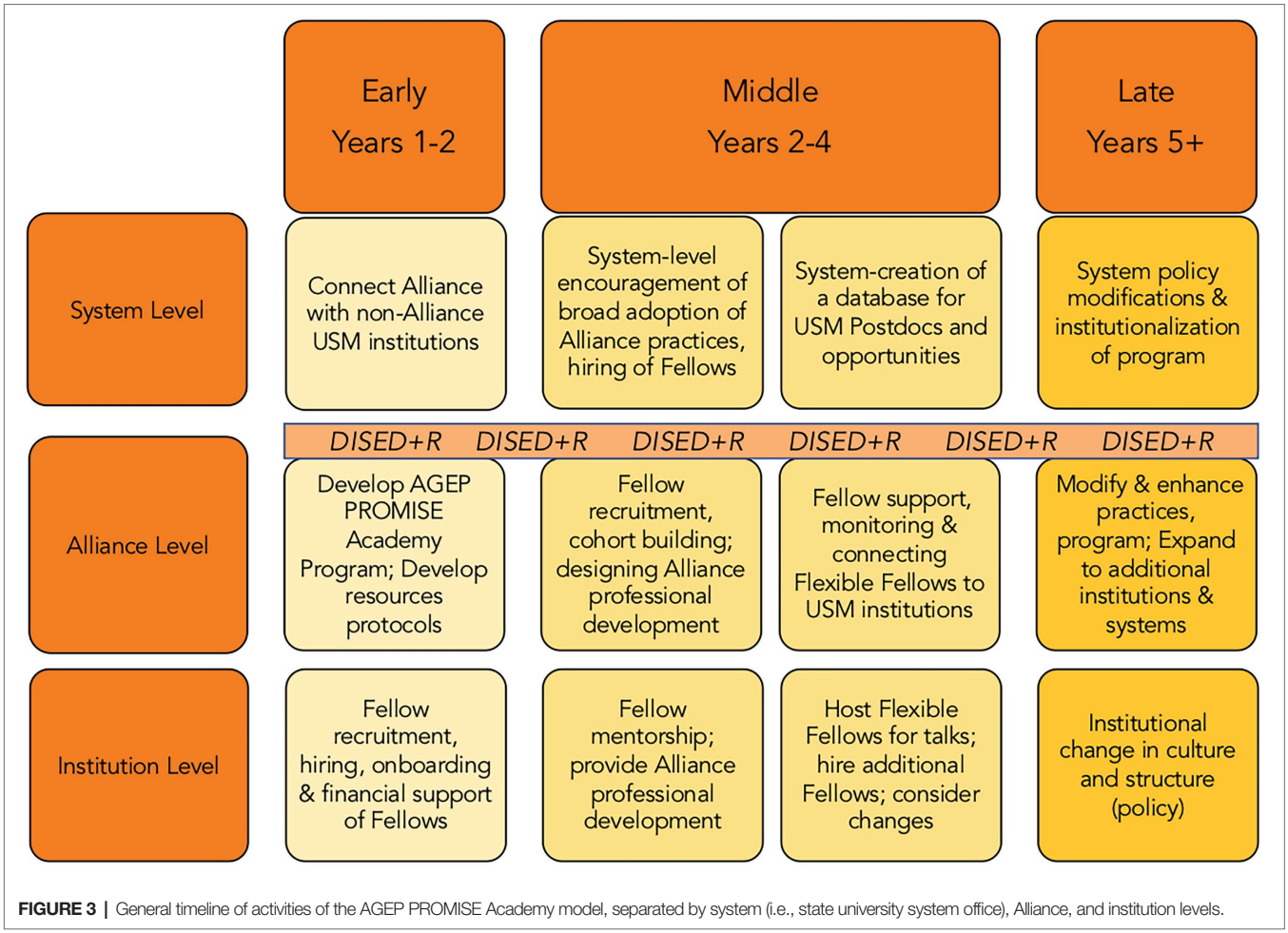

FIGURE 3 | General timeline of activities of the AGEP PROMISE Academy model, separated by system (i.e., state university system office), Alliance, and institution levels.

training and encourage best practices for faculty research on a predominantly undergraduate campus. Fellows then access grant-writing workshops from the medical school within our alliance (UMB) and mentorship training from the R1 institution (UMCP), while our R2 institution (UMBC) hosts underrepresented networking events and organizes Orientation and program-recruiting events. This model is effective because it draws from pre-existing programmatic elements on various campuses that simply need to be coordinated into a unified calendar. This is a culminating example of the CIS pillar "mutually reinforcing activities."

This inter-institutional professional development has the intentional added benefit of educating the Fellows about a broad range of institutional types at which Fellows can become a faculty member. This is important because, while most postdoctoral positions are housed at research-intensive R1s, most institutions that employ tenure-track faculty are not research-intensive. Indeed, one of the common learning outcomes for the program is to expose Fellows to multiple campus environments and help them make more informed choices about where they will be most fulfilled as they establish their faculty career. Learning about the different institutions happens at structured events (such as the yearly orientation and at an annual session held at one of the regional comprehensive Alliance institutions) as well as organically through Fellow interactions with each other at monthly meetings or group sessions with AGEP PROMISE Academy Mentors in Residence (faculty from underrepresented backgrounds from around the country).

Importantly, though, our program additionally focuses on *restructuring* the traditionally short-term nature of postdoctoral employment by incorporating a career pathway to a tenure-track professorship at the same institution or within the same statewide educational system where they are trained. The goal of this program is to diversify the tenure-track faculty within the university system through retention of Fellows as faculty. Alliance campuses have worked in years one-three of the project to solidify the "Predetermined pathway" (where the Fellow is retained at the campus where they are trained during the Fellowship, see **Figure 1**). This is based on two successful postdoc conversion programs at UMBC (Culpepper et al., 2021). Four of the nine fellows in our program are in the Predetermined pathway and four of the five campuses have a Predetermined pathway in place (the fifth campus is establishing this on their campus for a fall 2022 hire). We have simultaneously been building out a unique process we call the "Flexible pathway"—which is a greater challenge but expands the possibilities for postdocs to have a stable pathway to a tenure-track faculty

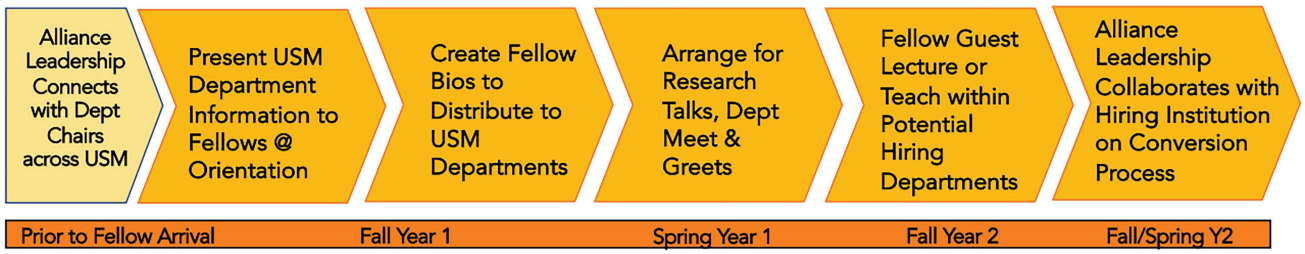

FIGURE 4 | Detail of the AGEP PROMISE Academy Flexible Pathway.

position within the broader USM. The Flexible pathway model (detailed in **Figure 4**) requires educating Fellows and institutions about each other and facilitation of opportunities to interact in a sort of professional matchmaking process. The aforementioned database of information about Fellows and institutional opportunities, being built by the USM Information Technology team, will facilitate matchmaking. The opportunities for Fellows thus far have been research talks at universities of interest within the system, but will most likely expand to include departmental guest lectures, teaching opportunities, or full day mock faculty interviews like those offered through the Cottrell Emerging Scholars program (Diversity program helps postdocs prepare for interviews, 2020). We have two Fellows currently starting their second year of this Flexible pathway and have another beginning their first. We will be hiring additional Fellows in this pathway in the coming years, and self-study and evaluation of this pathway will certainly enhance the process.

OVERCOMING BARRIERS AND MEASURING SUCCESSES

The overarching goal of this project is to develop, implement, self-study, evaluate, and disseminate a state system model to increase the number of historically underrepresented faculty in the biomedical sciences. In order to do so, we engage in multiple efforts to understand the factors that challenge and facilitate our work. Our external evaluator hosts yearly focus groups, meets with leadership, attends annual retreats and meetings and reviews documentation to help determine if we are succeeding in developing and implementing a model, and also helps identify factors that facilitate and hinder that progress. Our internal evaluator monitors institutional data to observe changes in overall faculty diversity, conducts interviews with Fellows, assesses the effectiveness of our professional development programming, and provides regular formative feedback to encourage leadership team efforts and self-study (our internal evaluator attends leadership meetings). We also have an external advisory board, made up of leaders of other institutions and organizations with experience developing and implementing programs aimed at diversifying the professoriate, and meet with them four times a year. We receive annual reports from the internal and external evaluator as well as the external advisory board each year. In addition, we have undergone two site visits by NSF program officers and external panelists in years one and three of the project to assess the strengths and weaknesses of ongoing work.

Establishing a state system model to diversify faculty comes with a number of built-in barriers to success. First, there is the simple issue of geography when dealing with institutions that are hours apart. We happen to be in a small state with most alliance institutions within 30–45 min of each other, but one of our institutions is 2.5 h away. We learned, as many have in the past year, to make good use of video conferencing and providing fellows with virtual professional development. Second, there are power dynamics at play when you build collaborations—racially, between institutions, between ranks, etc. This can manifest in a myriad of ways and can undermine collaborative decision-making. We had to be aware of these from the beginning and actively work to neutralize them when possible. Efforts like ensuring nametags had names but not titles at in-person retreats, conducting an anonymous survey about authorship determinations for dissemination, and inviting coordinator-level team members to participate actively and provide feedback has helped mitigate these dynamics. Another barrier we faced was understanding and navigating different institutional language and policy. Academia is traditionally siloed, and policies/governance is institutional, so creating a common vision and common language to use as we engage with each other across a system was very important. Within our system, different institutions have different definitions of postdoctoral scholars, for example, and not every institution has search waiver policies that could facilitate conversion of a Fellow into a faculty role. These obstacles were exposed and often at least partially surmounted by getting to know each other through retreats and group meetings, having consistent communication, as well as having accessible documentation (agendas, minutes, presentation copies, etc.) in a shared drive. For example, we decided as an Alliance to pursue system-wide search waiver language with the system office through their Appointment, Promotion and Tenure committee, hoping that the university system might adopt language that already exists on some campuses to permit the hire of a tenure-track faculty under special circumstances. This effort is ongoing, but two members of the Alliance leadership team have been appointed to the system committee reviewing the policy, which is an excellent start.

Faculty and department buy-in for initiatives will always be a requirement for institutional change that is sustainable and building buy-in or shifting culture across different departments at different institutions within a system will be an ongoing issue. This is especially true as we attempt to drive a culture shift of viewing postdoctoral fellows as future colleagues developing their own research agenda, as opposed to simply trainees gaining experience on a faculty member's project. This paradigm shift encourages departments to support postdocs as independent researchers training to be in charge of their own labs as faculty, as well as preparing for faculty careers more broadly (e.g., teaching, engaging in service). Engaging with hiring departments, chairs, STEM Deans, and even search committees about our model has helped build nominal support, but we recognize deeper adoption will take time and positive experiences with the program/our Fellows. Currently, we are in the process of assessing what we call "departmental readiness" across potential hiring departments at alliance institutions. Using a validated, qualitative, and time-intensive instrument to interview faculty, we hope to learn about the climate of departments and their true commitments (intellectually and financially) to support the recruitment and retention of underrepresented faculty. We have plans to work on a more streamlined assessment that will help us gauge *and support* departments more effectively, helping shed light on areas for improvement and directing them to resources to assist with that improvement.

Finally, a barrier for this project is the simple truth that policy creation is slow. The Predetermined pathway for postdoc conversion has relied on working with existing institutional policies or creating policy within an institution (still may be slow, but a known approach). The Flexible pathway will require policies and practices that *cross* institutions and possibly will require conversation and approval at the level of the Board of Regents—and acceptance within each USM institution. We recognize this challenge and advise working with advocates for equity and diversity within the USM early and often as they can assist in navigating that landscape successfully.

Despite these barriers, we can report multiple successes from the project thus far. First, as has been noted by our external evaluator and NSF panelists, we have built the essential collaborative infrastructure of human resources as the CIS pillar of "backbone support": a broadly engaged group of stakeholders, a leadership team, a program director, and key change agents at the university system office level. Focus group data from leadership and broad team members demonstrate that we have a highly functional leadership team with a project director and representatives from alliance institutions, including decision-makers, thought leaders and "doers" that implement programming directly with the Fellows. We thoughtfully constructed this leadership team with two representatives from most campuses, (1) a Dean or Vice Provost with influence over faculty or postdoctoral affairs and (2) an administrator or professional developer that engages with postdoctoral fellows and their mentors. Critically, all leadership team members and broad Alliance team members have a passion and track record of working on projects that increase diversity. To add expertise, we have curated an experienced and engaged external advisory board that provides substantive feedback that positively impacts our progress. For example, in response to feedback, we have taken on developing tools to investigate "departmental readiness" at Alliance institutions to hire, support, and advance faculty from underrepresented backgrounds. We take seriously the CIS pillar of "consistent communication" and engage in bi-weekly leadership team meetings, regular meetings with an external advisory board, and annual retreats and meetings with leadership across system universities and system office administration.

Second, we have generated a model with thoughtfully crafted programmatic elements (the AGEP PROMISE Academy, **Figure 1**) and a collaborative design of reciprocal influence across the Alliance, the University System of Maryland administration, and individual institutions (**Figure 2**). The developed model has been implemented across four of the five Alliance institutions, with the fifth institution implementing this year. We have hired nine of the 16 Fellows we set out to hire and have converted two Fellows to a tenure-track position both within the USM. Through regular self-study and integration of feedback from external and internal evaluators, this model has evolved continuously. To help us act as a unified Alliance, we have collaboratively built numerous resources for the program that are used on the campuses, such as guidelines for recruitment and hiring, onboarding checklists, common learning outcomes, mentor and mentee expectations, skills assessments, individualized development plan templates. While much of the qualitative data collection from Fellow interviews is protected and will remain confidential until the end of the grant period, we have received formative feedback that helps us see the positive impact of our program. Our Fellows have found community with each other through monthly meetings, and have engaged with cross-institution, professional development that has improved their tenure-track readiness (as has been self-assessed through a skill-assessment tool we developed). Fellows have connected to mentors and faculty outside their programs as well, especially through our mentor-in-residence program, workshops to help Fellows learn about faculty life at predominantly undergraduate institutions, and research seminars they have given at other alliance institutions. We have successfully helped expand their networks of peers, successful role models, mentors, and advocates through these activities in addition to our annual Summer Success Institute conference for underrepresented scholars in STEM.

