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Who Can Succeed? The Role Bridge Programs Play in Diversifying Who Gets Considered for STEM Graduate Programs

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Abstract

American Institutes for Research (AIR) conducted a three-year exploratory case study of four two-year graduate-level bridge programs designed to increase the number of historically underrepresented groups of individuals earning PhDs in science, technology, engineering, and mathematics (STEM). This article presents findings from one component of a three-year exploratory study of four two-year, intensive bridge programs. The study was designed to collect data on how the bridge programs were assessing intellectual capability and students' likelihood of success in STEM graduate study and whether the bridge programs were 1) actively seeking and drawing on an expanded pool of undergraduate talent, and 2) influencing general graduate program admissions through practices and advocacy for valuing nontraditional measures as predictors of graduate school success. Key findings suggest that the four bridge programs offered three different types of bridging pathways or "tracks" into STEM doctorate programs, each of which allowed for varying degrees of nontraditional recruitment and admissions practices considerations. While the four programs shared a commitment to broadening participation and providing a more diverse pool of students robust pathways to a PhD, the ways in which the bridge programs had to gain buy-in, coordinate, and communicate bridge student selection with general master's and PhD graduate program admissions may have reinforced, rather than challenged, deficit narratives about historically underrepresented students' abilities outside of these special programs.

Introduction

Providing all students with equitable access to advanced degrees in science, technology, engineering, and mathematics (STEM) is one of the nation's greatest education priorities and challenges. Despite years of research, investments, and programming focused on recruiting and retaining historically underrepresented groups of students in STEM postsecondary pathways, notable disparities in STEM graduate school enrollment and attainment remain. With general population projections showing that the United States will have a majority minority population by 2044 (Wilson, DePass, & Bean, 2018), there is a heightened urgency to address the broadening participation challenge in these critical fields. Scientific and technological advancement is linked to long-term economic growth, and the United States commits copious resources to training in the STEM fields at the graduate and professional levels (West, 2011; Wilson et al., 2018). These resources are best used to support diverse scientific communities. Men and women of different races, ethnicities, and background experiences bring new perspectives and approaches to research and practice, resulting in new types of scientific and technological innovations (Gibbs, 2014; Nelson & Brammer, 2010; Rosser & Taylor, 2008; Stassun et al., 2011; West, 2011; Wilson et al., 2018).

For these reasons, the persistent underrepresentation of certain groups of students in STEM doctoral programs (including students who identify as Black, African American, Hispanic or Latino, American Indians, Alaska Natives, Native Hawaiians, and Pacific Islanders) is troubling. Inequities in STEM research and innovation limit opportunities for the diversity of the nation's citizens to contribute to and benefit from an economically lucrative workforce. Inequities in STEM graduate education also reflects a failure on the part of STEM PhD programs to capitalize on an untapped pool of talent. Study results consistently demonstrate that students with diverse backgrounds, including racial and ethnic minority students, leave scientific studies or change scientific career aspirations because of STEM graduate school structures and cultures that weed out rather than nurture and encourage talent and diversity (National Research Council, 2009; President's Council of Advisors on Science and Technology, 2012; Sonnert, Fox, & Adkins, 2007; Wilson et al., 2018).

The statistics on science and engineering (S&E) degrees earned by students identifying as a racial or ethnic minority attest to persistent gaps in equity and are likely indicative of STEM academic structures and practices that disadvantage students who have traveled more nontraditional educational and experiential routes. Although the share of S&E bachelor's and doctorate degrees awarded to U.S. citizens or permanent residents identifying as Hispanic or Latino, Black or African American, and American Indian or Alaska Native has increased from 1996 through 2016, these groups continue to be underrepresented among S&E degree recipients relative to their representation in the overall population (National Science Foundation [NSF], National Center for Science and Engineering Statistics [NCSES], 2019). Students with these identities earned only 22% of all S&E bachelor's degrees and, at the graduate level, just a mere 9% of all S&E doctorate degrees (NSF, NCSES, 2019).

Diversifying Graduate Programs

The GRE. Research universities and the STEM graduate school departments within them are not blind to their shortfalls when it comes to diversifying their graduate programs. Many have established institutional and departmental commitments to broadening participation in STEM fields (Posselt et al., 2017). For some disciplines, particularly the life sciences, these efforts include placing less emphasis on applicants' GRE test scores in assessing students' talent and potential for success (Langin, 2019). In a survey examining the Ph.D. requirements for eight disciplines at 50 top-ranked U.S. institutions, *Science* found that close to half of the molecular biology programs surveyed would not require GRE scores starting in 2019-2020, and nearly one-third of neuroscience and ecology programs surveyed had either dropped or were planning to drop the GRE application requirement (Langin, 2019).

More broadly, there has also been a general acknowledgement across the higher education community that the GRE is an imperfect measure for predicting success in graduate school and should be used in combination with more holistic criteria to make graduate school admissions decisions (Langin, 2019). Nevertheless, many programs are hesitant to drop the GRE score requirement. According to the same *Science* survey, 90 percent of the chemistry, physics, geology, computer science, and psychology Ph.D. programs that were surveyed required general GRE scores in 2018, with just a few reporting that they were planning to drop this requirement in the future (Langin, 2019). Indeed, despite admissions policy changes in some fields and the more general nod to the need for more inclusive admissions criteria given the relatively weak correlations between GRE scores and indicators of graduate school success, there remain strong proponents of the GRE as a predictor and as a convenient metric for assessing and comparing student applicants (Langin, 2019; Posselt, 2016), as well as general cultures and faculty attitudes that do not effectively recognize the value of diverse and inclusive systems and practices (Leshner & Scherer, 2019).

In a report examining the apparent inertia among STEM departments to modernize graduate education despite clear research indicating a need to do so, Leshner and Scherer (2019), state the following:

> Central to making any pervasive change in STEM graduate education will be significant attitudinal, behavioral, and cultural changes throughout the system. The ways that faculty approach graduate education must be fundamentally reoriented to include a greater focus on the interests and needs of the students (p. 47).

Leshner and Scherer (2019) call attention to the need for systems-level change, with a lens to diversity and inclusion, going on to specifically note that "Faculty and administrators need to develop, implement, and continually assess strategies, starting with admissions policies, that not only increase diversity and inclusion of graduate students but also assure retention of such students throughout the process of achieving an advanced STEM degree" (p. 49) if graduate STEM education is going to stay "current with trends in the way science is conducted and with the nature of the student population and their career interests and opportunities" (p. 46).