Finally, along the way, we have created a significant culture of *systemness* and reciprocal impact: this model leverages collaboration and acknowledgment of distinct institutional strengths to create cross-institutional professional development and mentorship for our Fellows and has facilitated foundational work for novel system-wide policy. And while the goal is a system-wide approach, our work has inspired significant institutional change on alliance campuses. For example, the successful hiring and conversion of a Fellow into a tenure-track institution on Salisbury University's campus led to the

development of formalized Predetermined pathways on 3 campuses (UMCP, UMB, and TU) that had previously planned to only have Flexible Fellows. For the R1 institution, UMCP, this meant a culture and policy change as they implemented a new FAMILE initiative (Faculty Advancement at Maryland for Inclusive Learning and Excellence).[7] In this new program, postdoctoral scholars they hire as part of the AGEP PROMISE Academy (and concurrent President's Postdoctoral Fellowship appointment) have a pathway to a tenure-track position at the time of hire. At the professional school, UMB, the provost committed $20,000 a year toward salary for the first 2 years of postdoctoral fellowship and one additional year as a faculty member for Fellows hired into their predetermined program. And at TU, one of the regional comprehensive institutions in the Alliance, they decided to hire their first AGEP PROMISE Academy Fellow this coming academic year, as a postdoc with a pathway to conversion in the biology department. The institutional impacts extend beyond creation of conversion pathways. After hearing the research team and Alliance presentations at an annual meeting, the provost of Salisbury University invited research and leadership team members of the Alliance to come to several meetings and consult on the draft of "Plans to support Diversification and Success of Faculty." And while UMBC's institutional postdoc conversion program, the Provost's Postdoctoral Fellowship for Faculty Diversity, served as the model that inspired the AGEP PROMISE Academy, that program is now benefitting from lessons we are learning at the system level: They are evaluating a departmental readiness instrument we have designed for potential use in their own program. While our model is in too early a stage to measure the impact of increasing the number of underrepresented tenure-track faculty in the biomedical sciences, early signs indicate that we are forging pathways that will yield this result.

DISCUSSION: PRACTICAL IMPLICATIONS AND LESSONS LEARNED

Though the AGEP PROMISE Academy Alliance has too few fellows to report significant outcomes thus far in terms of conversions and impacts on faculty diversity, the hypothesis that this novel model enhances faculty diversity is testable. We are confident that postdoc conversion models, particularly those that can occur on a large scale, such as within consortia or a state system, have potential to realize the academy's hope to broaden participation and have equitable representation among faculty. The University of California's (UC) state system model to diversify faculty, the President's Postdoctoral Fellowship Program, started in 1984, has hired over 800 fellows, 67% of which move on to tenure-track positions, half of which are at UC institutions. Of those hired into faculty positions within the system, 98% were successful at achieving tenure and 90% have stayed within the UC system, demonstrating that state system alliances have been instrumental in increasing the number of faculty from diverse backgrounds. Programs like the UC President's Postdoctoral Fellowship and the AGEP PROMISE Academy upend some of the known challenges associated with an academic postdoc that may discourage underrepresented scholars: funding insecurity without a path to stability (Lambert et al., 2020; Woolston, 2020a), isolation and low sense of belonging as an underrepresented minority (Yadav et al., 2020), and lack of professional support and development (Yadav et al., 2020). Interestingly, in attempts to model the academic research system, Wood et al. (2016) created simulations that suggest that job insecurity of postdocs significantly reduces their productivity, particularly as they near the end of a fixed-term contract, and advocates moving postdocs into more secure, permanent positions to improve general scientific output and return on investment. Because the postdoc-to-tenure-track transition is a known place of departure for scholars of color (Meyers et al., 2018) it is critical to address these challenges.

The AGEP PROMISE Academy employs some best practices of other postdoc conversion models, including the University of California's model, while operating within a very different university system structure and funding model. This is important to note, because institutional, system, and state contexts will likely drive *necessary* variability between different consortia approaches. How positions are funded, system policy and language, institutional and departmental processes for hiring may look very different across an alliance. As our program is replicated with other consortia or other disciplines (currently, our AGEP PROMISE Academy focuses on the biomedical sciences), these contexts will need to be assessed and considered. The case could be made that our particular university system structure facilitated the development and implementation of this model as we have two postdoc-intensive institutions (the R1 and professional school), have multiple R2 research-intensive institutions that hire faculty with high research expectations, and have regional comprehensive institutions that, while teaching-focused, are open to hiring teaching-passionate postdocs with the hope to convert to faculty. That we have this distinct constellation of institutions with the system to comprise an Alliance may be viewed as a limitation to our ability to replicate the model in other systems, but we instead view our ability to work across these distinct institutions to successfully build a model as a sign of *increased* imitability. Most university systems have a flagship or R1 and numerous less research-intensive institutions. We have shown that all types of campuses can recruit and train postdoctoral fellows from underrepresented backgrounds, can provide meaningful professional development across a university system, and can contribute to alliance-wide protocols and practices for conversion and retention.

The multi-level collaboration with dynamic influence between the Alliance, the institutions and the university system administration, is a necessary part of the organizational change process (Kezar, 2001) that we hope to evoke at the state system level. While we have discussed numerous ways in which the implementation of this model includes changes in practice, the overall goal is to go beyond increasing diversity quantitatively

[7]https://www.faculty.umd.edu/media/183/download

and to shift culture, norms, and expectations within the system. The involvement of institution provosts, deans, department chairs, and staff, in combination with the regular engagement of key university system administrators, intentionally builds a network of responsibility for the hiring and future success of scholars from underrepresented backgrounds within the university system.

There are numerous limitations to the analysis that has been presented, including the short time frame in which this intervention has been implemented. Case studies, by nature, are descriptive investigations of a particular phenomenon with unknown generalizability. However, because this state university system model has been designed with diverse types of institutions, with leadership across divisions and ranks, and with a decentralized structure that requires each institution's financial buy-in (and subsequently provides institutional control of how they participate in the alliance), it is likely that this model can be replicated more easily than highly centralized approaches. Finally, this article relies on data collected by self-study as well as through external sources (external evaluators, advisory board members, and NSF-appointed panelist experts), and is therefore subject to researcher bias.

Despite these limitations, the accomplishment of designing and implementing a state university system to diversify faculty is noteworthy and we feel the stage is set for success of this model, such that it can be replicated beyond the biomedical sciences and beyond the USM. With that in mind, there are several lessons learned in *building* the alliance and the model that we thought were worth mentioning. Again, these lessons have been distilled from regular self-study, review by our external advisory board, assessments and reports from our External and Internal Evaluators, and two NSF site visits.

Leverage Existing Relationships and Seek External Expertise

External Evaluation has suggested that a positive facilitator of our success has been the history of previous collaboration among many of the institutions and institutional leaders within the alliance. Indeed, our alliance leverages relationships forged over 15 years of collaboration between three of the five institutions on a previous PROMISE AGEP that was focused on increasing enrollment and graduation of underrepresented minorities in STEM PhD programs through community building and professional development. However, not all the institutions were a part of that project, and external evaluators have noted that we have brought in the regional comprehensive institutions successfully. Intentional efforts to foster inclusion and reduce power dynamics have facilitated this according to self-study and evaluation. In focus groups with team members in year three, the external evaluator noted that team members from these institutions felt like meaningful contributors to the projects, whose expertise was respected and valued.

We also established a highly engaged external advisory board with higher education leaders and change agents who have histories of successful programmatic innovations and a passion to move the needle on faculty diversity. Our external advisory board meets with us at least four times a year: at our summer Annual Retreat, our winter Annual Meeting, and for video conference calls in the spring and fall. Finally, we took very seriously the feedback received from panelists and program officers in our two site visits organized by our funding agency, the NSF, and made meaningful shifts in the way we operated based on suggestions received.

Commit Staff Time Meaningfully to the Project at All Alliance Institutions

In addition to having a part-time Director of the project, we established a leadership team that included two individuals from each research-intensive campus (a dean-level co-PI as well as a coordinator) and a coordinator on each teaching intensive campus: a dean or director-level co-PI. This infrastructure was not in place at the beginning of the project and was put into place upon the recommendations of our first NSF Site Visit panel in year one of the project. Since then, this group meets at least every 2 weeks to move the project forward. This structure allows for high-level knowledge and decision-making, as well as boots on the ground implementation and assessments to be communicated regularly. In addition, external evaluation has determined that engaging members of the broad team (outside of the leadership team) on subgroups that develop drafts of protocols or documents (such as the common learning outcomes) has been a practice that has benefitted the project's progress.

Our external evaluation reports and NSF Site Visit reports (both from year one and year three) have noted that having an experienced staff leader acting as Director of the project is extremely beneficial, both for the Fellows as well as the leadership and broad project team. As part of self-study, the Director on this project tracked time spent on the project and found the work took up 35–40% of her time, while being funded for 10% of her time. The external evaluator determined that, generally, the limited time funded by the grant to run the project is a hindrance to project success. Thus, we advise that for replication efforts, institutions have a director who can dedicate (at least) 30–50% of their time to direct the project.

Learn From Other Models to Envision the Program as Comprehensively as Possible Prior to Bringing Fellows on Board

We wish we had the time to do this more effectively, instead of a "building the plane as you fly" approach, as we have worked diligently to have success in developing and executing and assessing the model simultaneously. We have sequentially tackled standardizing learning outcomes, aligning recruitment practices, developing inter-campus professional development, and solidifying onboarding procedures over the first 3 years of the project, all while Fellows have been in place. In a review article about postdoc conversion models (Culpepper et al., 2021), authors describe five stages of program establishment and execution: (1) Laying the Foundation; (2) Recruiting Fellows, Matching to a Mentor/Department and Pre-Arrival Preparation;

(3) The Fellowship Period; (4) Conversion to the Tenure-Track; and (5) Ongoing, Iterative Evaluation for Program Improvement. We highly recommend using this structure, and the resources provided within that publication, to plan out new consortia and state system models.

Bring in Institutional and University System Leadership Early and Often

This is critical to ensure that practices and policies are taking shape that will enable project implementation. We have our Provosts, who serve as PIs on the project, and university system leadership engage with us at least twice a year at annual retreats and meetings, but frequently engage with these groups two-four additional times throughout the year in less formal settings (for example, we invited system leadership to one of our leadership team meetings, we had PIs and the broad alliance team come together to learn from an existing postdoc conversion model, etc.). These interactions and relationships lay the foundation for institutionalization of these pathways at institutional, alliance, and system levels (e.g., influencing system policy and campus initiatives).

Have Plans for Regular Assessment

We self-study and evaluate the development of our state system model and the quality of postdoctoral experience in the program at our Annual Meetings and through internal and external evaluation. Structured self-study includes engaging the broad team of 35 senior personnel and Co-PIs across the system in staff, faculty, department chair, Dean, and Provost positions about what we are doing well and how we can improve. External evaluation includes studying the experience of the leadership team and broad Alliance team as we develop and implement the model and will include ascertaining the reflective experiences of the postdoctoral Fellows within the model at the end of their experience. Internal evaluation will help us determine the changing departmental demographics of our Alliance institutions (which we hope to influence), the impact of our professional development activities, the departmental climate and "readiness" for hiring and retaining more diverse scholars, and the ongoing experience of our Fellows. From this continuous self-study and evaluation, we have learned that several factors have likely contributed to our success: beginning with a pilot of five institutions of diverse types, ensuring regular communication across the Alliance (not just the leadership team) throughout the year, and making efforts to reduce and remove power differentials (e.g., wearing name tags with just first names and not titles). We have also made numerous changes based on this process, such as building out an Alliance Google drive and a website, providing summaries of activities to the broad team between annual retreats and meetings, adding additional mentors besides a primary research mentor, and developing an onboarding checklist for institutions bringing on a Fellow. We intend to continue to evolve our practice for our own benefit as well as the benefit of others, as we hope it facilitates our ability to assist other systems interested in replicating this unique model for diversifying faculty.

CONCLUSION

Here, we report significant progress in the development and implementation of a novel state university system approach for diversifying faculty in the biomedical sciences. While these efforts are still ongoing, this is an important case study from which to monitor and learn. The Alliance has only just entered year four and looks forward to providing more comprehensive analysis in future reports, including the perspective of the fellows, structural and climate changes occurring on participating campuses, and impacts to the diversity of biomedical faculty at Alliance institutions. As postdoc conversion models for underrepresented minority scholars are growing at a number of institutions, it is our sincere hope that state universities will consider a collaborative model like ours to expand the power and success of those programs beyond their individual institutions and that the lessons we have learned in overcoming barriers and finding success will facilitate adoption and adaptation of similar models in other state university systems. It is imperative that we work together to address the underrepresentation of minority scholars within faculty ranks. We encourage campuses to engage with their system office leadership and find advocates that will be genuine partners on these projects; to build multi-level commitments from institutional, college, and departmental leadership; and to be open to working through the inherent challenges of working with different types of institutions across a broad geographic area.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

RC, CG, JR, WC-V, JA, JB, BE, EG, YM, and MS collaborated heavily on the development, implementation, and self-study of the model described in the paper, and all contributed intellectually to the paper. RC was the manager of the project and did most of the writing. CG created the outline of the paper, determined basic content, and helped review the literature and collect citable resources. CG drafted the introduction and context sections while RC drafted the section about the model and the discussion. BE, EG, JA, JB, JR, MS, YM, and WC-V added comments, suggestions, and edits at multiple stages. All authors contributed to the article and approved the submitted version.

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Postdocs as Key to Faculty Diversity: A Structured and Collaborative Approach for Research Universities

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Over the past 50 years the diversity of higher education faculty in the mathematical, physical, computer, and engineering sciences (MPCES) has advanced very little at 4-year universities in the United States. This is despite laws and policies such as affirmative action, interventions by universities, and enormous financial investment by federal agencies to diversify science, technology, mathematics, and engineering (STEM) career pathways into academia. Data comparing the fraction of underrepresented minority (URM) postdoctoral scholars to the fraction of faculty at these institutions offer a straightforward empirical explanation for this state of affairs. URM postdoc appointments lag significantly behind progress in terms of both undergraduate and Ph.D.-level STEM student populations. Indeed, URM postdoc appointments lag well-behind faculty diversity itself in the MPCES fields, most of which draw their faculty heavily from the postdoctoral ranks, particularly at research-intensive (R1) universities. Thus, a sea-change in how postdocs are recruited, how their careers are developed, and how they are identified as potential faculty is required in order to diversify the nation's faculty, and particularly the R1 MPCES professoriate. Our research shows that both Ph.D. students and postdocs benefit from intentional structure at various levels of their respective "apprentice" experiences, a factor that we believe has been neglected. Several key structural approaches are highly effective in these regards: (1) A collaborative approach in which leading research universities collectively identify outstanding URM candidates; (2) Faculty engagement in recruiting and supporting these postdocs; (3) Inter-institutional exchange programs to heighten the visibility and broaden the professional experiences of these postdocs; (4) Community-building activities that create a sense of belonging and encourage continuing in academia for each cohort; and (5) Continuing research based on outcomes and new experimental approaches. The California Alliance, consisting of UC Berkeley, UCLA, Caltech, and Stanford, has been engaged in such a program for almost a decade now, with most of the California Alliance URM postdocs now in tenure track positions or on the path toward careers as faculty at research intensive (R1) institutions. If this approach was brought to scale by involving the top 25 or so URM Ph.D.-producing R1 institutions in the MPCES fields, about 40% of

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the national URM postdoctoral population in these fields could be affected. Although this impact would fall short of bringing URM MPCES faculty ranks up to full representation of the United States population as a whole, it would vastly improve the outlook for URM students and their aspirations to take on leadership roles as scientists and engineers.

Keywords: postdoctoral, faculty, equity, doctoral, underrepresented minority, URM, diversity, STEM

INTRODUCTION

Ethnic or racial minorities now constitute more than half of the United States population under age eighteen (U.S. Census Bureau, 2019; NCES, 2021). Yet, most United States scientists and engineers – majority and underrepresented minority (URM)[1] – will enter their professional lives without ever having a URM K-12 science teacher, university professor, or even graduate teaching assistant (Towns, 2010; Jones, 2018). Most may have no more than one or two URM science colleagues throughout their careers. While it is important to address the lack of diversity in science, technology, mathematics, and engineering (STEM) at every level, if 4-year universities, including research-intensive (R1) universities, in the United States diversify their STEM faculty, that will have a major impact that can cascade across all levels.

At our nation's 4-year universities, underrepresented minorities constitute 7% of the mathematical, physical, computer, and engineering sciences (MPCES) tenure and tenure-track faculty. This severe underrepresentation among faculty has persisted for decades, so that we have actually lost ground relative to our country's increasing URM population (see **Figure 1**). In turn, the lack of URM faculty role models is discouraging to a large fraction of the United States population who could be joining and contributing to our scientific and engineering workforce (Stockard et al., 2021). Indeed, only about one-third of URM undergraduate students entering our research universities intending to major in MPCES fields persist to obtain these degrees, compared to a completion rate of approximately two-thirds by majority male students (Hsu et al., 2008; HERI, 2010; ACT, 2013; Chen, 2013; Wadhwani and Eppig, 2018; NSF, 2019).

Why So Little Progress?

Despite the passage of Title VII, which barred discrimination on the basis of race and gender in higher education employment, for decades the diversity of the STEM faculty did not increase beyond tokenism. Affirmative action policies also did not fundamentally alter the demographics of the STEM faculty (Wood et al., 2008). Then, in 1996, Proposition 209 passed in California, banning affirmative action in California, and similar laws passed in other states. The elimination of the National Science Foundation's (NSF) Minority Graduate Research Fellowship program during this period, in 1998, exemplifies the way that political winds were reframing how diversity could be addressed in higher education (Muller-Parker et al., 2020). Universities and federal agencies sought new approaches to diversify STEM (Malcom, 1976; Duderstadt, 2015; Phillips, 2019).

Universities and federal agencies began to focus keenly on diversifying the undergraduate and graduate ranks of STEM students through outreach and recruitment of "diversity" students into STEM. At the faculty level, the ADVANCE program focused on institutional change to improve conditions for women faculty, but did not address the postdoctoral level. The federal government's science agencies also invested in this effort (Dero et al., 2019). For example, the Government Accountability Office reports that in 2016 approximately $2.9 billion was spent on STEM education and diversity programs, of which the NSF received $1.2 billion (Clark and Esters, 2018; GAO, 2018).

The NSF progressed from its focus, starting in 1991, on undergraduates through the Louis Stokes Alliances for Minorities Program (LSAMP), to graduate recruitment in its Minority Graduate Education (MGE) program, starting in 1998, then graduate retention in the MGE program, which was renamed the Alliances for Graduate Education and the Professoriate (AGEP), and recently, has widened its focus through the AGEP program to include models that address diversity at the postdoc and faculty levels. The newest NSF diversity program, started in 2016, is INCLUDES, which supports linkages across educational levels and institutional types to increase diversity—but also excludes a distinct and substantial focus on the postdoctoral level. This progression over the past 30 years exemplifies the excruciating slowness of recognition at either federal grant-making agencies or universities that diversifying the faculty will take more than increasing URMs in the bachelor's degree (BA) or doctoral degree (Ph.D.) pools. While the NSF's focus on the undergraduate and graduate educational years certainly is necessary, it has been insufficient for increasing the available pool of candidates to enter the faculty.

Turning to university efforts, one of the main foci of advocates for diversifying the faculty has been addressing bias in faculty searches and hiring processes. A plethora of guidelines, training materials and requirements, and an accompanying growth in diversity specialists and consultants has emerged to guide search committees and department leaders. Much of this push for change relies on teaching the members of search committees about psychological findings on how bias enters into decision making, inclusion of women and minorities on search committees, active outreach, and requirements that candidates offer their views in "diversity statements" (Goulden et al., 2019; UCOP, 2019). This approach is valuable in alerting search committees to considerations for equitable hiring when there is a diverse pool of applicants, encouraging search committees to engage in active outreach (Clauset et al., 2015), and signaling that

[1]Underrepresented minority or URM is defined as African American, Chicanx/Latinx, Pacific Islander, or Native American/Alaska Native.

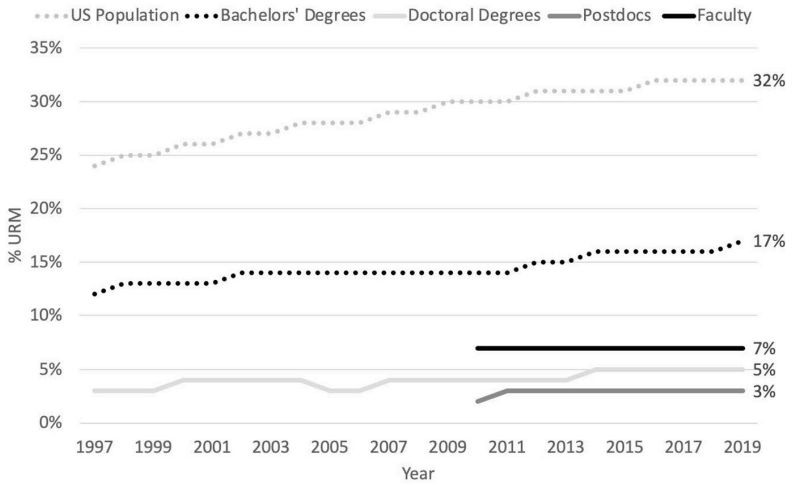

FIGURE 1 | Trends in URM representation in MPCES, 2010–2019. URM (Hispanic; Black or African American, non-Hispanic; American Indian or Alaska Native, non-Hispanic; and where the data permits Native Hawaiian or Other Pacific Islander, non-Hispanic) representation in the United States has increased from 30% in 2010 to 32% in 2019. Over that same period the general population trends have been mirrored by URM representation among all MPCES bachelor degrees (including Temporary visa holders) which has increased from 14% to 17%. URM representation among MPCES doctoral degrees (including Temporary visa holders), and among MPCES postdocs (including Temporary visa holders), has increased only slightly from 4 to 5%, and 2 to 3%, respectively. URM representation among MPCES faculty has held steady at 7% over this period (CDC, 2021; NCES, 2021a,b,c).

diversity matters to the department and institution, but it too has been insufficient.

These important thrusts toward diversification of the STEM faculty have ignored the final turning point on the path to the professoriate: the postdoctoral experience. Completing a postdoctoral experience was once an expectation for prospective faculty only in a limited set of STEM fields, but over the past two decades, this requirement has expanded across STEM fields rapidly, and in some fields, escalated into an expectation that competitive candidates will complete long or multiple postdoctoral fellowships. At doctoral granting research universities, in particular, which are the largest employers of tenure-track faculty (AAUP, 2018), a Ph.D. is rarely sufficient for winning a MPCES faculty job – most faculty are recruited from the postdoctoral ranks (AAU, 1998; Su, 2013; Yang and Webber, 2015). Indeed, most scientific and increasingly most engineering professional positions in STEM research, are no longer filled by new Ph.D. recipients, but rather by postdoctoral researchers. This is true not only with respect to faculty at research universities, but also for research scientists at Federally Funded R&D Centers (FFRDCs), and in research and development (R&D) in private industry.

Yet despite this reality, the "URM availability pool" for faculty hiring continues to be defined as the number and percentage of URM Ph.D.s, with university administrators unaware of or not recognizing the expanded credentialing that faculty now require as they assess junior colleagues' candidacy for tenure track positions (Stacy et al., 2018; University of Michigan, 2018; Cornell University, 2021). This reliance on the demographics of the graduating cohort of Ph.D.s, rather than the demographics of the cohort of employed postdocs, to define URM availability pools for faculty jobs is a widespread "blindspot" that obfuscates the challenge of diversifying the faculty. It should therefore come as no surprise that little progress has been made in diversifying the professoriate, or that the problem is acute at research universities.

As a result of the last two decades of inaction to diversify the postdoctoral level, the fraction of URM Ph.D. degree recipients in the MPCES fields has increased from about 4% to about 5%, but, shockingly, the fraction of URM postdoctoral scholars has remained even smaller, increasing only from about 2% to 3% of all postdocs, including foreign nationals (see **Figure 1**; U.S. Department of Education, 2010–2019a,b,c; CDC, 2021). Among United States citizens and residents, the fraction of URM Ph.D. recipients in MPCES has increased from 9% to 11%, and URM postdocs from 6% to 7%.

Diversifying the postdoctoral level is complicated by several factors, especially the highly decentralized sources of postdoctoral fellowships, the atomized locations of postdoctoral scholars, and the short duration of these positions. Most postdoctoral fellowships in academia attach to extramural grants won by individual faculty, who, as principal investigators (PIs), select and hire postdocs, often seeking candidates with niche technical training best suited to the focus of their grants. When grants are made, they tend to be of relatively short duration and the need to hire quickly, therefore, is pressing to a PI if they are to yield results during the award period. In this context, it is understandable that PIs turn to their own scientific networks, perhaps their own advisers or former students, to identify qualified individuals, and that they, usually alone, hire the postdoc of their choice.

Though this conventional approach to postdoc hiring makes sense in context, it is, in practice, a closed system, easily taking on the qualities of a proverbial "old boys' network." Universities tend not to impose requirements for advertising these positions, perhaps for pragmatic reasons, and indeed, there

tend to be few uniformities in postdoctoral fellowship hiring across institutions, or even within institutions. In some contexts, postdoctoral fellowships are understood to be the direct route into a permanent position, thereby extending the problem with this closed system of hiring postdocs to the next professional level. Given the way postdoctoral fellows are hired and the reality that their professional lives often are experienced in a single lab with a direct report to the person who hired them, it is rare for mid-level or high-level administrators to recognize the cumulative demographics of a department's or other campus unit's postdoctoral population.

From a graduating student's perspective, the main approach to finding postdocs usually involves a somewhat random walk through unlinked websites of postdoc programs, dependence on *ad hoc* scientific networks, and the attentiveness of their Ph.D. advisers. Once in a postdoc, this kind of *ad hoc* process for career advancement can worsen, with increased isolation and uncertainty. Often postdoc scholars' network expansion – critical for advancement to the ranks of the faculty or professional research positions that lead to leadership in the scientific community – becomes almost entirely dependent on a single postdoc mentor and a postdoc's own initiative. The prospects of one's fate being sealed by a career step that is crucial for scholarly and career advancement, but difficult to win and with uncertain outcomes, and that is generally experienced in a new geographic location without scientific, institutional, or familiar community supports, can be daunting for graduating students (Ferguson et al., 2017). For those without financial safety nets, the uncertainties of the postdoc stage may seem too risky (Ferguson et al., 2017). Many turn away at this stage.

Exacerbating the problem is the reality that it would be exceptional for any institution to consider the diversification of the postdoc level (or even their own postdoc population) to be a high-level priority, even those with deep commitments to diversity at every other educational and career level. Most universities have little incentive to increase postdoc diversity, relative to their incentive to increase graduate student or faculty diversity. In part this is a result of the national inattention to the postdoctoral level, in general. This inattention is illustrated by the key recommendation of the National Postdoctoral Association in its most recent report. It calls for the provision of adequate institutional resources to staff institutional postdoc affairs offices, and to achieve equality in benefits, offer adequate parental leave and family-friendly policies, and track postdocs after they leave the institution (Ferguson et al., 2021). And so the problem persists — not only unaddressed, but also largely unrecognized.

What to Do?

First, universities and federal funding agencies must recognize the problem. The continued homogeneity of the postdoc pool makes diversifying the nation's MPCES faculty an intractable problem. Secondly, the scientific community, universities, and federal agencies must acknowledge the complexity of diversifying the postdoctoral population, a challenge that is not akin to diversifying the educational experiences that precede it, nor the professional positions that proceed from it. To address this problem, the scientific community must identify outstanding URM Ph.D. candidates, encourage promising URM graduate students to pursue postdocs at research universities, increase their awareness of available postdoctoral jobs and the awareness of their scientific accomplishments among those who can hire them as postdocs, approach both postdoc hiring and career advancement beyond the postdoc with intentionality and coordination, support URM postdocs in their ambitions to successfully seek faculty positions, increase the visibility of URM postdocs among those who are in positions to hire them as faculty, and ensure that both for postdoctoral and faculty positions, advertising, selection, and hiring processes are free of bias.

A Call for Leadership

Addressing underrepresentation at the postdoctoral level requires a coordinated national effort that goes beyond local programs or initiatives, and requires new leadership from granting agencies (especially NSF), professional societies, and research universities.

Most efforts to date rely upon parallel but separate tracks of funding to recruit URM postdocs and postdocs who, in other ways, contribute to diversity. Exemplars of these approaches are the University of California's President's Postdoctoral Fellowship Program and its partner programs, as well as the new AGEP Promise Academy Alliance. These are immensely valuable programs in offering opportunities for scholars who will contribute to faculty diversity to advance within these institutions, but they are not designed to, and cannot address the problem of underrepresentation at the national scale.

Instead, we argue for a strategy that connects graduate students to prospective mentors nationally with far greater intentionality and inter-institutional cooperation – a common applicant pool, mentored inter-institutional visits, multi-layered professional development, a "concierge" approach to linking highly sought-after URM advanced graduate students to prospective postdoc mentors, and national and institutional recognition of the importance of focusing resources and attention on diversifying the postdoctoral level. This approach would diversify the MPCES professoriate by leveraging existing structures and norms to mainstream the success of URM postdocs as faculty candidates. Given that the fraction of URM MPCES Ph.D.s is currently almost double that of postdocs and is steadily (albeit far too slowly) increasing, truly significant change should be possible within just a few years.