With respect to admissions in particular, recent research examining graduate program admissions practices and structures point to well-entrenched White male-dominated cultures that continue to influence how student selection decisions are made and what factors carry the most weight among the faculty reviewing application packages (Posselt et al., 2017). Implicit biases, if not hostile and racist academic environments (Figueroa & Hurtado, 2013); and continued adherence to "'sink or swim'" mentalities (Blume-Kohout, 2017, p. 4) appear to trump voiced efforts or policies that would otherwise seem to tip the balance to diversity and inclusion. For example, attention to diversity often comes too late in the recruitment and admissions processes—after many students from historically underrepresented backgrounds have already been automatically screened out of consideration based on metrics that fail to holistically capture their full potential. Generic and familiar indicators such as selectivity of undergraduate institution, GPA, and the GRE remain largely remain the standard by which applicants are judged (Hurtado, Milem, & Clayton-Pedersen, 1998; Malesic, n.d.; Posselt, 2016; Posselt et al., 2017; Scherr, Plisch, Gray, Potvin, & Hodapp, 2017).

The GRE, in particular, has long been shown to be a poor indicator of a student's likelihood of graduate school success, particularly for students who hold historically gendered or minoritized identities (Clayton, 2016; Kent & McCarthy 2016; Miller & Stassun, 2014). The test's developer, ETS, has even issued its own warnings that the test is a weak predictor of graduate school progress, performance, and successful degree completion (Malesic, 2017). Beyond the traditional pool of STEM graduate school applicants who demonstrate "proven ability" on measures like GRE scores or successful performance in rigorous high school and undergraduate courses, there are diverse populations of students who bring an alternative set of skills, experiences, and potential to the table. These include, for example, individuals who are talented and capable and can succeed given proper guidance, but who either have not been properly developed or properly evaluated. For example, a student's undergraduate transcript might show a low grade point average (GPA) that, on closer inspection, reveals a slow start but a clear upward trajectory. Another might have an excellent GPA but is missing upper-level courses in the major because there were none available at the undergraduate institution. Still another might only have made a strong positive impression in person on a faculty recruiter during a poster presentation at a conference (Stassun et al., 2011, p. 377).

Notably, studies continue to show that, despite broad recognition of the flaws in using the GRE as a deciding factor in making admissions decisions and voiced commitments to holistic approaches, STEM graduate program admissions committee members, even if GRE scores are not required, still consider test results and weigh those heavily against other factors that are harder to clearly define and measure objectively in making admissions recommendations (Kent & McCarthy, 2016; Posselt, 2016). The continued reliance on the GRE and other traditional metrics as early or initial admissions screeners reflects a STEM graduate program culture that is, overall, risk-averse; wary of adopting new, more untested approaches; and guided by fears that using alternative criteria for evaluating students' potential for success in a PhD program could weaken departmental standards and the quality of the students admitted (Posselt, 2016; West-Faulcon, 2011). There are exceptions as more and more graduate programs explore the use of alternate measures; however, concerns about the reliability of noncognitive factors such as "grit" as a predictor for graduate student success (Crede, Tynan, & Harms, 2017; Jaschik, 2017), and uncertainty about the core set of practices or criteria that can serve as strong predictors of student success in graduate programs hinder widespread reform (Kent & McCarthy, 2016).

Faculty Composition and Bridge Programs. Another factor challenging more diverse and inclusive admissions practices is the relative scarcity of robust relationships between faculty at selective predominantly White institution (PWI) research universities and faculty at minority serving institutions (MSIs). Cross-institution faculty relationships play an important role in the recruitment and admissions of high-potential, talented undergraduate students into graduate programs as faculty who know and trust each other exchange information and recommendations for who may be a good fit for certain programs or positions. Without a professional network of colleagues at MSIs or deep familiarity with MSI STEM programs, research university faculty are frequently unaware of the learning and skills students at these types of institutions are developing and the experiences and perspectives they could bring to their labs. They are more inclined to recruit students from colleges and universities with which they are familiar and have strong professional networks to whom they can turn for recommendations (Aspray & Bernat, 2000).

The relative lack of diversity on STEM graduate program admissions committees also likely affects who gets considered and admitted. Admissions processes at selective universities are driven largely by committees of White male faculty and legacies of racial and ethnic inclusion and exclusion can often seep in, even when policies and practices have been established to try to mitigate that risk (Posselt et al., 2017). Admissions is inevitably a "human process" (Malesic, n.d., paras. 10-11) and implicit biases against historically underrepresented student candidates in STEM are likely to influence preferences and decisions. People tend to prefer candidates who they are comfortable with and feel a connection to—people who look like them, come from similar backgrounds, and fit the standard profile (Ken, 2008; Leddy, 2014; Nunez, 2014).

In the absence of achieving greater equity at scale in underrepresented minority student representation in STEM doctoral programs, two-year intensive bridge to the doctorate programs (bridge programs) have arisen to increase the number of students with diverse backgrounds applying to, persisting in, and successfully earning STEM PhDs. Their intent is to identify talent among undergraduate students who might not consider doctorate study or be fully prepared to succeed in a doctoral program without active encouragement, additional resources, or mentoring and academic supports to help them navigate and successfully "bridge" from an undergraduate STEM degree program to a graduate one. Another key feature of these bridge programs is the deliberate attention to relationship development between faculty at different institutions that they may not have otherwise considered as strong sources for student recruitment. Numerous bridge program models exist, including those supported by federal agencies such as NSF, the National Institutes for Health, and the American Physical Society (APS) to name a few. Some are implemented as alliances between two institutions or among multiple institutions or STEM departments, including between PWIs and MSIs that are in relatively close proximity to one another.

Although the specific features and structures of these different bridge program models vary, they typically operate on the periphery of STEM graduate departments with their own admissions process and committees. They often stand out as well because, due to their missions and their "bridging" function, they implement either a more holistic set of criteria to evaluate students' potential for success, or put greater weight on more subjective or noncognitive criteria in selecting students than what is used for regular graduate admissions, knowing that once admitted the students will be provided with close mentoring and supports to help ensure their potential and talents are cultivated and they don't "fall through the cracks."

Although campuses implementing different bridge program models have evidenced some success in increasing the number of students with historically minoritized and gendered identities graduating with STEM PhDs (see Clewell et al., 2005, Hodapp & Woodle, 2017; Stassun et al., 2014), their abilities as ancillary programs to create an equitably diverse community of STEM PhD holders at scale may be limited. At the same time, there may also be potential for bridge programs to serve as influencers of change by serving as models of more diverse and inclusive graduate program approaches and practices. Bridge programs are often designed to challenge the status quo by initiating new ways of assessing who can thrive and excel in STEM graduate programs and by introducing research faculty to undergraduate STEM programs and students with different backgrounds and profiles than they are used to seeing in their classrooms and labs. The presence of a bridge program on campus and the interactions between bridge program administrators and the faculty in STEM departments as they introduce and put forward bridge student candidates for doctoral programs may lead to a "seepage" of more diverse and inclusive approaches to identifying and cultivating student talent, particularly as faculty experience the benefits of having bridge students in their classrooms and labs.