A Solvable Problem

The time has come to work with common purpose, and at scale, to generate a diverse professional scientific community. Beyond focusing on undergraduates, graduate students, and faculty, we must address a key overlooked population—postdoctoral scholars.

A WAKE-UP CALL: PUBLICATION AND STRUCTURE

Laying a Foundation

For over a decade the authors have convened a STEM Diversity Research Group at the University of California, Berkeley,

consisting of the Dean for Mathematical and Physical Sciences, prominent diversity program directors, faculty and graduate students in psychology and sociology, and institutional data analysts. Initially funded by the Mitchell Kapor Foundation (now the Kapor Center for Social Impact) and the National Science Foundation, our group dutifully undertook an intensive survey of both graduate and undergraduate students in the mathematical, physical, and computer sciences in order assess various aspects of student life in the STEM fields at Berkeley, and to lay groundwork for addressing racial, ethnic, and gender disparities.

The Berkeley Life in Science Survey (BLISS), conducted in 2013–2014, consisted of many of the standard questions regarding progress to degree, mentorship, financial support, etc. However, the survey also queried graduate students as to whether they had participated as an author on a paper submitted for publication in the past year. As it turns out, there were almost no previous studies regarding this issue. However, results from this question opened an entirely new avenue for research, and provided important insights for future progress in STEM diversity.

Publication Disparities

The results of this work have been published in detail elsewhere (Mendoza-Denton et al., 2017), but the most important outcome is summarized in **Figure 2**. When we aggregated all Ph.D. student respondents, we found that both underrepresented minority men and women (URM) and non-URM women students were significantly less likely to have submitted a paper for publication in the last year than their male non-URM (white and Asian-American) counterparts – URM's were only about half as likely to have submitted a paper for publication, which was quite disturbing, but also suggested a clue to explaining disparate career outcomes for Ph.D. students.

As discussed by Mendoza-Denton et al. (2017), these results were carefully controlled for such confounding variables as number of years in the Ph.D. program, advancement to candidacy, and time spent employed in research, teaching and on fellowship, but the results of **Figure 2** remained robust.

We quickly sought to understand if these results were department-specific, and in that process one result stood out in stark relief. As indicated in **Figure 2**, Ph.D. students in Berkeley's College of Chemistry did not show resolvable disparities in publication rates according to race/ethnicity or gender, whereas the remainder of the survey group consisting of the Departments of Astronomy, Earth and Planetary Science, Mathematics, Physics, Statistics, and Electrical Engineering and Computer Science showed even greater disparities with the Chemistry respondents separated out.

Fortunately, we quickly found that an independent survey conducted by Berkeley's Graduate Division offered unequivocal support for these findings. This survey had been administered from 1998 to 2015, was completed by 98% of all graduating Ph.D. students at Berkeley, and included questions about publication similar to those in the BLISS survey. As described in Mendoza-Denton et al. (2017), the Graduate Division survey yielded essentially the same results with many more participants and much greater longitudinal control: as a whole URM Ph.D.'s in the MPCS fields at Berkeley were only about half as likely to publish as their male non-URM counterparts, again with the conspicuous exception of Chemistry, where publishing frequency was statistically independent of race/ethnicity and gender. Clearly, Berkeley's College of Chemistry had figured out something about eliminating disparities that other departments had not!

What's So Special About Berkeley Chemistry?

To gain insight, we conducted qualitative research. Berkeley is unique in that the Departments of Chemistry and Chemical Engineering, both consistently ranked as top departments nationally, constitute an independent College of Chemistry, with an equally unique culture for graduate study. In these programs, students entering the College of Chemistry encounter a highly structured environment in which expectations for selection of advisers, the timeline for conducting research, writing, and publication are made clear at the outset. Most of the features of this structured approach pertain to progress through the first few years of the program, establishing both short-and long-term expectations and creating the conditions under which these expectations can be met, with hands-on involvement and management of each stage of the process by designated faculty who are not the students' research advisers. The following practices exemplify the highly structured process for Chemistry Ph.D. students: students are expected to begin writing their first paper no later than their second year—they are required to submit a formal paper or proposal on which they receive comments from two faculty; there is a routinized approach, managed by a designated faculty member, to the matching of students and thesis advisers; students are required to meet with and rank their choices of advisers, and faculty to rank their choices of students, thus enabling multiple advisors to become aware of student progress at an early stage of the graduate program.

It is also noteworthy that the Berkeley Chemistry doctoral program has been heralded as the most successful in the country in terms of placing it's women Ph.D.s into faculty positions at doctoral (R1) universities (Laursen and Weston, 2014).

Why Does All This Matter?

For many years, studies of disparate outcomes in STEM have focused on recruitment (who gets admitted to elite Ph.D. programs?) and normative outcomes such as advancement to candidacy and degree completion, as well as mentoring relationships and financial support, and of course both implicit and explicit bias. All of these factors matter, but even mitigating for such factors it is widely understood that the single most important factor that influences whether a newly graduated Ph.D. or postdoctoral scholar makes the short list or is hired for a faculty position in a research university is their publication record (Van Dijk et al., 2014; Fernandes et al., 2020).

To put it bluntly, if URM Ph.D.'s publish only half as much as non-URM's, they are at a serious disadvantage in highly

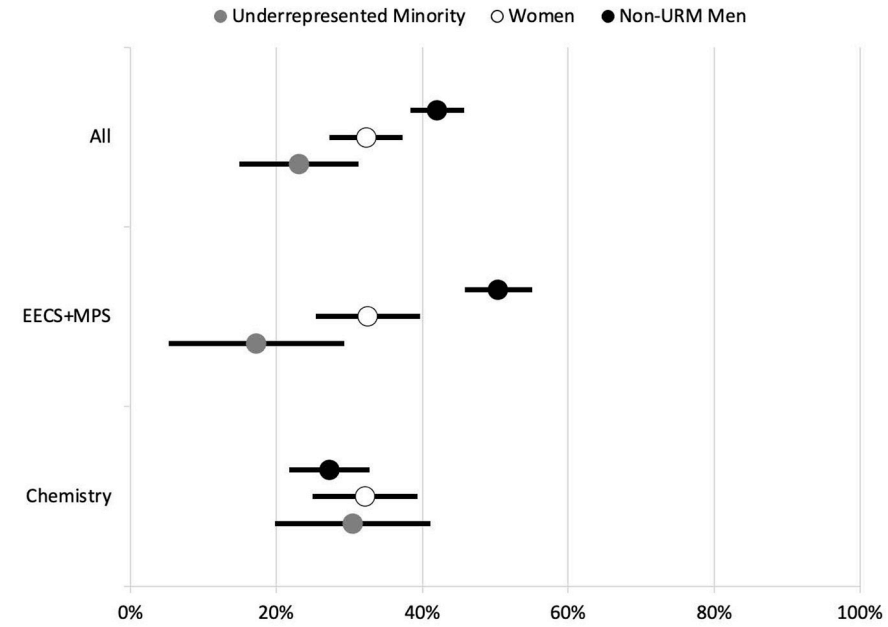

FIGURE 2 | Berkeley doctoral student paper submission rates in the mathematical, physical, and computer sciences. Self-reported paper submission rates differ greatly among URMs (African American, Chicanx/Latinx, and Native American/Alaska Native), women, and non-URM men for Berkeley Ph.D. students in the mathematical, physical, and computer sciences with non-URM men having the highest rates of papers submitted for publication (42%) followed by women (32%) and then URMs (23%). These differences are exacerbated in Electrical Engineering and Computer Science (EECS) and Mathematical and Physical Sciences (MPS) but disappear in Chemistry. Error bars show 95th percentile confidence intervals. Figure adapted from Mendoza-Denton et al. (2017).

competitive searches. Thus, we need to know what factors contribute to equitable outcomes in terms of publication of research results for graduate students.

Structure and Belonging

From our work we have come to advocate for a new paradigm in which the more traditional notions of mentorship, community, and sense of belonging are complemented by the equally important notion of structure, wherein the norms and expectations for advanced study in STEM are made clear to all. URM students often do not arrive in graduate programs with the same amount of social or cultural capital that is valued in academia as their non-URM counterparts –in part because they are more likely to be first-generation college students from relatively low-income economic backgrounds, and therefore are less likely than their peers to have attended elite high schools and colleges, and are less likely to have grown up in close contact with professionals or academics.

At the graduate level, the research literature shows that graduate and postdoctoral education for URM students, fails to provide key experiences. Chief among these is a sense of belonging in the community (Mendoza-Denton et al., 2002; Walton and Cohen, 2007, 2011; Good et al., 2012). A lack of belonging often arises from being excluded, intentionally or otherwise, from the informal social networks and gatherings where critical information and budding collaborations occur (Austin, 2002; Nettles and Millett, 2006). Importantly, URM students are systematically provided with poorer mentorship relative to their majority group peers, either because of bias (Moss-Racusin et al., 2012) or apprehension around intergroup mentorship (Mendoza-Denton et al., 2002, 2018a; Crosby and Monin, 2007; Mendoza-Denton and Page-Gould, 2008; Page-Gould et al., 2010). There is reason to believe that postdoctoral scholars may experience isolation and stress even more acutely than graduate students (Arnold, 2014). Thus, a robust literature documents systematic limitations in STEM education around networking, information sharing, belonging, and community for URM scholars (Walker et al., 2008). In our previous research, we have noted that clarity of expectations and a sense of belonging are critical aspects of programs that aim to achieve equity in outcomes (Mendoza-Denton et al., 2017; Mendoza-Denton et al., 2018b; Fisher et al., 2019). For all these reasons, URM students may only realize the key importance of publication (as opposed to degree completion) relatively late in their graduate studies unless such expectations are made explicit at the outset. The "secret handshake" culture of many academic fields does not always work well for URM students.

Indeed, the research demonstrates more generally the simple principle that "ambiguity is the breeding ground for bias" (Mendoza-Denton et al., 2018b). But clearly the Chemistry doctoral program at Berkeley has short-circuited this source of bias in ways that have yielded equitable outcomes in a fashion that we consider spectacular relative to most STEM Ph.D. programs at R1 universities in the United States (Laursen and Weston, 2014; Fisher et al., 2019).

CALIFORNIA ALLIANCE FORMATION AND PROGRAM DESIGN

Structural Bias and Systemic Inertia

The results summarized in the foregoing section could be characterized as a particular, and in our opinion particularly important, form of structural bias. In fact, lack of structure, or ambiguity, regarding norms and expectations in many if not most STEM Ph.D. programs is what we have highlighted above. Lack of publications is but one symptom of this kind of bias, and in this section, we address a broader interventional approach that includes addressing structural bias that works to disadvantage both Ph.D. students and postdoctoral scholars, especially when it comes to pursuing, or even envisioning, careers as faculty at leading research universities.

Over the past decade we have focused on diversifying the populations of both advanced Ph.D. students and postdocs in the MPCES fields for reasons made clear in the opening section of this paper —unless these populations become much more diverse there is no way that the professoriate will do so. In order to explain our approach, we begin with some observations:

(1) Most postdocs have traditionally been recruited through back-channel means, typically one professor recommending a finishing Ph.D. student to a professor at another institution. True searches for postdoc positions remain rare. This constitutes the ultimate "old boy network," in which mostly white male professors recommend their mostly white and Asian male students to other mostly white male professors.
(2) It is rarely a high priority for individual institutions to pay much attention to the diversity of their postdocs, even if they are keen on diversifying their own graduate student and professorial ranks, because postdocs most commonly do not remain at their host institution for faculty positions.
(3) Federal agencies have until only very recently paid little attention to the diversity of the postdoc ranks, as these positions are more difficult to track than graduate students, and norms for mentoring and support are highly variable.
(4) Expectations for the postdoctoral experience remain poorly defined; as a result, postdocs often are in a kind of limbo state in most research groups, with few assurances of specific normative outcomes (e.g., degrees) other than the next job, academic or otherwise.
(5) though postdocs are widely understood to be a rite of passage for most MPCES faculty positions at R1 universities, the social capital gap for URM Ph.D. students described in the previous section can become exacerbated by a lack of clarity as to how this step actually works in practice, and compounded by uncertainty of the career outcome, particularly for scientists from low-income backgrounds.

California Alliance Inception, Design, and Outcomes

For the above reasons, four leading research universities in California – Berkeley, Stanford, UCLA, and Caltech – undertook in 2011 to band together to build upon their collective prestige and interest in diversifying their Ph.D. student, postdoctoral, and professorial ranks. Thus was born the California Alliance. The principal motivating factor behind this unprecedented grouping was to overcome structural bias through collaboration to identify and nurture the careers of aspiring URM MPCES scholars by introducing new practices to their recruitment and development. Out of many creative and fruitful discussions among academic leaders at the four California Alliance institutions eventually sprang the following parallel approaches that have combined to yield great success. The California Alliance's collaborative efforts lead to the hiring of 40 URM postdocs across the four universities.

(1) Initially, key to the Alliance's approach was a national solicitation on the part of all four institutions to identify outstanding URM candidates for postdoctoral appointments across the MPCES fields, but with a new and key ingredient —all the applicants for the California Alliance postdocs could be considered and recruited by any, or all, of the four institutions. The solicitation was distributed widely to scientific organizations and associations of URM scientists, contacts of the California Alliance partners' faculty, and directors of program serving URM. This made the solicitation very attractive nationally, resulting in more than 60 applicants most years. NSF funding provided for approximately five postdoctoral fellowships over approximately 6–8 years, but it was understood among the four partner institutions that they needed to come up with significant matching funds, so that the NSF resources could be stretched, and more outstanding URM candidates hired. The final institutional/NSF matching ratio turned out to be more than 7:1. Put another way, once an exciting candidate pool was developed, the partner institutions were eager to hire the applicants. This constituted an interruption of the traditional, proverbial "old boy network" for postdoctoral hiring, and brought the Alliance successful candidates whom they otherwise would never have known about.
(2) In time, with a growing cadre of both advanced URM Ph.D. students and postdocs within the Alliance, the member institutions decided to further leverage their collective prestige to further interrupt systemic structural bias. This resulted in the formation of the Research Exchange, wherein advanced Ph.D. students and postdocs were invited to experience 1- to 2-week mentored visits with research groups at the other participating institutions in order to expand their scientific experience and horizons at critical career stages, and to increase their visibility as potential faculty members. This approach involved minimal costs (mainly travel), and has turned out to be both extremely effective and very popular, both with visiting candidates and their respective inter-institutional mentors.

TABLE 1 | National context for URM postdocs.

	Yearly averages – All		Yearly averages – URM		Shares – URM	
Group	**2010–2014**	**2015–2019**	**2010–2014**	**2015–2019**	**2010–2014**	**2015–2019**
All fields	62,893	64,867	2,595	2,878	4.1%	4.4%
Science and Engineering	44,060	45,872	1,606	1,799	3.6%	3.9%
MPCES	18,009	18,942	492	515	2.7%	2.7%
MPCES – peer institutions	6,223	6,556	183	151	2.9%	2.3%
MPCES – CA Alliance	1,978	2,019	38	43	1.9%	2.1%
CA Alliance postdocs		19		19	n/a	100.0%

Sources: California Alliance, U.S. Census Bureau (2019), NCES (2021a,b,c), NSF Survey of Graduate Students and Postdoctorates in Science and Engineering.

(3) The third structural element of the California Alliance can be thought of as "career development," with annual retreats and informal networking among participants being the most prominent activities. Each year one institution hosted a 2- to 3-day pan-Alliance retreat for students, postdocs, and faculty across all four institutions. Activities included brief scientific presentations/posters, breakout sessions on mentoring, publication, applying for jobs, addressing bias, etc., and social activities to form relationships and increase comfort and familiarity with the professorial world. In fact, these retreats proved to be just as popular among faculty as students and postdocs, with many faculty who had never before participated in diversity work becoming inspired by and heavily involved with the diversity goals of the Alliance.
(4) The California Alliance partners also worked together on applied social science research focused on better understanding and addressing the reasons for continuing underrepresentation of minorities at the advanced levels of the scientific community (e.g., Fisher et al., 2019).

Recently, the Alliance has expanded (with new NSF support) to include five other leading R1 universities – University of Michigan, The University of Texas at Austin, University of Washington, Georgia Institute of Technology, and Harvard University. Most of the above program elements remain active in this new Research Universities Alliance (RUA), which we hope will lead to a larger national effort and greater national impact.

PUTTING THE CALIFORNIA ALLIANCE POSTDOCS IN A NATIONAL CONTEXT

The California Alliance started hiring postdocs in 2015, and as of 2019 it employed an average of 19 underrepresented minority (URM) postdocs per year[2] (**Table 1**). In the 5 years prior, Alliance institutions employed an average of 38 URM postdocs per year in MPCES[3] which represented 1.9% of the postdocs in those fields at Alliance institutions. In the 5 years after the Alliance started hiring postdocs, Alliance institutions employed an average of 43 URM postdocs per year in MPCES fields, which represented 2.1% of postdocs in those fields at Alliance institutions —a 15% increase in the number of URM postdocs and a 13% increase in the share of URM postdocs. Over those same periods, national URM postdocs in MPCES increased by just under 5% and declined by 1% as a share of all MPCES postdocs. If national URM postdoc share in MPCES had increased by the 13% seen by the Alliance opposed to the 1% decline actually observed, it would have translated to an increase of 68 URM postdocs in MPCES employed per year. At peer institutions[4] (NRC, 2011) to the California Alliance in MPCES fields, URM postdocs declined by 17% in absolute numbers and declined by 21% in terms of representation among all MPCES postdocs. If the URM postdoc share in MPCES at peer institutions had increased by the 13% seen by the Alliance opposed to the 21% decline actually observed, it would have translated to an increase of 66 URM postdocs in MPCES employed by peer institutions per year[5] (**Table 1**).

During 2015–2019, the four California Alliance institutions hired 8% of all URM postdocs in MPCES, and its twenty peer institutions hired 29% of all URM postdocs in MPCES. The California Alliance itself hired just under 4% of all URM postdocs in MPCES despite having only 0.1% of all MPCES postdocs. Ideally, the California Alliance institutions will continue to increase the number of URM postdocs in MPCES fields until the alliance represents at least 11% of all URM MPCES postdocs— as it employed 11% of overall MPCES postdocs from 2015 to 2019.

Of the 40 URM postdocs hired by the California Alliance over 2015–2019, 21 of them (53%) are currently in tenure-track faculty positions and an additional 6 (15%) are still postdocs and are still in the pool to become faculty in the future.

Previous studies have estimated the national hiring rates of postdocs to be around 15% (McConnell et al., 2018), but field and institution-specific data are not available in aggregate much less disaggregated by race/ethnicity. Given these limitations it is

[2]Annual counts are averaged to get postdocs employed per year.

[3]MPCES is defined as Mathematics, Geosciences, Physical Sciences, Engineering, and Computer Science fields.

[4]Peer institutions are defined as institutions with more than one MPCES program in the top 20 of both the statistical- and survey-based rankings from National Research Council 2011. *A Data-Based Assessment of Research-Doctorate Programs in the United States (with CD)*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12994. Peer institutions, according to this definition, are: Caltech, MIT, UC Berkeley, Stanford, Harvard University, Princeton University, UC Santa Barbara, U Michigan, Northwestern, W Washington, Cornell, Georgia Tech, Carnegie Mellon, NYU, Penn State, U Arizona, UCLA, UC San Diego, U Chicago, U Colorado Boulder, UIUC, U Minnesota Twin Cities, UT Austin, U Wisconsin Madison.

[5]This hypothetical is almost as large as the hypothetical for national MPCES due the much larger decline of URM postdocs at peer institutions.

hard to say definitively whether the 53% hiring rate of California Alliance URM postdocs in MPCES is higher or lower than peer trends. In the future, it might be possible to use Early Career Doctorates Survey data (NCES, 2017) to estimate the relevant trends, but at present this data cannot be used for this purpose given publicly available tables.

Within the first few years of operating the Research Exchange (2017–2019), 105 advanced graduate students and postdoctoral fellows applied to participate. Of these applicants, 32 URM advanced graduate students and postdoctoral fellows completed visits to faculty, labs, and research groups of interest within the alliance institutions before the Covid-19 pandemic prevented travel. Of these 32 participants, when the California Alliance's National Science Foundation grant ended in 2021, 11 were continuing their graduate studies, three had become faculty, 16 had continued to postdoctoral positions and two had taken positions in industry (NSF, 2022). Since then, despite complications with travel during the Covid-19 pandemic, the Research Exchange expanded as part of the Research University Alliance with an increasing number of participants subsequently taking faculty positions. The initial successes of the California Alliance's (and now RUA's) Research Exchange in encouraging continuation on the academic path through the advanced graduate years to the postdoc and to the faculty, along with the postdoc program's success in advancing URM graduate students into postdocs that make them competitive for and interested in taking tenure track jobs, offer promising new approaches for strategies that can be taken to scale in the United States.

CONCLUSION

Achieving racial, ethnic, and gender diversity in the STEM disciplines is a national imperative. However, over the past half-century startlingly little progress has been made, especially among faculty in United States research universities. The non-biological sciences, including the MPCES fields, have proven particularly resistant to change, which has been the focus of our work (Li and Koedel, 2017; Meyers et al., 2018). Here we have emphasized two particular aspects of the problem and solution pathways. First, in most of the MPCES fields, the lack of diversity among faculty parallels a long-neglected lack of diversity among the population of postdoctoral scholars, who are commonly recruited to fill the professorial ranks. Second, structural bias (or lack of programmatic structure) persists in both graduate programs and the postdoctoral programs they feed, and is more of a barrier than has previously been recognized.

Following on these basic observations, we have implemented a program targeted at interrupting systemic bias by developing a collaborative effort among leading research universities, focusing on both advanced Ph.D. students and postdocs in the MPCES fields. Essential elements of this program include combining institutional resources to recruit (and hire) a strong applicant pool of underrepresented minority (URM) postdoctoral candidates; inter-institutional visits by both Ph.D. students and postdocs to increase their visibility, broaden their experience, and elevate their career aspirations; professional development at all career stages leading to the professoriate, including pan-institutional retreats and extensive faculty involvement; collaborative sociological research across the consortium to test out new ideas and approaches to mitigation of historical bias.

This consortium, which now includes nine institutions, has yielded tangible results far exceeding the success of other approaches with which we are familiar. In particular, a remarkable fraction of our Ph.D.s and postdocs are successfully seeking faculty positions at R1 universities. These nine universities, together, employ 21% of the nation's URM MPCES postdoctoral fellows. Indeed, only approximately 52 universities have track-records of hiring any MPCES URM postdoctoral fellows, according to data from the Survey of Earned Doctorates. These nine universities, together, also educate 14% of the nation's URM Ph.D.s. This success suggests that scaling these mitigations to perhaps the top 25 or so URM Ph.D.-producing institutions in the MPCES fields would dramatically increase the fraction of URM faculty in the United States, and in turn lead to a much more robust cadre of mentors (Allen et al., 2004; Boykin et al., 2015; NASEM, 2019) for the burgeoning numbers of URM undergraduate students seeking careers in STEM.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: U.S. Census Bureau. Population Division. "Annual Estimates of the Resident Population by Sex, Race, and Hispanic Origin for the United States: April 1, 2010 to July 1, 2019 (NC-EST2019-SR11H)" Release Date: June 2020. Based on data accessed in August 2021. U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), 2010–2019, Degrees Awarded by Colleges and Universities. Retrieved from https://ncsesdata.nsf.gov/builder/ipeds_c on August 14, 2021. U.S. Department of Education, National Center for Education Statistics, Survey of Graduate Students and Post-doctorates in Science and Engineering, 2010–2019, Post-doctorates. Retrieved from https://ncsesdata.nsf.gov/builder/gss on August 14, 2021. U.S. Department of Education, National Center for Education Statistics, Survey of Doctorate Recipients, 2010, 2013, 2015, 2017, and 2019, Table 19. Retrieved from https://www.nsf.gov/statistics/srvydoctoratework/ on August 14, 2021.

ETHICS STATEMENT

Data presented here from research by the authors that involved human participants is cited from studies reviewed and approved by the Committee for the Protection of Human Subjects, University of California, Berkeley. The participants provided their written informed consent to participate in those studies. All other data involving participants is available from public sources.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception and design of the work and acquisition, analysis, and interpretation

of data for the work, drafted the manuscript and revised it critically for important intellectual content, provided approval for publication of the content, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2021.759263/full#supplementary-material

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Critical Faculty and Peer Instructor Development: Core Components for Building Inclusive STEM Programs in Higher Education

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First-generation college students and those from ethnic groups such as African Americans, Latinx, Native Americans, or Indigenous Peoples in the United States are less likely to pursue STEM-related professions. How might we develop conceptual and methodological approaches to understand instructional differences between various undergraduate STEM programs that contribute to racial and social class disparities in psychological indicators of academic success such as learning orientations and engagement? Within social psychology, research has focused mainly on student-level mechanisms surrounding threat, motivation, and identity. A largely parallel literature in sociology, meanwhile, has taken a more institutional and critical approach to inequalities in STEM education, pointing to the macro level historical, cultural, and structural roots of those inequalities. In this paper, we bridge these two perspectives by focusing on *critical faculty and peer instructor development* as targets for inclusive STEM education. These practices, especially when deployed together, have the potential to disrupt the unseen but powerful historical forces that perpetuate STEM inequalities, while also positively affecting student-level proximate factors, especially for historically marginalized students.

Keywords: faculty development, stem, culturally responsive teaching, teacher professional development, peer to peer, multicultural education, liberation pedagogy

INTRODUCTION

The challenges to effectively serving students from groups historically underserved in STEM are deep and longstanding. A long line of research shows that first-generation college students, as well as Black, Indigenous, People of Color (BIPOC) students, often lose interest after their initial engagement with STEM education at the college level. Research has identified multiple obstacles that these students face in STEM educational environments, including feelings of isolation due to the low numbers of their close peers in STEM, gaps in preparation, and experiences with structural and interpersonal prejudice within STEM programs (Seymour and Hewitt, 1997; Barr et al., 2008; Vanasupa et al., 2009; Smith et al., 2015; Harackiewicz et al., 2016; Harrington et al., 2016; Killpack and Melón, 2016; McGee, 2016; Aikens et al., 2017; Eastman et al., 2017; Farrell and Minerick, 2018).

Social psychology and sociology approach the understanding of these obstacles from different perspectives. Social psychology, by and large, has historically focused on the individual-level mechanisms and psychological processes that affect student engagement, belonging, identification, and achievement. Such *student*-level analyses generally have not focused on the *macro* level processes that sociological approaches emphasize: the ways in which historically rooted, gender, race, and class-informed structures of power create and exacerbate inequalities in STEM education.

Both student and macro perspectives are crucial to understanding and reducing inequalities in STEM education, but because they approach their analyses from different vantage points, their implications for intervention – that is, for reducing disparities – can appear at odds, and difficult to integrate. One of our goals in this paper is to bridge the student and macro perspectives specifically with respect to the development and evaluation of intervention. We strive to connect the institutional and organizational context not only to the historical and cultural forces, but to the individual-level experience, with the objective of designing interventions to bring about systemic change. We do so by focusing on interventions at the *meso*-level; that is, the systems through which macro level influences are translated to individuals within communities (Serpa and Ferreira, 2019). Meso level structures include both formal and informal systems that organize social groups, and include both physical structures (e.g., banks and schools) as well as "ways of doing" (e.g., curricula, promotion, and hiring processes). More specifically, we focus on *critical faculty and peer instructor development* as two separable but related meso level practices through which to effect change in the broader ecology of STEM education. Both practices, we argue, can positively impact minoritized students' achievement and belonging, while also shining a light and disrupting some of the otherwise invisible macro level influences that contribute to inequities in STEM education.

Broadly, critical approaches to pedagogy encompass a group of meta-reflective practices that encourage instructors to actively recognize the hidden influences, assumptions, and norms that govern instruction and learning (e.g., López and Burciaga, 2014; Ladson-Billings and Tate, 2016). These approaches depart from traditional pedagogical training in that they do not focus so much on content *per se*, but rather, on the historical and sociological forces that act upon the practice of pedagogy. Critical approaches to pedagogy openly invite analysis and reflection of topics traditionally not considered in STEM training, including history, discrimination, power dynamics, and one's own positionality within the learning environment. Here we discuss how critical approaches can be used as an essential tool for faculty development in STEM, and we also explore how critical approaches can help inform the *intentional* training of peer instructors. Intentional peer instruction refers to education by peer instructors in a structured or scaffolded way, and stands in contrast from student-initiated informal peer instruction (e.g., getting help from a friend on homework). This approach aims to make sure that peer instructors learn and grow themselves, at the same time that they are helping or assisting their peers.

Figure 1 presents a schematic representation of how these practices interrupt an otherwise cyclical process. The two large circles in the bottom half of the figure represent a faculty member and a minoritized student, each with a set of thoughts or cognitions that might represent their thought processes in a traditional STEM course or program. Given that the majority of STEM faculty are white and male (Bennett et al., 2020), we conceptualize the faculty member as possessing these characteristics. Above the faculty member and the student are the constructs that we have outlined here. In the top left corner, we list the broad and historically influenced macro level processes that then shape both the taken-for-granted norms and assumptions of the traditional educational system (arrow 1), as well as the behavioral manifestations of these processes relating to access and resource allocation (arrow 2). Arrow 3 acknowledges that the system norms facilitate decisions about access and resources, which tend to favor the people who have historically ended up as faculty (4) but disfavor minoritized students (5). Both the assumptions and the disparities in access and resources create the environment for the student level processes we summarize here (6 and 7), which then affect the student's thought process and decision-making (8). These processes have been linked to disparities in completion and retention that affect minoritized students most severely (9), which contributes to social reproduction of the macro level conditions (10) that feed the recursive system.