Components of This Study

In this article, we present findings from one component of a three-year exploratory study of four two-year, intensive bridge programs. The study was designed to collect data on how the bridge programs were assessing intellectual capability and students' likelihood of success in STEM graduate study and whether the bridge programs served as influencers of change to the general graduate program admissions processes through practices and advocacy for considering alternative measures of student talent and potential.

The purpose of this exploration was to attend to identified gaps in knowledge about the range of admissions criteria and approaches graduate-level bridge programs are using to diversify the pool of students pursuing and completing PhDs in STEM and the extent to which they were disrupting, or potentially perpetuating, gendered and minoritized narratives about who can succeed at the doctoral level. Although some research has been conducted on intervention programs and holistic graduate admissions processes in STEM (Aspray & Bernat, 2000; Kent & McCarthy, 2016; Posselt et al., 2017), researchers conducting these studies have indicated a need for additional exploration to determine whether the holistic admissions practices they observed "were unique or also present in other STEM graduate programs that have been successful graduating women and students of color" (Posselt et al., 2017, pp. 31–32). In addition, researchers have called for more studies that examine how equity efforts at the department level interact with institutional and disciplinary contexts (Posselt et al., 2017).

Method

This examination of bridge program admissions is part of a larger exploratory research study aimed at understanding the cultural factors that affected the implementation of four two-year STEM bridge programs and the experiences of bridge students. In this article, we present findings specific to the types students bridge programs targeted, their recruitment and admissions practices, and the factors that facilitated and challenged their programmatic efforts to increase the number of underrepresented students earning STEM PhDs. The central component of our work were case studies of the four bridge programs. We selected a case study approach because of our interest in determining what was common and what was particular across the four bridge program sites (Stake, 1995) and because case studies allow for a multifaceted exploration of "bounded systems" (Creswell, 2013; Merriam, 2009, p. 40). Case studies also lend themselves well to illuminating why decisions are made, how decisions and processes are implemented, and the factors that influence actions and choices (Feagin, 1991; Merriam, 1988; Yin, 2003).

We took a realist approach to our case study design. We relied on data from interviews and focus groups as evidence rather than observational data. Specifically, we used our conversations with key stakeholders to explore unobservable phenomena, including experiences, beliefs, intentions, prior behavior, and perceived effects. We drew on participants' reported experiences and knowledge to explore the historical background, setting, and other components of the contexts and cultures in which the bridge programs in our study are situated. The case studies entailed five rounds of multiday site visits to each of the programs conducted over a three-year period.

Case Study Sample. The four bridge programs were purposefully selected to ensure variance in bridge program model, whether implemented as an alliance or by a single institution, type of institution at which the program was housed (at an MSI or PWI), student cohort size, years of program implementation, and STEM disciplinary focus. Two programs were located at a PWI, one program was located at an MSI, and one program was formed as a partnership between an MSI and a predominantly White research institution. At the start of the study, program maturity ranged from approximately two to 10 years, and each site used various funding streams to support program operations and participating students. Three of the four programs served students across a range of STEM disciplines on campus, including astronomy, biology, chemistry engineering, mathematics, physics, and computer science. The fourth program focused only on one science discipline (see Table 1).

Table 1. Bridge Program Sites

Site*	Single Institution or Alliance	Program Location on Campus	Institutional Type	Participating STEM** Departments	Average Student Cohort Size	Program Maturity***
MSI STEM Bridge Program	Single Institution	Program Leader's Department	MSI	All STEM departments	12	Between 5 and 10 years
PWI/MSI Bridge Program	Alliance	PWI Program Leader's Department	PWI/MSI	3 STEM departments	10–11	10 or more years
PWI Science Bridge Program	Single Institution	Program Leader's Department	PWI	1 STEM department	3–4	Less than 5 years
PWI University Bridge Program	Single Institution	University Level Office	PWI	All STEM departments	12	10 or more years

*Pseudonyms for the bridge programs are used to maintain the anonymity of the four bridge program sites and to protect the confidentiality of respondents.
**Defined here, STEM is exclusive of the social, economic, and behavioral sciences.
***Ranges are provided to protect the anonymity of the sites.

In addition to the features of the bridge programs presented in Table 1, the four programs in our study largely fell into three different types of bridging pathways or "tracks" into STEM doctorate programs:

1. PhD Track 1: The MSI STEM Bridge Program is purely a Master's program designed to help prepare students for doctoral study, but with no direct link or relationship to a doctoral program to which students would have a ready "bridge." However, there is attention to recruiting historically underrepresented individuals into the masters' STEM programs to support the goals of the program.
2. PhD Track 2: The PWI/MSI Bridge Program and PSI Science Bridge Program provide more direct "bridges" to doctoral programs, using an alternate admissions process to admit students who are not likely to be selected for PhD programs using traditional criteria (i.e. there is an intentional focus on expanding the pool of diverse students prepared for and applying to doctoral programs). Although students are not guaranteed admissions into the doctoral program, there are purposeful activities and efforts to introduce bridge students to (and have them work with) faculty in the doctoral program the program partners with or links to and for bridge students to take doctoral-level coursework.

3. PhD Track 3: The PWI University Bridge Program is largely a funding mechanism for students who have already been granted entry into the doctoral program at the university. Thus, the "bridge" is more about supporting historically minoritized students already in the system, rather than expanding the doctoral pool of applicants and an alternate pathway into and through STEM PhD programs.

As will be discussed, these different "tracks" are used as a lens for understanding the influence of the bridge programs on traditional policies and faculty practices and mindsets related to student admissions. More detailed descriptions of each of the bridge program sites in our study, informed by interviews with program administrators, faculty, and administrators as well as a review of bridge program documents and websites, are provided below.

MSI STEM Bridge Program (PhD Track 1). The MSI STEM Bridge Program, which is supported by NSF's Louis Stokes Alliances for Minority Participation Bridge to the Doctorate (LSAMP BD) grant, is located at an MSI and, at the start of this study, had enrolled nearly 10 cohorts of students. Being an LSAMP BD site, the program specifically targets students who earned their undergraduate degree from an LSAMP-funded institution. In this program, bridge students earn a master's degree in STEM, with the expectation that they will then apply to a doctoral program at another university.

According to campus officials and program administrators, diversity is built into their institution's strategic plans. For example, MSI STEM Bridge Program administrators reported that the institution had a long history of implementing efforts to promote the postsecondary advancement and success of historically underrepresented students and to involve diverse students in research. They described an institutional commitment to serving a more diverse population of students and a campus culture that is open to diversity and inclusion.