In the center of the figure, in green, are the meso level interventions we outline below. The green arrows stemming from the green box are specifically interruptive processes within the otherwise recursive system. The pedagogical interventions provide an opportunity to change the cognitions and attitudes of the faculty member (11), as well as of the student (12). The interventions interrupt social reproduction processes (13), and ultimately, we hope, have an effect on the macro processes themselves by increasing access and representation in the field.

Our central argument is that meso level interventions that include a critical approach to faculty and peer instructor development may be key to addressing STEM disparities, given that meso level processes play a mediational role between macro and student-level factors. To illustrate the usefulness of this approach, we select and discuss a few prominent factors identified in the psychological and sociological literatures to further elucidate some of the macro and student-level constructs in the figure. Our aim here being illustrative rather than encyclopedic, we do not aim for a comprehensive review of all the student-level or macro level processes that ultimately affect student achievement. Similarly, at the meso level, we focus on a few examples of interventions relevant to student achievement. Throughout this process we have been informed by interviews and focus groups conducted with students in Data Science at UC Berkeley; their experiences and insights both inform and shape the recommendations we present here. We present data from these qualitative sources to give voice to the challenges and opportunities that minoritized students face in the academy. In addition, we present an illustrative case study from a program at UC Berkeley to demonstrate both the promise and the challenges of interventions at this level. While a single program cannot hope

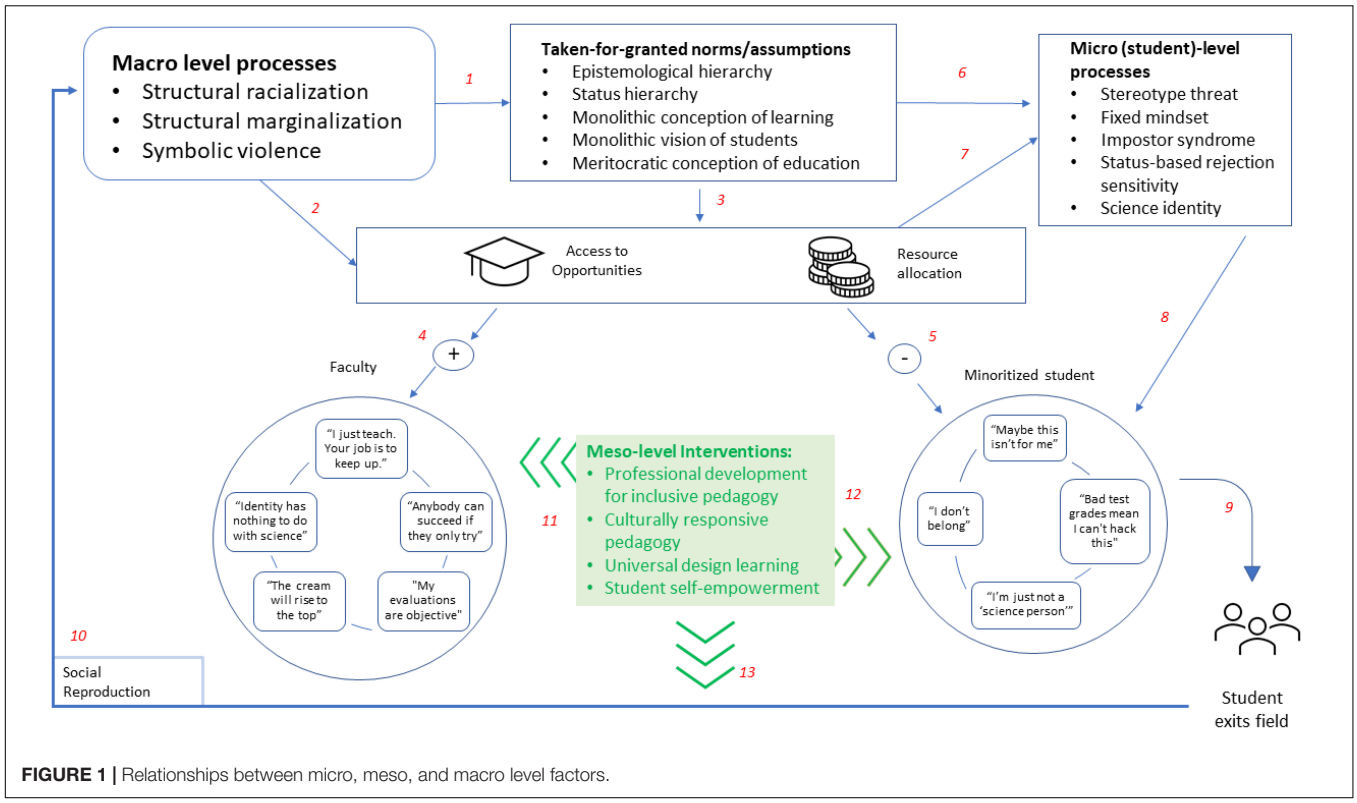

FIGURE 1 | Relationships between micro, meso, and macro level factors.

to be representative of the entire landscape of various STEM programs in a wide array of heterogeneous institutional settings, the Berkeley program is discussed here for illustrative purposes.

STUDENT-LEVEL CONSTRUCTS

The micro or student-level perspective, rooted in social and educational psychology, tries to elucidate the psychological processes that are broadly relevant to student motivation and achievement. Disparities are explained through the differential processes that affect marginalized or stigmatized students relative to non-minoritized students. As such, the currency of this approach is the motivational, perceptual, and attitudinal factors that influence achievement. By implication, intervention from this perspective involves targeting (i.e., changing) the psychology of the student.

Leveraging findings from psychological interventions, we briefly discuss six key student-level constructs that are central to understanding the psychological experience of minoritized students in STEM fields: sense of belonging, growth mindset, imposter syndrome, stereotype threat, status-based rejection sensitivity, and scientific identity. We focus on these constructs because prior interventions demonstrate that these six factors interactively contribute to lack of persistence in STEM among historically marginalized students. We view the constructs below as interrelated and these relationships as being part of a broader constellation of constructs that are used to understand the student experience.

Sense of Belonging

Research has shown that when historically marginalized students experience adversity throughout any segment of their student career, they are more likely to interpret these experiences as indicators of not fitting in socially or academically (Walton and Cohen, 2007). A sense of belonging has been shown to increase social and academic fit in college, and to decrease the propensity to view adversity as proof of not fitting in Walton and Cohen (2007). A sense of belonging has been tied to behaviors that include more time studying, sending emails to professors, attending office hours, fewer visits to the doctor, improved health and happiness, and more "outgroup" friends (Walton and Cohen, 2007; Walton et al., 2015).

Moreover, a sense of belonging improves students' evaluation of their "in group" as it pertains to STEM performance and increases persistence in STEM enrollment (Walton et al., 2015; Murphy et al., 2020). Lastly, feelings of belonging in college also impact the future development of students' professional careers and well-being such that they report greater satisfaction and success in their careers, involvement in leadership roles, and life satisfaction (Brady et al., 2020).

Growth Mindset

Meanwhile, some people believe that intelligence is fixed, i.e., that one has a certain level of inborn intelligence that does not change through environmental input. However, there is a compelling body of research that shows that the belief that people's intelligence can be developed through dedication and hard work (that is, grow one's intelligence), the meaning of failure

is transformed away from a diagnostic tool of one's capacity to an opportunity to learn from one's mistakes (Dweck and Yeager, 2019). When marginalized students hold a growth mindset, they are resilient to the effects of stereotype threat and earn higher grade point averages (Aronson et al., 2002).

Imposter Syndrome

Imposter syndrome can be defined as a collection of feelings of inadequacy that persist despite evident success (Clance and Imes, 1978). "Imposters" suffer from a chronic sense of intellectual fraudulence that overrides feelings of success or external proof of their competence. Marginalized students are likely to confront imposter syndrome, in which they contend with feelings of doubt regarding whether they have earned their success (Clance and Imes, 1978; Canning et al., 2019a). Moreover, imposter feelings are heightened for first-generation students when they perceive their classroom environments to be competitive. This is associated with lower levels of class engagement, attendance, grades, and greater dropout intentions (Canning et al., 2019a).

Stereotype Threat

An additional barrier that marginalized students face is stereotype threat, a phenomenon in which individuals become aware of and or are nervous about confirming a negative stereotype about their group in a domain where they are subject to negative evaluation (Steele, 1997). Stereotype threat has been shown to affect academic performance through task disengagement and domain disidentification (the former being constrained to a given academic task, the latter being more generalized such that one disengages self-esteem from the domain) (Spencer et al., 1999; Walton and Spencer, 2009; Mello et al., 2012; Casad and Bryant, 2016; Martiny and Nikitin, 2019).

Status-Based Rejection Sensitivity

The model of status-based rejection sensitivity proposes that beyond concerns about being evaluated in light of negative stereotypes, marginalized students are likely to experience and be concerned about exclusion, marginalization, and ostracism due to their social identity. In other words, status-based rejection sensitivity recognizes the social and interpersonal implications of stigmatized status that go beyond stereotypes *per se* (i.e., people just don't like you because of a specific characteristic). The construct of status-based rejection sensitivity has been applied to a number of different identities that include race, gender, social class, appearance, sexual orientation, age, and weight (see Mendoza-Denton and Leitner, 2018). The academic impact of status-based rejection sensitivity is mediated through the social processes through which education occurs: concerns about being rejected, for example, leading to avoidance of professors' office hours, decreased trust in the university, and greater anxiety about belonging (Mendoza-Denton et al., 2002). Additionally, Mendoza-Denton et al. (2002) found that African status-based rejection sensitivity among African Americans was related to declines in grade point average over the course of five semesters at a Predominantly White University.

Science Identity

According to Chen et al. (2021), students hold a strong science identity when they and their important reference groups consider them to be a "science person." Past research has demonstrated that minority students' self-reported scientific identity is positively associated with intentions to socially integrate into the scientific community, participate in conducting research, and apply to graduate school above and beyond the effects of self-efficacy and endorsing the science community values (Estrada et al., 2011). Woodcock et al. (2012) found that both Latinx and African American students demonstrated a positive association between scientific identity and intentions to pursue a science career (Woodcock et al., 2012). More recent research has found science identity to be positively associated with higher performance in gateway STEM classes (Chen et al., 2021), and to be a protective factor against academic underperformance for minoritized students in particular. To further elucidate the impact of science identity on performance, Chen et al. (2021) conducted a social belonging intervention that demonstrated that a sense of belonging untethered the effect of science identity from performance.

MACRO PERSPECTIVES

The above student-level constructs offer a granularized view into the proximate social forces that affect student outcomes. In introducing the macro literature, we begin by briefly describing three of the most commonly used theoretical frameworks and then discuss key macro constructs that inform our understanding of the educational climate experienced by students from marginalized groups. We then discuss how these theoretical approaches can translate into pedagogical practice.

Theoretical Frameworks for Understanding Macro Level Inequalities

Critical race theory (CRT), a theoretical tradition rooted in African American and emancipatory thought, offers helpful insights into how issues of belongingness are racially motivated and the solutions that can be used in addressing them. CRT explores the conditions under which anti-blackness is manifested, and takes the explicit stance of naming the violence of anti-blackness across temporal, ideological and political contexts (Crenshaw, 2011). CRT was originally developed to critique legal scholarship (Caldwell, 1996), and Ladson-Billings and Tate (2016) extend CRT to higher education. They draw connections between systemic iterations of racism to stratification within higher education, showing how racism is deeply ingrained within the American educational system through its assumptions, cultural ideals, and day-to-day practices.

Another theoretical approach to addressing marginalization is post-colonial theory. Within this theoretical approach, the histories of colonial oppression are traced to their present-day impact on institutional logics and practices. This approach recognizes that the history of the American university is deeply embedded within the history of colonialism in the United States. Positioned as a frontier for western empiricism, institutions

of higher education were founded on the premise of a need for religious and often agricultural expertise. Such college qualifications for many years exclusively elevated white men into America's burgeoning middle class. From this came the development of curricula and classrooms that were centered around Whiteness (Kliebard, 2004). The deep resistance that efforts toward integration were met with laid the groundwork for the continued otherization of minoritized students within the higher education institutions (López and Burciaga, 2014).

Indigenous ways of knowing offer us an epistemological alternative to the current paradigm in which we imagine STEM instruction. While it can often expand beyond western categories of knowledge, indigenous scholars have positioned these practices as important interventions for decolonizing the academy. Sisseton-Wahpeton Oyate scholar, TallBear (2019), proposes a theory of *relationality* that prioritizes an ethic of recognition beyond social hierarchies that are often rooted in a racist and imperial past. In recognition of a colonial history of dehumanizing people and things that differ from whiteness, indigenous traditions of honoring kin have helped combat logics of otherness that have justified the marginalization of minoritized people. Métis scholar Max Liberion's practice of citational justice illustrates how local knowledge can be preserved within the academe (Liboiron, 2021) through the art of expliciting and repeatedly acknowledging genealogies that have not commonly been recognized within academic citational practices. Liberion shows us the necessity of acknowledging the diverse avenues of knowledge production can occur, which often is not limited to pedigree and established authority. Furthermore, we see such an ethic of care as both integral to indigenous ways of knowing and emancipatory within the classroom because of its explicit recognition of agency and a shared mutual investment in power among teachers and students alike.

Similar to Indigenous scholarship, approaches like critical race theory and post-colonial theory focus their analytical attention on deconstructing structural systems rather than individuals, urging us to focus critique on systems of oppression. These frameworks emphasize that the exclusion of members of stigmatized and marginalized groups from land, resources, capital, and status is not a function of the simple aggregation of individual discriminatory behaviors, but rather is a feature of how institutions work – their internal logics, norms, and daily practices. Institutions carry forward past injustices, harms, and power relations in ways that are not easily discernible precisely because they are built into the very fabric of how the institution functions. Bourdieu and Passeron (1990), for example, develop the concept of symbolic violence, which refers to non-physical violence manifested in the difference in power relations between social groups. Symbolic violence is unconsciously agreed upon by the dominant and dominated. Norms are imposed by the group possessing greater social power over subordinate group members.

Higher Education Institutions Through a Macro Lens

One way to understand structural and systemic inequality within the university is through what Powell (2013) calls structural racialization or structural marginalization. He positions these forms of marginalization as processes, rather than as acute events, "that may generate disparities or depress life outcomes without any racist actors" (Powell, 2013, p. 4). More importantly, with this definition, Powell prompts an analysis of "the genesis and formation of critical structures, not just how a structure operates or how programs are administered" (ibid). Embedded within these institutions are a series of financial, cultural and meritorical practices that codify the marginalization of underrepresented students.