The MSI STEM Bridge Program is operated out of one STEM department, but the program is inclusive of all STEM programs offered on the campus, exclusive of the social and psychological sciences. The program aims to enroll 12 master's students in each cohort across a range of disciplines and, throughout the course of the two years, provide them with the encouragement and academic and social supports necessary to ensure they are effectively prepared for doctoral study.

PWI/MSI Bridge Program (PhD Track 2). The PWI/MSI Bridge Program was first implemented several years before our study began and was formed as a partnership between an MSI and a predominantly White research university. While the MSI and PWI have a history of partnership and collaboration, program administrators, faculty, and campus officials at the PWI acknowledged that institutional racism remains a challenge at the PWI campus, despite voiced commitments by leadership and new diversity-focused positions being established to cultivate a more diverse and inclusive campus culture.

Interested students apply to the PWI/MSI Bride Program as prospective master's students. Approximately 9-11 students are accepted into the program as master's students each year. Depending on their academic field of study and track, students have varying degrees of course-taking and engagement with faculty and peers on the MSI and PWI campuses; courses are selected in consultation with bridge program administrators and students' advisors with attention to requirements for master's degree completion and a students' intended areas of PhD study. Upon successfully completing their master's degree, PWI/MSI Bridge Program students are not guaranteed admissions to a doctoral program at the PWI. Bridge students must submit an application to the PWI doctoral program they are pursuing like any other interested student, though they do have the potential advantage of being familiar to any PWI faculty who are familiar with the program and/or with whom they have interacted or completed course or research for. Although program administrators indicated that they would like to see their bridge students matriculate into a STEM doctoral program at the PWI, students are encouraged to explore and apply to programs at other institutions to increase their chances of acceptance.

PWI Science Bridge Program (PhD Track 2). The PWI Science Bridge Program is located at a large, predominantly White research university and was the most recently established program in our sample—about 2 years prior to start of data collection. It operates on a relatively small scale, serving approximately 3 to 4 students in each cohort, in one STEM department.

According to program administrators, the university's president has placed an increased focus and voiced commitment to drawing a more diverse applicant pool at the undergraduate and graduate levels and cultivating a more inclusive campus environment. The decision to adopt the bridge program thus aligned well with larger institutional initiatives to expand access and reach, with a lens to identifying and addressing policies, practices, and attitudes or cultures that challenge diversity and inclusion. The introduction and implementation of the bridge program in this STEM department has been supported by the relative influence and authority the bridge program administrator is afforded by being in a senior leadership position in STEM graduate studies.

At this program, bridge students are accepted through a bridge-specific admissions process separate from standard PhD program admissions. For students admitted into the program through the bridge "track," the expectation is that, after the two "bridge" years, their performance will be reviewed and assessed by a faculty committee. Bridge students' formal admissions into the doctoral program is contingent on evidence that they are capable of meeting the expectations and level of rigor of the PhD program.

PWI University Bridge Program (PhD Track 3). The PWI University Bridge Program is also located at a large, predominantly White research university that, according to campus administrators, has become a much more "culturally sensitive" campus over time. Administrators reported that the university established a central office dedicated to implementing and coordinating initiatives that focus on diversity and inclusion. According to PWI University Bridge Program administrators and campus officials, the programs operated out of this central office have played a key role in increasing the number of students identifying as a racial or ethnic minority on campus and that the presence of diverse students on campus and their academic success has helped deconstruct cultural assumptions about the ability of students with nontraditional backgrounds to succeed in STEM-related fields.

Like the MSI STEM Bridge Program, this bridge program is also supported by an NSF LSAMP BD grant. As such, the program primarily targets students who earned their undergraduate degrees at an LSAMP-funded institution. At the time of this study, the program had served nearly 10 cohorts of students. This bridge program is different from the other three in the study sample in that students are nominated and selected for the bridge program only after first being accepted into a STEM PhD program at the university through the regular graduate admissions process. Students do not separately apply to the bridge program, and many may not even be aware of the bridge program's existence until after they have officially enrolled and then been put forward by faculty in their department for bridge program consideration. Specifically, STEM departments are encouraged by bridge program administrators to nominate students for consideration from among their pool of new students based on their understanding of the types of students the program aims to serve and with knowledge of the types of additional supports and mentoring bridge students will receive. Student nominations are submitted to the bridge program office for review and selected students are provided with a two-year fellowship and academic and mentoring supports to help ensure their persistence and likelihood of earning a PhD.

Participants and Data Sources. Data collection began in spring 2016 and concluded in spring 2018. A team of site visitors conducted bi-annual multi-day site visits at each institution for three academic school years, totaling five visits to each program site. The visits to each of these four programs entailed semi-structured interviews and focus groups with program administrators; faculty involved in supporting bridge activities and/or teaching or advising bridge students; university administrators with knowledge or oversight of the bridge program, or who were running complementary programs on campus; and bridge students themselves. The findings presented here primarily reflect data collected from bridge program administrators, as well as STEM faculty and university officials. These principals could speak to where and how the bridge programs were positioned in relation to the STEM departments into which students tracked (and the broader mission and culture of the institution), how bridge programs navigated and coordinated the recruitment and admissions of nontraditional students into STEM graduate programs, and what were bridge programs' relative sphere of influence with respect to upending or potentially perpetuating minoritized and racialized practices and mindsets about students with diverse backgrounds in STEM.

In our recruitment of study participants, we asked program administrators to identify the appropriate faculty and campus officials for interviews and focus groups because the research team did not have an existing connection to any of the bridge program sites or universities in which they were housed. The bridge program administrators reached out to these individuals to inform them of the study and to determine their willingness to speak with the research team.

Across the four programs and the five rounds of site visits, a total of 53 interviews were conducted with program administrators, 63 with faculty, and 8 with university officials. Some key respondents were interviewed more than once. For example, program administrators and faculty who played central roles in the bridge program were interviewed during every site visit to capture additional information and document changes in bridge program or campus structures, governance, practices, and stakeholder experiences over the three-year period.

The first round of interviews with the program administrators focused on the history of the programs' development, the key features of the bridge program, and the programs' approaches to recruiting, admitting, and supporting students. In Years 2 and 3 of the study, the interviews with program administrators included focused questions on the programs' missions and their perceptions of how their missions aligned or conflicted with the missions and the socialization processes of their institutions and STEM departments on campus. Focused questions also included how the program administrators communicated the value of using nontraditional approaches to assess and cultivate student talent in STEM and the extent to which they perceived that the bridge program's efforts were motivating STEM departments and faculty to consider adopting more holistic admissions practices.

Interviews with faculty were used to better understand their involvement in bridge programs' supports and activities, how committed their departments were to the mission and goals of the bridge programs, and whether their departments developed new approaches to graduate student recruitment and admissions as a result of observing the efforts and successes of the bridge programs. The interviews with university administrators were primarily designed to explore how the bridge programs were situated in the larger organizational structure and culture of the university and the alignment of the mission and goals of the bridge programs with the institution's mission and goals overall. All interviews and focus groups were audio-recorded and transcribed.

Data Analysis. We used a purposeful and integrated analytic approach. For this component of the study, we triangulated data from the set of bridge program administrator, faculty, and university official interviews to enhance our understanding of bridge programs' approaches to recruitment and admissions and to explore differences in practices across the four programs in the study, including what institutional and departmental cultural factors might explain these differences. Specifically, we undertook iterative thematic coding of each major topic and interview question to surface recurring patterns and common themes (Maxwell, 2013; Merriam,

1998) across all these respondents; to assess the prevalence of practices across sites; and to identify examples of recruitment and admissions practices and models that may be of interest to institutional leaders, bridge program administrators, STEM departments, faculty, and others involved in diversity and inclusion efforts on their campuses.

The analytic approach was designed to support within and cross-case analyses. Data analysis techniques began with "memoing" as an iterative process for moving from our raw data to a preliminary, conceptual understanding of the research phenomena (Birks, Chapman, & Francis, 2008). Following the first round of site visits, we developed program site-specific memos or summaries to capture important contextual information and immediate impressions and reflections on what we heard and observed in the field. The research team reviewed and updated our initial site summary memos following the third and fourth rounds of site visits to capture new or additional information and to revisit and refine our understanding of previously identified themes and patterns. The memos were also updated to track and communicate continuity of conception and contemplation among the research team and lay the foundation for our formal coding procedures (Birks et al., 2008).

At the close of data collection, we developed a comprehensive codebook to support robust within and cross-case analyses of the transcribed interview data using NVivo 11 Plus, a qualitative data analysis software. Codebook development entailed two major steps: (1) we first established a preliminary set of codes based on our key constructs of interest and the themes that had emerged from our memoing process, and (2) we used this preliminary set of codes to code a sample of the interview transcripts, using both inductive and deductive coding methods to generate a final set of codes. We structured the final set of codes so that analysts could apply more than one code to the same interview passage, as applicable.

Throughout the analytic process, the research team engaged in regular communication to ensure consistent application of the coding structure, strategies, and rules for coding the data. Specifically, to ensure that our data were coded consistently and reliably, the coding stage involved a multistep process that included practice coding and an initial assessment of interrater agreement, frequent debriefing, and review of coded data by the research team. The analysts for this study each independently coded several pages of an interview transcript. The team then discussed and reconciled the few discrepancies in their application of codes and finalized the codes and code definitions to guide the subsequent coding process. Major emergent patterns and themes also were identified and discussed to support shared understanding and interpretation of the coded data.

Trustworthiness of the Data. Efforts to assess and ensure the validity, reliability, and credibility of the data were made throughout the data collection and analytic process. To establish construct validity (Rowley, 2002), we developed a mapping of our interview protocol questions to our key constructs of interest. We assured reliability through the multiple rounds of site visits to each of the four bridge program sites, which included interviews with the same core set of program administrators and key faculty each time, and by maintaining a robust case study database (Rowley, 2002), consisting of interview transcripts, audio recordings, memos, and an NVivo coding file. We addressed credibility through member checks (Creswell, 2009) as a check against possible researcher bias and to confirm the accuracy of our interpretations of the data. As part of our final round of site visits to the four program sites, we shared our preliminary findings with the program administrators to confirm the accuracy of our analysis and the emerging themes and patterns. We also maintained credibility by using an audit trail that consisted of tracing key themes and findings to direct quotes from the interview transcriptions.

Limitations. The generalizability of this study's findings is limited by the small size of the sample. The four bridge programs in the study sample represent only a small number of the many bridge programs sites that are presently being operated by alliances and institutions across the nation. The results also are based largely on the reports and perceptions of the study participants, all of whom were involved to some degree in the bridge programs and identified as program supporters; thus, the views of the respondents may reflect selection bias. The data obtained through participant interviews also are limited to the recall, perceptions, and comfort of the individual respondents in sharing information at the time of the interview and reflect the experiences, observations, and actions that respondents found relevant enough to mention and chose to share with the research team. Despite these limitations, we collected diverse and rich data on the recruitment and admissions practices of the four STEM bridge programs in our study and academic departments' receptiveness to integrating nontraditional approaches to selecting students into their STEM graduate programs.

Results

Each of the four programs had distinctive features and were differently positioned on their respective campuses to support a track for historically underrepresented students in STEM to successfully navigate and complete a PhD. While they shared some commonalities, the structure of the bridges or tracks into STEM doctorate programs they provided appeared to influence the extent to which they were able, outside of the parameters of their programs, to more broadly impact departmental policies and practices that affect diversity and inclusion. The discussion that follows describes the similarities and differences across the programs with respect to the types of students the programs targeted, the admissions and student recruitment processes they employed, how they operated and coordinated their efforts with STEM departments, and the extent to which their efforts appeared to be influencing mindsets and practices on a larger scale.

Program Mission and Students Served. To gain a better understanding of who the bridge programs were trying to reach and the philosophies in which their admissions and recruitment strategies were grounded, we first asked program administrators, faculty, and administrators to describe the types of students they targeted. We were interested not only in what made a student eligible for the bridge program but also in the key characteristics of the students the programs aimed to serve in their efforts to close equity gaps in STEM PhD programs. Consistent with their shared goal of increasing the number of students with diverse backgrounds earning doctoral degrees in STEM and the requirements of the funding agency, the four bridge programs targeted students identifying as African American, Hispanic or Latino, and/or Native American/Alaska Native students who had earned undergraduate degrees in a STEM field. Many of the students they targeted also identified as other historically underrepresented groups in STEM including as women, students with disabilities, low-income, and/or first-generation.