Critical theories also understand the university as a potential site of social reproduction rather than social mobility or opportunity. Social reproduction refers to reproducing social classes in order to maintain and reify social hierarchies. Students who are born into working, middle and upper classes are led to stay within the same class as adults. Class reproduction, poverty, and unequal educational outcomes for low-income students are maintained by the role "sorting machines" that school plays (Willis, 1981; Bowles and Gintis, 2002). Although initially focused on primary and secondary schooling as institutions of class reproduction, the social reproduction perspective can be extended to post-secondary institutions. With the advent of neoliberalism, globalized and corporatized universities become more selective, and students with higher economic mobility have better chances of admission into competitive schools. These students also have the resources to maintain their standing within these institutions (through material means that afford access to housing, nourishment, and technology, for example) and receive "good quality" assistance from hired help. Social reproduction allows for educational spaces to maintain social and economic inequalities by inhibiting the social mobility of marginalized populations (Bourdieu and Passeron, 1990). From this perspective, rather than being gateways to social mobility, schools make valuable resources and coursework available to students with higher socioeconomic statuses, further marginalizing and maintaining the class positions of students.

Implications for Curriculum and Pedagogy in STEM Education

Critical Race Theory, Post-Colonial Theory, and other macro perspectives posit multiple broad influences on STEM education that affect its participants – both instructors and learners – deeply yet invisibly, by guiding and constraining the choices, opportunities, and psychologies of individual actors. Importantly, as these processes are historical, cultural, and institutional, their influences are invisible – that is, they are "baked in" to the structure of the system in such a way that to be able to engage in the system, one must necessarily accept (or go along with) the logics and norms mandated by these processes.

These macro level influences on curriculum and pedagogy in STEM Education can be understood as a set of taken-for-granted assumptions about learning and effective teaching practices. As in the micro level section above, the discussion below is not exhaustive, but provides a blueprint for the kinds of factors that the perspective highlights.

Epistemological Hierarchy

Derived from European models of scientific knowledge and epistemology, this conception privileges quantifiable and seemingly objective practices of scientific measurement and explanation at the expense of knowledge derived from deep and long standing personal experiences. In implicitly or explicitly rejecting such ways of knowing and the information they can provide to science as anecdotal or unscientific, such conceptions can devalue the personal experiences of first-generation students and students of color as secondary, even when studying topics where they have direct lived experiences.

Status Hierarchy

Long standing, unspoken, and institutionalized notions of status and authority within the university and its classrooms can render students as passive recipients of faculty knowledge and expertise, rather than as co-creators of the learning environment. Such taken-for-granted power hierarchies disempower students and shield faculty from criticism or the need for reflection, responsiveness, or self-awareness.

Monolithic Conception of Learning

This conception assumes that all students learn in the same way, and that conventional or traditional modes of instruction and design of assignments and labs continue to be the most effective methods. Such a notion can be attached to the instructor's own prior experience as a student and what was effective for them, despite scientific evidence that other methods may be more effective for a larger and wider range of students. Closely linked to this notion are ideas about what sorts of assessments are both fair and effective, such as a reliance on high-stakes tests.

Monolithic Vision of "the Student"

This understanding derives from the assumption that the normative college student is white and comes from a middle class background. Curricula and pedagogy are designed around strategies, timelines, and expectations that have typically worked well with that population of students in the past. A related notion is that students who differ in their racial, income, and educational background must conform to white, middle class notions of a student, rather than the instructor and institution adapting to the increasing diversity on college campuses.

Conception of Education as Meritocratic

A central assumption of traditional educational systems is that anybody, by dint of hard work, can achieve the highest level of success. By implication, a lack of achievement reflects on the individual's own talents or abilities. This worldview protects against critical examination, and is fundamentally incompatible with, the recognition of the structural processes implicated in systematic oppression.

THE MESO LEVEL

In this section, we turn our attention to the meso level that links the student-level proximate outcomes and the macro level influences to the contexts in which instruction takes place. We conceptualize the meso level as active: the pedagogical practices through which educators socialize students, model and enforce norms, and transmit the cultural standards of the macro level. This conceptualization is based on research that has demonstrated the ways in which the macro factors can influence specific behavioral responses of instructors in the meso level and how the meso level can be redesigned to encourage behaviors that result in student academic persistence (Mendoza-Denton and Mischel, 2007; Stephens et al., 2012).

The active quality of this level, we argue, provides a potential target for intervention. We focus on two specific groups of practices: critical faculty development for inclusive pedagogy, and intentional peer instruction. These pedagogies move away from deficit-oriented thinking, highlighting the learning context's role in affecting student engagement, and the development of dialogic education.

As we elaborate and illustrate the value of inclusive teaching practices, we draw examples from our ongoing survey and qualitative research on the experiences of first-generation and BIPOC students in the UC Berkeley data science program (see **Supplementary Appendix A** for more information). The survey data offer insight on the factors relating to student success in data science and their continuation in this field (persistence), as moderated by the supports provided by components in the model. Within this larger correlational investigation, we embed qualitative focus groups to gain a deeper understanding of students' experiences and the processes they deem important that contribute to their progress (or lack thereof) in their STEM experiences. The qualitative and survey studies were approved by the UC Berkeley Institutional Review Board.

To understand the relationships from the quantitative data, a subset of underrepresented undergraduate students was selected to participate in four focus groups. This qualitative data allows us to explore the experiences from the students' perspective and the factors that students feel to be significant to their success and persistence. These qualitative data reveal the subjective perceptions and detailed experiences that are not knowable from the survey data alone. An important goal of the focus groups is also to understand the nature of the intellectual community experienced by students from underrepresented groups.

We emphasize that the data presented below are not intended to either test specific hypotheses derived from the framework or evaluate the Berkeley program. Rather, we present these data to help illustrate how the ideas, practices, and constructs we discuss are experienced in the day-to-day educational journeys of students.

Berkeley Data Science as an Illustrative Case Study

Data science is a new STEM field, one with great potential to engage students historically marginalized in STEM through its use of social data and emphasis on social impact. Research suggests that students from diverse backgrounds often find a decontextualized model of science learning frustrating and that it too frequently fails to address the social relevance that many underrepresented students find motivating

(Roundtable on Data Science Post-Secondary Education, 2017). By contrast, intellectual pursuits framed around altruistic goals—that is, goals focused on the greater good—are often strong motivators that are personally and professionally meaningful to students, particularly those who otherwise do not persist or are not retained in the sciences (Thoman et al., 2015).

UC Berkeley's Data Science Undergraduate Studies within the Division of Computing, Data Science, and Society (Adhikari et al., 2021) employs an interrelated set of pedagogical and institutional strategies that attempt to address the linked challenges of diversity and scale and to serve undergraduates from both STEM and non-STEM majors. Berkeley's program includes instructional Modules that "push in" data science into the existing curriculum, a zero-prerequisite Foundations course currently taken by more than 1500 students per semester, concurrent Connector courses that delve into substantive data science applications, a Data Scholars program to support students traditionally underserved in STEM, and Discovery Projects that provide students the opportunity to apply data science skills in real-world settings. The program has also recently developed both a data science major and a data science minor. Formal course curricula are enhanced by a larger ecosystem of support programs as well as student-led extra-curricular activities centered around the application of data science in multiple substantive domains. Students in the program are offered a buffet of opportunities and options to self-select into allowing for flexibility in a broad range of points of contact.

While Berkeley's Data Science program is a nationally recognized model that is being adapted and refined by many other colleges and universities (National Academies of Sciences, Engineering, and Medicine, 2018), it nevertheless faces many of the challenges with diverse and broad STEM education faced that are felt by programs around the country, including retention of scholars, broad access, and scalability (Xu, 2016; Tuthill and Berestecky, 2017). The data presented below illustrate the ways that students experience such challenges and inform our recommendations for meso-level interventions.

Faculty Development for Inclusive Pedagogy

An inclusive pedagogy STEM faculty development can focus on reflection, empathy, and awareness of social relations and interactions in the learning environment. These issues cut across various educational approaches, with a common focus on the constant critical analysis of the macro level processes affecting learning.

Reflexivity

Normally used to refer to the research process, reflexivity involves reflecting on the process of knowledge creation and the ways that our own perceptions shape everything that we see (Brownlee et al., 2017). Therefore, an examination of one's own beliefs, judgments and practices both in the research but also in the instructional process can enable faculty to question taken for granted assumptions. In relation to this it also creates opportunities to more critically engage with diverse student identities. By articulating syllabi and curriculum that meaningfully incorporate and engage with diverse scholarship, students are provided with a more enriching educational experience. For example, the Cite Black Women movement (Smith et al., 2021) encourages multiple principles of engagement and inclusion of Black scholarship in coursework.

Central to this work is an exploration of the implicit biases that one possesses regarding their students, which stem from macro level factors like status hierarchy, a monolithic vision of the student, and conception of education as meritocratic. Thinking of a student as being a member of a minority group, being underprepared, having a disability, or being a second language learner is a different perspective from realizing that collectively minoritized groups have power and voice. Indigenous ways of knowing foreground the expertise that students derive from their daily lives and collective community experience and wisdom. For example, being disabled can mean that students bring a unique perspective to the materials. Being multilingual means understanding problems from multiple vantage points. Students come to the classroom with a variety of experiences and perspectives that can be leveraged in the work if they are encouraged and supported in doing so. However, we know that deficit perspectives, such as those derived from epistemological hierarchy, status hierarchy, and the monolithic conception of learning, are linked to lower expectations and further marginalization (Ash et al., 2020).

These claims are empirically supported by prior research. For example, when first generation students heard stories from panelists about how their social class backgrounds presented them with unique challenges in college and the strength to overcome those challenges, this resulted in a reduction in the achievement gap between first and continuing generation students, an effect that was mediated by increases in students' tendencies to seek college resources (Stephens et al., 2014). A follow up study found that the first generation students in the intervention condition were more likely to discuss their backgrounds when giving a speech and demonstrated higher physiological thriving after a stressful evaluative task in comparison to first generation students in the control condition (Stephens et al., 2015). More recent research has also demonstrated that endorsement of lower socio-economic status students' backgrounds is positively correlated with their academic achievement (Hernandez et al., 2021).

Research on the impact of faculty growth mindsets provides another empirical example. STEM professors' fixed (compared to growth) mindsets about student intelligence was significantly associated with decreases in student grades, motivation, perception of faculty as emphasizing learning and development, and recommendation of their courses to other students (Canning et al., 2019a). Moreover, courses taught by STEM professors who held fixed rather than growth mindsets exhibited achievement gaps for underrepresented (Black, Latino, and Native American) students in comparison to White and Asian students (Canning et al., 2019b).

Consider also the following example, in which students of color felt excluded and othered by textbook examples used to illustrate statistical concepts.

"There are a lot of examples in the textbook where it… reiterates, like stereotypes that many people face, many cultures face. So there was one about the first project talking about the world population and poverty rates in certain cultures and countries. And not a lot of people liked that since they felt like it was just emphasizing the stereotypes of many of the people, and they just didn't feel like many people would understand their concerns since they themselves don't have to deal with that in their day to day lives. Yeah, so that was a challenge, basing the material and having to suck up your own feelings and just do the work."

As this example demonstrates, pedagogy needs to reflect on the impact that particular examples or scenarios may have on students.

Empathy

Building relationships with students requires understanding their backgrounds, and their educational voyage, along with their ways of thinking and understanding the world around them. Creating community building opportunities outside the classroom can be a powerful way to connect with a diverse student body. Co-constructing third spaces can help students come out of their shell and lower their anxieties about the university context, potentially countering imposter syndrome and stereotype threat and promoting a sense of belonging and science identity. At the same time, these activities can build empathy on the part of faculty and other instructors by themselves learning about the historical and social context of the students they are teaching (Moll et al., 1992).

Killpack and Melón (2016) argue that this change needs to occur alongside changes in institutional culture. They provide evidence that faculty development opportunities limit discussion to comfortable topics and miss opportunities for deeper issues to be explored such as faculty privilege, implicit bias, and cues for stereotype threat. These areas of bias engender discrimination and become pervasive among faculty, instructors, undergraduate student instructors, TA's, and section leaders.

Awareness of Social Relations and Interactions in Classroom Learning Environments

Countering feelings of threat and exclusion at the level of the individual, as well as fostering a sense of belonging and inclusivity, requires attention to daily micro level interactions. Language and tone are key to creating inclusive classroom environments that welcome diverse groups of students and model constructive peer norms.

The idea of a safe space originates from Lesbian, Gay, Bisexual, Transexual, Queer (LGBTQ) spaces intended to bring attention to consciousness raising in the women's movement, in which efforts have been made historically to co-construct spaces were marginalized communities could find and build community, empowerment, and resistance to social oppression. These spaces were not free from internal disagreements, but instead were characterized by shared commitments to social change. Faculty can start building a safer space by examining their own identity in relationship to the students' identities and to the topic being taught. They can also practice having conversations that are sensitive. This can begin with establishing norms of conduct for the class that apply to both instructors and student peers. Norms of conduct can begin with an acknowledgment of the inherent issues of bias and power in data and the effort to make these issues more transparent. Faculty can welcome reflection on the part of the students and invite their thoughtful and constructive critique and can explicitly welcome student voices from every perspective, every age, race/ethnicity, national origin, immigration status, level of experience, gender, gender identity, gender expression, sexual orientation, range of abilities, or physical appearance.

Faculty can play an important role in establishing peer norms in the classroom. When pro-diversity norms are made salient in STEM classrooms (by showing students a brief video that discussed how their peers value diversity and enjoy getting to know students from different social groups) the achievement gap between privileged and marginalized students narrowed, whereas the achievement gap persisted in STEM classes assigned to the control condition (Murrar et al., 2020).

Awareness of social relations and interactions in the learning environments is also the type of knowledge, skills and disposition that faculty can develop and then foment among their graduate and undergraduate instructors, teaching assistants, and section leaders. Such efforts implicitly involve surfacing unspoken macro level assumptions like epistemological hierarchy, status hierarchy, monolithic conception of learning, monolithic vision of the student, and a conception of education as meritocratic. Diversity education reduces race-related biases among participants and can help build bias reduction strategies (Devine and Ash, 2022). Faculty from medicine and STEM departments involved in these types of faculty development have increased their personal awareness of biases, increased motivation and belief in their ability to promote equity. When at least 25% of a department's faculty were involved in gender bias training, participants reported statistically significant increases in their personal efforts to promote gender equity (Carnes et al., 2015). These studies shed light on the potential for positive change through these faculty development programs provided that there is broad participation.

Culturally Responsive Pedagogy

Culturally responsive pedagogy is defined as using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching students more effectively (Kleinfeld, 1975; Au and Kawakami, 1994; Ladson-Billings, 1994, 1995; Foster, 1995; Gay, 2000). Both Freire (1968) and Hooks (2014) also imagined liberatory pedagogies that center questions of agency and power within the classroom as ways that counter epistemological and status hierarchies.