According to program administrators and faculty, the program sought out students who demonstrated talent in the field and intellectual capability, even if not by the traditional metrics (e.g. GRE) used by STEM graduate programs. For the MSI STEM Bridge Program, PWI/MSI Bridge Program, the intent was not to simply recruit and support underrepresented groups of students who were already on a strong pathway to a STEM doctorate degree. Rather, their goal was to expand the pool of diverse students in doctoral education by providing financial and academic support for students that need the additional preparation to be able to apply for STEM PhD programs. These are students who may not have had the educational experiences and opportunities to be fully prepared for a PhD program because of limited access to research opportunities, rigorous STEM courses, GRE preparation courses, and/or had attended a smaller teaching-focused undergraduate institution such as a Historically Black College and University (HBCU). As the program leader from one of these sites reported,

> *We don't go for those students who have the 4.-something GPA, and were going to get into a PhD program straight out of undergraduate.... We go for ones who are promising, but maybe have a GPA that's lower because they had six years through community college before they got to a four-year institution because it took them a while to figure out what they wanted.*

Program administrators from the MSI STEM Bridge Program and the PWI University Bridge Program further noted that they also sought out students with relatively strong academic records but whose talents had been overlooked or misguided in ways that steered them out of doctoral pathways, or who, despite having solid academic records, they believed would be at risk of struggling or dropping out without proactive and high-touch mentoring. As the program leader from one of these sites noted, the students they targeted generally "need an additional year or two of polishing before they are ready to—not only be admitted, because a lot of these kids I think might be admissible, but I don't know if they would succeed in PhD programs."

The PWI University Bridge Program had less flexibility in who they targeted and served than the other three programs. As noted earlier, unlike the other three programs, where students applied directly to the bridge program and were accepted into STEM graduate school via the bridge program, the PWI University Bridge Program targeted students who had already been accepted into a STEM PhD program at the university and **met the criteria for admission to both the graduate school and their respective graduate program at the university.** Some departments that were knowledgeable about the bridge program would nominate students for the program. In other instances, the bridge program director would reach out to departments directly to let them know the bridge program is available and to encourage them to recommend students who "fit" the program's mission. The individual departments then sent their student nominations to the bridge program administrators for consideration. Thus, these departments were not being asked to change any of what they were already doing in terms of their practices and the criteria they used for reviewing and admitting students. Rather, to achieve their goal of increasing the number of more diverse students who persisted and successfully completely STEM PhDs, the PWI University Bridge Program administrators were largely dependent on trying to support students identifying as from a historically underrepresented group already in the pipeline.

By targeting these types of students, the four bridge programs in our study were largely effective in increasing the number of students with diverse backgrounds matriculating into and successfully earning STEM PhDs. For two programs—the MSI STEM Bridge Program, the PWI/MSI Bridge Program, and the PWI Science Bridge program, they were casting a wider net to seek out students who could benefit from an alternate pathway to a linked PhD program (the "Track "2 programs). For the MSI Bridge Program ("Track 1" program), the institution was already serving admitting and serving large numbers of historically minoritized students through their STEM master's programs by virtue of being and MSI and serving a diverse student population overall, but, with the bridge, were also providing master's bridge students, if not with a ready connection to a doctoral program, targeted resources, professional development, and academic supports to facilitate their successful pursuit of a PhD program. For the PWI University Bridge Program ("Track 3" program, they were targeting newly admitted racial and ethnic minority doctoral students with the intent of providing the financial resources, proactive mentoring and encouragement, and academic supports research has demonstrated can promote the retention of historically underrepresented students in STEM graduate programs (Okahana et al., 2018; Sowell, Allum, & Okahana, 2015). This Track 3 program differs the most from the others in that their attention to diversity comes *after* the admissions process and may, as will be discussed, have implications for perpetuating rather than pushing against the status quo.

Student Selection Considerations and Admissions Decisions. Despite the differences in how programs operationalized their "tracks" to the PhD, there were some common processes and measures for evaluating bridge student candidates across the four programs. Even for the two programs that specifically targeted students whose backgrounds and academic profiles differ from the archetypal STEM graduate student candidate (the Track 2 programs: the PWI/MSI Bridge Program and the PWI Science Bridge Program), the bridge programs' admissions processes and standards were rigorous and highly selective, if not firmly based on traditional metrics. The student cohorts across the programs were small and, while GRE and GPA carried less weight or was not considered at all in the traditional sense, student applicants had to demonstrate high levels of capacity, leadership, and intellectual and research acumen to be accepted. For the PWI/MSI Bridge Program, evidence of a strong desire for a PhD was also an important criterion for admission.

In brief, a student's noncognitive assets were highly valued, with bridge program administrators and faculty involved in student selection decisions applying a growth mindset-based approach rather than the fixed mindset approach typically used in STEM graduate admissions. They looked more holistically at students' backgrounds, experiences, and educational trajectories to consider their potential for success. In describing the factors that are considered when making student selection decisions, the leader of one of these programs explained,

> *We pay particular attention to these factors called noncognitive variables. So a lot of these students haven't taken the GRE test, so we don't obviously look at that score…. For students that do, maybe it provides additional information, [but] strong letters from faculty showing research promise are one of our more important criteria.*

More specifically, program administrators from across the four sites described an intent to select students with grit, a passion for their field of study, a strong desire for a PhD, and a willingness to work hard. When traditional measures of performance were considered, they were often assessed in nontraditional ways. For example, course-taking history and GPA were used as strong indicators of not only student performance but also demonstration of students' persistence, willingness to challenge themselves, and cognitive growth and development. As an administrator involved in bridge program admissions at one of the programs stated, the admissions committee does not only look at overall GPA:

> *They're going to look at GPA within the major, and also GPA within the last 20 months or something like that. A lot of [our] students were at community college for many years, before getting into the [university], so they have very, very long academic records. And some of these students struggled in the past…. Sometimes they go to community college, do really badly, go back into the workforce and then come back…an overall GPA is not a good read [of] those students.*

Similarly, a faculty member from another program stated, "[We] generally favor someone who might have a lower GPA, but you can see the trajectory of their grades was getting much better, especially as they're taking courses that they were interested in." For one faculty member at the PWI University Bridge Program, a high GPA even served as a red flag, given the mindset needed to conduct scientific research. For this faculty member, "Sometimes I worry the most about students that come in with a 4.0 GPA because they've never failed. They don't know what failure is, and in research, unless you're incredibly lucky, you're going to face some real failures." Likewise, another faculty member described seeking out "students who don't give up just when experiments don't go well…we want them to have sort of a thirst that they want to know what the answer was. They want to figure out for themselves why it didn't work."

These findings are consistent with a study of the University of Michigan's APS Bridge Program, which found that, similar to the bridge programs in our study, there were intentional efforts to rethink the characteristics of the "best" candidates and to reinvent and put a new lens on admissions approaches and student selection criteria that valued noncognitive factors such as risk taking and a willingness to challenge oneself (Posselt, et al., 2017).

The administrators of the MSI STEM Bridge Program, the PWI/MSI STEM Bridge Program, and the PWI Science Bridge Program also reported considering applicants with an eye toward whether the student candidate had, what one leader described as, a "clear path" through the bridge program into a doctoral program. For example, they indicated that some strong student candidates may not be recommended for admissions if the STEM program would not be able to support their specific research interests because of capacity constraints or misalignment between the student's interests and the research faculty were conducting. These three bridge programs wanted to ensure that students would be able to connect with a research advisor and lab, and, for that reason, department faculty played a key if not deciding role in which students would be selected. For the MSI STEM Bridge Program, for example, students' applications were required to provide evidence of having already been in touch with potential research mentors in the graduate program who would accept them into their research lab. Before accepting students into this bridge program, the program administrators reached out to the faculty identified in a student's application to make sure they had communicated with the student, were aware of the bridge program expectations and requirements for research mentors, and were committed to supporting the bridge student during the course of the two years.

Across three of the four programs (all but the Track 3 PWI University Bridge Program), the bridge admissions process was purposefully undertaken by groups of individuals or admissions committees who brought diverse perspectives to evaluating student candidates. For example, at the PWI/MSI STEM Bridge Program, admissions decisions were made by three bridge program admissions committees, one for each of the three major STEM departments into which bridge students were accepted at the master's level. Each committee comprised one faculty member in the department at the MSI and one faculty member at the PWI. For the PWI Science Bridge Program, the bridge program admissions committee included program administrators, faculty, and one student.

While valuing these diverse perspectives, the programs also wanted to establish consistency in how applicants were evaluated to help ensure that they were staying true to their missions and admitting the types of students they targeted. Although program administrators and bridge program admissions committee members were all typically looking for students who demonstrated intellectual capability and the persistence to overcome challenges and setbacks, what constitutes intellectual talent and grit is subjective. To help mitigate potential biases and standardize the assessment of applicants, the PWI/MSI Bridge Program and the PWI Science Bridge Program had established a structured protocol to guide admissions interviews with students and had developed a scoring rubric to inform admissions decisions. The committee members interviewed student applicants using the bridge program's structured interview protocol, and then each committee member individually scored and ranked students, including on indicators that spoke to a student's "grit" such as ability to overcome difficult circumstances and long-term determination. Committee members would then holistically review and discuss their scores and the applicants as a group to make final admissions decisions.

While the intent of the bridge programs, by using these approaches, was to bring attention to diverse students who are often overlooked in STEM graduate recruitment and admissions, the assignation and potential stigma associated with being a "bridge student" who needs extra support or an alternate entry into graduate study must be recognized. The implicit messages sent to students and faculty may hold risk for perpetuating rather than disrupting traditional narratives that hinder change. This may particularly be the case in the context of the PWI University Bridge Program, categorized as "Track 3," that first admits students and then nominates them for a "special" program. While the bridge program has introduced a more intentional focus on diversity in STEM through the program administrators' communications and interactions with STEM departments about the opportunities the program provides to historically underrepresented groups of students, these messages can undermine students' self-efficacy and sense of belonging. An unintended consequence may be the reinforcement of deficit-based narratives about minoritized students' abilities in STEM.

Broader Influence of Bridge Programs. The institutions in which the four bridge programs were located were described by campus administrators, bridge program administrators, and faculty as attuned to the changing demographic environment and the national attention and priorities on diversifying STEM fields. The universities' missions and strategic plans reflected this changing environment and an institutional commitment to becoming more open and inclusive campuses, although the extent to which these institutional commitments played out in practice varied across STEM departments. Despite the bridge programs and their institutions appearing to have aligned missions when it comes to increasing diversity on campus, the bridge programs experienced some challenges and barriers in their efforts to recruit and admit students using nontraditional and alternative criteria, with perhaps the exception of the MSI STEM Bridge Program. Some STEM departments and faculty were described as wary of having to adapt to a changing environment and adopt new more inclusive and holistic approaches. In that regard, the bridge programs' efforts to introduce new approaches to evaluating who can excel in STEM graduate education were limited by the cultures and readiness of STEM departments on their campuses to abandon old and trusted practices.

Overall, the bridge programs were limited in their influence with respect to changing doctoral admissions practices and policies, with the exception of the PWI Science Bridge Program where the program leader was also the head of the STEM department and held a stronger position of authority within the STEM department. At best, the bridge programs were described as successful programs that were serving as strong examples on their respective campuses for how programs targeting historically underrepresented groups of students could work to support growing institutional commitments to diversity-focused goals and pathways into the PhD. At the PWI/MSI Bridge Program, a campus administrator described growing acceptance for programs that aim to increase diversity, but not any sort of scaled change:

> *The [PWI/MSI Bridge Program] came along, really, at a time when [the university], as an institution, was starting to make an extraordinarily concerted effort to increase our diversity…. We'd always thought it was a valuable component of who we were and what we did. But I would say that only in the last five years or so has the institution really taken this on as one of the items that's at the core of our mission. Specifically, in graduate education…I am definitely seeing much more not only acceptance of the [bridge] program but also actively embracing of the program.*

The two Track 2 programs (the PWI/MSI Bridge Program and the PWI Science Bridge Program intentionally aimed to dispel assumptions about the abilities and potential of racial and ethnic minorities in PhD programs by bringing more diverse students onto the campus and increasing faculty interactions and experiences with them. However, to do so, they also largely had to emphasize with faculty the types of additional supports and services the students would receive to make sure they can achieve at the same level as their majority peers. There appeared to be an inherent tension in the messages they sent to students, which focused on developing their confidence in their academic abilities and sense of belonging and those they used with faculty, which focused more on assurances the students they accepted *could* be successful with the support of the bridge.

Program administrators were not unaware of this tension and talked about the need to work within slow-to-change departmental and institutional contexts to achieve their primary goal—to increase the number of historically minoritized students enrolling in and completing STEM PhDs. In working within the bounds of the present "readiness" of the STEM departments to consider and accept nontraditional students, they also took active steps to try to develop and embed a more diverse and inclusive community that could advance efforts at larger scale change.

For example, according to one of the PWI/MSI program administrators, they envisioned the bridge program as one way to "chip away at the wall of traditional [university] PhD admissions" by bringing in capable students and proving to STEM faculty how successful nontraditional student applicants could be. They tried to achieve this by using a "bottom up" approach to gaining faculty buy-in, outreaching first to junior faculty who they perceived as more receptive to adopting new ways of thinking. STEM faculty's openness to accepting bridge students, however, was typically described by the faculty themselves as not just due to their support of diversity, but heavily influenced by the funding attached to that student. The faculty often highlighting the benefit of bringing students into their labs who they did not have to find financial support for on their own. That being said, faculty respondents did emphasize that, beyond the financial value, their experiences with bridge students were positive and they were impressed with the quality of their research, motivation and work ethic, and performance in their labs. Thus, for faculty who had been more intimately involved in the program, they described some dissolution of preconceived notions about who can be successful in STEM. Program administrators and faculty from these programs remarked, however, that this wasn't the case for all their colleagues who continued to hold stereotypes or perceive bridge programs as "back doors" into the doctorate.