When the curriculum is not closely related to students, it can result in alienation from their sense of knowing and from education broadly (Au, 2012). With culturally responsive teaching comes the acknowledgment or reclaiming of the curriculum. Versions of history that were previously invisible or illegible within classrooms can come to light (Au et al., 2016). Black feminist epistemologies of thought have historically centered knowledge building practices around the personal and affective experiences of the individual (Collins, 2002).

Also, Indigenous knowledge practices have challenged western empiricism and prioritized local knowledge practices that are contextually and geographically sensitive (Kimmerer, 2013; Coulthard, 2014; Smith et al., 2015). The reclamation of multicultural history, voices and research enriches the classroom. Diverse histories and ways of knowing need to be incorporated into the curriculum and there needs to be acknowledgment that these epistemologies and ontologies are essential for advancing contemporary thought on campuses. There is mounting evidence that instructional congruence has a positive effect on learners' ability to assimilate knowledge (Lee and Fradd, 2001; Cuevas et al., 2005). However, this approach requires an extensive amount of commitment, including reflection upon the instructor's identity, culture and language and match or mismatch to students' own identity, culture, and language.

The value of cultural congruence is illustrated by a student who preferred to learn data science ethics in a department where they expected greater congruence with their own identities and experiences. The focus group students agreed and shared their preference to wait for an ethics course to be offered in the African American Studies Department that would meet the curricular requirement. The students felt that this specific course would most closely align with their interests and was worth the wait for an irregular offering rather than taking the standard Data Science ethics course.

We acknowledge and understand that professors already manage a complex set of formal and informal roles and responsibilities, such as serving as research leaders, upholding standards of scholarship, influencing public debate, representing their department and university, serving on university committees, and generally being a role model. However, in this paper we want to highlight the importance of faculty as critics, advocates, and intellectual leaders who are vested in social and political concerns. Data science is a rich ground to develop efforts for social good and social justice, whether related to the incarceration system, refugee crisis, houselessness, health, or the environment, etc. Expectations of professors are implied and there is increasing agreement that faculty members, like any other professional, need guidance and development and there are indications that there is very little provision of these (Macfarlane, 2012).

Universal Design for Learning

The effort to articulate materials in diverse ways for student reception and the acceptance of multiple forms of expression is the basis of Universal Design for Learning (UDL) (Meyer et al., 2014). Universal Design for Learning is an educational framework based on research in the learning sciences, including cognitive neuroscience that guides the development of flexible learning environments and learning spaces that can accommodate individual learning differences. It is also consistent with an ethic of care that prioritizes meeting all students where they are. Students in our focus groups discussed self-knowledge about their preferences for particular forms of curricular materials (project-based vs. tests) and its impact on their learning. They shared awareness about how the course design has a direct impact on their success. We highlight the opportunity of UDL in the design and ongoing iterative implementation of courses that invite and engage student voices in ever-changing technosocial spheres.

For example, one student in our focus groups highlighted concerns with trying to understand and navigate the multiple avenues of communication and activity that a course uses. She shared her confusion and concerns, which eventually led to the development of a chart that would clearly outline each of the web based spaces, providing access and defining the use for each. This facilitated her understanding of what she was expected to be doing and how she was to access these course resources. This was not an initial part of classroom planning but certainly provides a valuable resource that could be built in from the start of coursework design. It allows for both explicit access and demonstrates multiple means of participation where students can demonstrate their knowledge and share questions. Other students shared that near-peer programs offered well designed and executed programming to help them build skills at crucial moments with accessible content, meeting their learning needs at their current point in their learning trajectory.

Universal Design for Learning provides multiple facets of instructional design that open up a variety of avenues for students to engage receptively and expressively with contant. These mechanisms break down previously assumed epistemological and status hierarchies of instructional format and encourage courses that are dynamic and iterative in order to enhance the teaching and learning experiences of instructors and students, thereby promoting sense of belonging, growth mindset, and science identity while countering imposter syndrome, stereotype threat, and status-based rejection sensitivity. This work has been taken up and expanded in close relationship to Critical Race Theory by Fritzgerald and Rice (2020). This effort potentially can interrupt stereotypes and bias in curricular materials and lectures by acknowledging and critiquing power differentials that frequently can manifest in microaggressions and institutional violence.

The Role of Peer Instructors in Supporting Students From Various Backgrounds

As faculty develop their own inclusive pedagogical practices, they can in turn model and transmit these same practices to peer instructors through discussion and mentorship. Consistent with several scholars' conceptualizations (Talbot et al., 2015; Vickrey et al., 2015; Schell and Butler, 2018), we view an important part of near-peer instruction as facilitating peer group discussions independent of the larger lecture course that is led by a faculty instructor. This is because interactions between peers, unmediated by faculty, produce important learning gains for both peer learners and peer instructors (Secomb, 2008; Evans and Cuffe, 2009; Talbot et al., 2015; Balta et al., 2017).

Peers can have a unique and powerful influence in the context of instruction, as students may see peer instructors as more relatable, less threatening, and easier to approach. Nonetheless, peer-to-peer dynamics are not immune from the dynamics of prejudice and exclusion that can characterize faculty-student

interaction. In the following section, we review some of the benefits – as well as the challenges – that students of color experienced in the context of peer instruction.

Building on the literature on third spaces that welcomes multiple scripts into a space of interaction and engagement focused on learning (Gutierrez et al., 1997), students in our focus groups appreciated the ability to come with the subject in dynamic workshops and in an environment where any question was welcome. Even more powerful are self-organized groups, like a group of Black engineering students at UC Berkeley who call themselves the "C.S. mob." They have created organic peer-to-peer networks that became nets of information sharing and support. A student elaborated:

> *I do think that I genuinely gravitate towards people who look like me, either like ethnic minorities or women. I think that there's just a sense of comfortability, as well as seeing someone who looks like you. I have a friend who said, honestly, "(Person's name), if you didn't reach out to me while we were taking 61A, I don't think I'd be studying CS anymore." And, being able to. Want to work with us or if they have any questions. Maybe they know what they're doing and maybe they can help my friends and then go to classes and meet other people from very similar backgrounds to you. Just having that sort of group build.*

This student went on to discuss how the organization looks for other students to invite in. The student discusses how with any given question they feel comfortable reaching out, knowing that someone will reach back and support them in solving problems. These forms of student self-organized groups bring together critical elements of student self-determination with resources to build a supportive data science education framework. The need for students to build their own groups stems from their collective effort to build educational spaces that resolve the challenges that they experience within the current education framework. Continuing to investigate how these organizations connect with departmental and curricular networks to utilize and leverage resources to their networks can provide models for encouraging other groups to build and sustain such practices.

Many students also described collaborative group projects as better aligned with their learning styles, especially when they provide opportunities to work with students from similar backgrounds and are appropriately supported by peer leaders. One student remarked:

> *"I do wanna say that I'm happy that at least my project, 3 out of the 5 students are in the Data Science Scholars because we get to see each other like on the side and like we have our group meetings. So, like just with the Data Scholar students, so it's kinda like team building, like we all get to talk as a group so it does make me feel more comfortable with the students. Whereas if I didn't have these facilitated, like team-bonding type of things, it would have been a lot harder to communicate and express ourselves with each other. And I do think it helps that there are students that are in the Data Scholars program because we all come from different backgrounds that are more similar to students that aren't in the program. And I think one thing that helps too is that our lead is pretty helpful."*

A strength and a challenge of the UC Berkeley program is the use of scalable near-peer instruction with teams of undergraduates who support peer learning and co-create course materials. These peer instructors apply their learning and thereby advance their own understanding and skills. Students from our qualitative research shared the critical role of these instructors as it relates to completing course assignments. They described the variability in instructional practices, noting it was difficult in office hours to go through multiple instructors providing minimal support until finally finding a peer instructor who would work closely with them through multiple-step questions:

> *"...the third person was like, 'oh well okay. Well let's actually delete all of this and rework it out and let's go step by step.' And it's the fact that it took like three people to help me in that process, like that's ridiculous."*

We also learned of other difficulties in peer-instruction spaces. One example included a student noting exclusion in these spaces remains, noting it was "not as friendly. Like it was supposed to be a collaborative session where you worked with your partner, and again, it's just really hard to find a group of people who would want to work with you in those sections." Students provided examples where they had issues finding a project partner or having peers turn and look away from them during activities, so as not to end up as partners with them. Students across focus groups brought up concerns about the lack of diversity in the peer instructors, difficulties being able to access these employment opportunities, and the necessity for these roles to be filled with individuals who understand teaching the content from diverse points of entry. Also, it is challenging for a peer to provide mentoring if they themselves have not been mentored. We know from research that mentorship is rare and marginalized students rarely receive mentorship in higher education (Trujillo et al., 2015).

Recommendations for Reforming Peer Instruction

Research on peer instruction has typically been conducted in college contexts that are predominantly white, and the benefits of this pedagogical approach are still unclear in more diverse colleges (Vickrey et al., 2015). Research is needed to understand the effects of peer instruction in racially diverse college contexts on racial minority students' learning. Developing peer instruction programs requires attention to research that shows that peer interactions can *either* ameliorate *or* exacerbate the effects of stereotype threat on racially diverse students' learning outcomes and subsequent degree progress (Taylor and Walton, 2011; Leslie et al., 2015; Storage et al., 2016; Murrar et al., 2020).

We suggest that peer instruction can be improved by using findings from the growth mindset, social belonging, and future identity literatures to provide structured guidelines that leverage the unique social influence of each student to cultivate learning environments that minimize the effects of stereotype threat (Wilson, 2011; Destin et al., 2018). We focus on both the growth mindset and social belonging literature because the effects of these interventions have been replicated throughout the United States and have been shown to reduce the racial achievement gaps in regards to end of term grades. We also include the future identity literature because it demonstrates promising effects for underrepresented students who might feel they are stereotyped as only being able to obtain low status

and or non-science based jobs and therefore disengage from academic spaces or efforts to obtain upward social mobility. In the following sections, we will discuss suggestions for reforming peer instruction with an emphasis on the ways that peer instructors can leverage research results when developing their pedagogical approach. These are not intended to be comprehensive, but rather provide some examples of the types of interventions that are expected to improve student learning and retention based on prior research.

Peer Instructors Can Encourage Growth Mindsets

When near-peer instructors are reviewing concepts from a faculty lecture, they can emphasize that some concepts might require more effort to learn and provide their peers with examples of different study strategies. Moreover, as near-peer instructors guide their peers in discussing concepts with one another, they can encourage students to discuss the strategies that they used to overcome challenges in learning the concepts. This group discussion strategy removes the negative effects of the stereotype that racially diverse students may face regarding their groups' intellectual ability by placing emphasis on learning requiring effort and not innate ability, that is, by cultivating growth mindsets (Aronson et al., 2002). This approach to leading peer discussion will result in peer group members feeling less imposter syndrome, more trust and commitment toward the group, and perceive others as more collaborative (Canning et al., 2020; Muradoglu et al., 2021). These findings are important for peer learning because such approaches empower students to encourage one another to develop growth mindsets, in turn creating a learning environment that explicitly discourages stereotypes.

Peer Instructors Can Cultivate a Welcoming Environment

When instructors first begin meeting with their peers, they can lead their students through group exercises that create a pro-diversity norm and reframe adversity as both common and surmountable. We highlight two such exercises, validated in the research literature. One is a brief norm setting exercise that might include everyone in the class sharing with one another one or two reasons why they value diversity. The research suggests that activities like this can help underrepresented students perceive a more inclusive and welcoming environment while non-minority students will notice this pro-diversity norm and tune their behavior to display more friendly behaviors toward their peers (Murrar et al., 2020). A second exercise includes everyone discussing a challenge that they have experienced at one point or another in their college careers and explaining how they were able to overcome it. The research has demonstrated that such discussions prevent challenges from being interpreted as indicators of lack of belonging (Binning et al., 2020). Such exercises are significant because underrepresented students have come to expect that they will be rejected in educational spaces by their non-minority peers, faculty, and campus administration due to racial stigma (Mendoza-Denton and Leitner, 2018). These exercises are likely to encourage racial minority students to feel more comfortable when engaging with non-minority peers in discussion groups because they will not be as concerned with race-based rejection (Martiny and Nikitin, 2019). These two brief exercises can substantially improve the traditional peer instruction model by creating a context that values diversity and views challenges as surmountable.

Peers Instructors Can Nurture Their Peers' Possible Future Scientific Selves

The negative stereotypes that racially minority students confront regarding their groups' intellectual abilities likely limit the types of careers that they envision for themselves. As a result, such students may be less likely to engage with science education than their white peers or to be motivated to persist in the face of adversity. Near-peer instructors are in a unique position to assist their peers with developing an understanding of the science careers that they might consider. This can be done through discussions on career options and by discussing how to reach those careers through education. These peer group discussions will likely benefit all students, but especially racial minority students who are still developing their plans for science education and science careers (Oyserman et al., 2006; Destin and Hernandez, 2020).

CONCLUSION

Parallel literatures in Psychology and Sociology have historically approached inequities in higher education from different angles. Psychology, with its focus on the individual, has tended to focus on student-level mechanisms that affect motivation and performance. Examples of such mechanisms that we have presented here center around feelings of threat, identity, and belonging. Sociology, with its focus on social organizations and institutions, has tended to focus on structural forces at work in the development and maintenance of inequities. Such a focus has given rise to critical approaches from which concepts such as structural marginalization and structural racism arise.

We have proposed here that interventions aimed at the meso level, directed toward those who teach and mentor students (both faculty and peers), are likely to be effective and long-lasting because they can acknowledge and act both on macro level and student-level processes. Many of the ideas we propose, including empathy, reflection, culturally responsive pedagogies, and Universal Design for Learning, encourage educators to move beyond the "sage on the stage" model of top-down learning (Mendoza-Denton, 2019), and instead reflect critically on their positionalities and the ways that students' own backgrounds and knowledge influence learning. Peer-to-peer learning can also help break down hierarchical barriers; however, programs must be intentional to make sure that peer instructors reap benefits and professional development opportunities from their own efforts to help their peers. We have presented an example of the Data Science Program at Berkeley as an illustration of the tensions and challenges that can arise from one attempt to implement a program at the meso level. Our ultimate contention here is that instructors need to engage in a critical exploration of not only many bodies of knowledge, and ways of knowing, but also the

political structure of the university, and the higher education classroom, including the various technologies associated with current teaching practices.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because we are unable to share study data due to IRB protections. Requests to access the datasets should be directed to DH, dharding@berkeley.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by UC Berkeley Committee for the Protection of Human Subjects. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CV, RM-D, and DH contributed to conception and design of the study. CV, MR, RS, SO, AM, and RM-D reviewed the literature. CV, RS, and SO collected and analyzed the qualitative data. AL and EM performed statistical analysis. CV wrote the first draft of the manuscript. All authors contributed to the development of the theoretical framework, wrote sections of the manuscript, revised the manuscript, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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