Nevertheless, some shift in mindsets were observed, even with senior faculty at this institution. Program administrators indicated that they had observed support building over time. One stated, "The more senior professors later on got engaged…[but] they [had] to see it first...as the program grew and became so successful, and the word got spread out, the more senior professors also embraced it." Another program leader confirmed this observation, noting,

> *That's usually how [faculty] get involved…they have a student that comes to their lab…. And then, they're like, hey what's this? This is a good student. Like, how do I get more students like this? And then, they sort of get into the fold of it. And then, they become a place where we routinely send students.*

The administrators from this program went on to suggest that they were seeing less and less pushback from faculty to put less weight on GRE scores in considering student applicants overall and that a recent workshop they had given on holistic admissions practices was well attended by faculty from many of the different STEM departments on campus. The same sort of sentiments and observations were noted by respondents from the PWI University Bridge Program and PWI Science Bridge Program. A campus administrator at the PWI University Bridge Program noted, "I do see that the culture towards diversity in this campus has gradually changed…when you bring these diverse groups of students in, it does change perceptions." The respondents at this university further noted that the visibility of the bridge program and the success of underrepresented students in STEM had increased and academic departments campus wide, not only the STEM departments were taking note. One respondent described how "psychology is one department that has been working with us a lot. They're not STEM, but they saw what was happening in STEM in diversity…and they've come to us saying, can you help us with diversity recruiting?"

The PWI Science Bridge Program leader described shifts in the department's overall approach to reviewing PhD student applicants, stating, "Our Graduate Studies Committee, at least this year, I would say, is very much looking for other criteria, especially these high test scores…. So, they now are very much on board with looking at other things besides that in making decisions." Program administrators and faculty attributed this shift in mindset to the bridge program and the program's efforts to introduce faculty in the department to new ways of thinking about students and because of the successes of the bridge students that faculty had observed. They also, however, attributed this to the department's overall "readiness" to consider new approaches because of the university's greater focus on diversity in its mission and an awareness of the changing demographic environment. As one faculty member noted, "It's definitely pushed us, I think, practices that we've developed for bridge program admissions are in people's minds now when they go into the regular admissions process. But the faculty, they were ready."

Our findings are consistent with a previous case study of the University of Michigan's APS program. This study found that "as cohorts of students progressed through the program, faculty and other leaders observed a record of success among students whose profiles differed markedly from the conventional achievers privileged in graduate admissions. This recognition helped broaden faculty members' conception of the ideal applicant's profile" (Posselt et al., 2017, p. 15).

At the same time, these indications of changing faculty beliefs or perceptions of diverse students in their courses and labs, actual recruitment and admission practices did not necessarily follow. STEM faculty and campus administrators described the bridge programs as the primary mechanism for proactively recruiting and bringing diverse students into STEM graduate programs. Faculty in the various departments indicated that they and/or their colleagues did not expend efforts to actively outreach and recruit underrepresented groups of students, beyond sending a few faculty members to conferences targeting historically underrepresented populations of students in STEM. It appeared that, while voicing support for bringing more diverse students into their graduate STEM programs, many faculty members and their departments did not see diversity as something they were directly responsible for or felt any urgency about. As a faculty member from one program noted,

> *Honestly, I don't know how much we do recruitment because students tend to sort of come to us for the most part and…we have our website up and people apply to our program who are interested…. I don't think we ever actively try to recruit underrepresented students in particular.*

The study's findings indicate that when it came to student outreach and recruitment, although there was some collaboration and coordination with departments for bringing bridge students into the various disciplines, the actual recruitment of diverse students at three of the sites largely fell on the shoulders of the bridge programs. Most of the STEM departments were described by bridge program administrators and departmental faculty as only passively involved in active and intentional recruitment efforts look outside of the traditional pools of student candidates and broaden participation in STEM.

Conclusion and Discussion

This study was motivated by a desire to deepen understanding of how bridge programs are re-envisioning who belongs in STEM PhD programs and their potential role as influencers of change in the STEM departments they touch and university-wide. Through exploratory case studies of four STEM bridge programs, we aimed to shed more light on who comprises the "untapped pool of talent" that these four STEM bridge programs were designed to serve and the nontraditional metrics they were using as promising predictors of PhD success.

Our study results demonstrate that the bridge programs approached student admissions with rigor and selectivity but took a different lens to the indicators that could best predict success. A common thread across the four programs was their attention to students who demonstrated self-determination, persistence, and who took intellectual risks, as demonstrated less by GRE test scores and overall GPA, but of academic growth over time, of overcoming hardships in and out of school, and of taking courses that challenged their thinking and skills. Student applicants were pressed to demonstrate evidence of these traits through their application materials and, for three of the four programs, through in-depth structured interviews with faculty.

Looking forward, STEM bridge programs could consider developing a data collection and tracking protocol that would allow for the testing of the relationship between their admissions practices, selection criteria, and student outcomes, such as performance in STEM master's program coursework, matriculation into a STEM doctorate program, STEM doctorate completion, and job placement. These data could help program administrators identify stronger predictors of success and build an evidence base for admissions reform, as current tools and metrics are not sufficient.

The bridge programs actively engaged STEM departments and faculty in the admissions process. Doing so was critical to obtain buy-in and help ensure that bridge students would be recognized for their potential and supported in the graduate program of study. Tools such as structured interview protocols and scoring rubrics helped at least two bridge programs clearly define their target population and ensure that admissions committee members gave due weight to noncognitive indicators of potential for success.

Our study results also suggest that the bridge students themselves are among the most powerful drivers of change. As faculty observed for themselves how well bridge students thrived and excelled in graduate study and in the research lab, they became more interested in and open to applying a more holistic, growth-mindset approach to considering student applicants.

Nevertheless, the bridge programs in our study remained limited in their capacity to effect reforms on a large scale. STEM departments varied in the degree to which they engaged in diversity and inclusion efforts, including with the bridge programs. Study participants frequently indicated that broadening participation was largely viewed as falling outside the direct purview of faculty's responsibility. They relied on intervention programs, like the bridge programs, to do the work of diversity for them.

In thinking about future research and investigations that can build off of the results presented here, the STEM academic community would benefit from a large-scale survey of bridge program admissions processes and criteria to identify common practices and metrics being applied. Once these are known, focused examinations of how consistent these are with the traits STEM PhD programs want to see in their students could help identify a set of indicators that can more effectively predict likelihood of success. Furthermore, additional in-depth studies of how the promising practices used by discrete intervention programs to identify and select students for graduate programs can successfully translate and become more institutionalized practices are warranted. Understanding the factors and strategies that can accelerate large-scale change are needed to push the STEM community beyond having to use intervention programs as "bypasses" to the status quo.

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