The Fisk-Vanderbilt Masters-to-PhD Bridge Program: A Model for Broadening Participation of Underrepresented Groups in the Physical Sciences through Effective Partnerships with Minority-Serving Institutions

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ABSTRACT

We describe the Fisk-Vanderbilt Masters-to-PhD Bridge program as a successful model for effective partnerships with minority-serving institutions toward significantly broadening the participation of underrepresented groups in the physical sciences. The program couples targeted recruitment with active retention strategies, and is built upon a clearly defined structure that is flexible enough to address individual student needs while maintaining clearly communicated baseline standards for student performance. A key precept of the program's philosophy is to eliminate passivity in student mentoring; students are deliberately groomed to successfully transition into the PhD program through active involvement in research experiences with future PhD advisers, coursework that demonstrates competency in core PhD subject areas, and frequent interactions with joint mentoring committees. This approach allows student progress and performance to be monitored and evaluated in a more holistic manner than usually afforded by limited metrics such as standardized tests. Since its inception in 2004, the program has attracted a total of 35 students, 32 of them underrepresented minorities, 60% female, with a retention rate of 91%. Recent research indicates that minority students are nearly twice as likely as non-minority students to seek a Masters degree en route to the PhD. In essence, the Bridge program described here builds upon this increasingly important pathway, with a dedicated mentoring process designed to ensure that the Masters-to-PhD transition is a successful one.

INTRODUCTION

The under-representation of minorities in the space sciences is an order-of-magnitude problem, and is one of the major challenges facing the United States' science, technology, engineering, and mathematics (STEM) workforce as a whole (National Science Board 2003). Black, Hispanic, and Native Americans comprise roughly 30% of the U.S. population, yet represent only 3% of all astronomy and astrophysics Ph.D.'s earned. In raw numbers, this translates into an average minority PhD production rate of about four individuals per year. Put another way, each of the roughly 50 astronomy and astrophysics Ph.D. programs in the U.S. has an average PhD production rate of 1 underrepresented minority every 13 years (Stassun 2005). This pattern of underrepresentation has remained largely unchanged for the past 30 years (Data source: Survey of Earned Doctorates NSF/NIH/USED/NEH/USDA/NASA).

Similar statistics apply in earth-science and space-related engineering disciplines (see, e.g., Huntoon & Lane 2007). For example, in 2008, 265 PhD's were produced in aerospace, aeronautic, and astronautical engineering. Of these, only 6 PhD's (i.e. 2%) were awarded to members of underrepresented minorities who are U.S. citizens or permanent residents. Significantly, only 121 of the 265 total PhD's were awarded to U.S. citizens of any ethnicity; that is, less than half of all PhD's earned in these space-science related disciplines are now being awarded within the domestic U.S. STEM workforce (Data source: Survey of Earned Doctorates NSF/NIH/USED/NEH/USDA/NASA).

Of course, students from other countries contribute greatly to the Nation's STEM community, and bring much to the workforce in terms of diversity. However, such students are frequently disqualified from support by federal grants, and we attract many more qualified applicants than we can serve. Finally, it is worth noting that foreign students earn almost five times as many PhD's than do African-American and Hispanic citizens of the U.S. (Woodrow Wilson National Fellowship Foundation 2005).

Thus, while commitment to diversity must be at the strategic core of the Nation's future STEM workforce, a specific focus on domestic students from underrepresented populations also has a potentially strong, practical dimension. The number of non-U.S. citizens entering the STEM workforce has dropped dramatically in the post-9/11 era. This means that we must tap deeper into the domestic candidate pool for exceptional students if we hope to continue, and ideally surpass, our present production of future scientists and engineers. Additionally, we must continue to recognize the underrepresentation of female scientists. The National Science Foundation, as well as numerous professional organizations, have underscored women's underrepresentation in STEM fields: Women continue to be significantly underrepresented in almost all STEM fields, constituting only approximately 25% of the STEM workforce at large. Women from minorities underrepresented in STEM constitute only 2% of STEM faculty in four-year colleges and universities.

Minority-serving institutions are important producers of minority talent in the sciences. For example, roughly one-third of all STEM baccalaureate degrees earned by African-Americans are earned at Historically Black

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Colleges and Universities (HBCUs), and the top ten producers of Black baccalaureates in physics are all HBCUs. These institutions have a rich cultural and academic tradition, with a large number of graduates going on to earn advanced degrees. For example, prior to the Hurricane Katrina disaster, Xavier University of Louisiana was the Nation's largest producer of African-American physics bachelor's degrees, graduating more Black physics students per year than all of the Big Ten schools combined[1]. Institutional partnerships with HBCUs are thus a promising avenue for broadening participation in the physical sciences (Stassun 2003).

At the same time, recent research on the educational pathways of underrepresented minority students in STEM disciplines indicates that these students are roughly twice as likely as their non-minority counterparts to seek a Masters degree en route to the PhD (Lange 2006). This fact motivates programmatic approaches aimed at deliberately preparing underrepresented minority students for success as they traverse the critical Masters-to-PhD transition.

In this contribution, we describe a program developed in a partnership between Vanderbilt University, a PhD-granting Research I university, and Fisk University, a research active HBCU located 1.5 miles from Vanderbilt. The Fisk-Vanderbilt Masters-to-PhD Bridge program (see www.vanderbilt.edu/gradschool/bridge) is designed for students who need (or want) additional coursework or research experience before beginning PhD-level work. The Bridge program provides a continuous path—a bridge—to the PhD that we have found is a particularly effective approach for students whose baccalaureate degrees are from small, minority-serving institutions, and who may for a variety of reasons seek a master's degree en route to the PhD. The program is flexible and individualized to the goals of each student. Courses are selected to address any gaps in undergraduate preparation, and research experiences are designed to pave the way for Ph.D.-level work in the chosen area of study. While at Fisk, students enjoy regular interaction with Vanderbilt faculty. This includes access to Vanderbilt courses and, in some cases, thesis research performed under the supervision of Vanderbilt faculty. In all cases, we deliberately develop mentoring relationships between students and faculty that will foster a successful transition to the PhD. Originally designed to link the physics programs at Fisk and Vanderbilt, the program now includes PhD tracks in materials science, imaging science, and the biomedical sciences, providing a variety of discipline-specific options.

We begin with an overview of relevant trends in the STEM educational pipeline for minority students (Sec. 2), emphasizing the increasing importance of Masters-to-PhD transitions for these students and the geographical concentration of the minority-serving institutions that produce the lion's share of minority baccalaureates in STEM. In Sec. 3, we provide a detailed description of the Fisk-Vanderbilt Bridge program, including programmatic structure and design considerations, recruitment and retention strategies, and outcomes achieved to date. We then present a brief discussion of questions for future study in Sec. 4, and summarize in Sec. 5.

RELEVANT TRENDS IN THE STEM EDUCATIONAL PIPELINE (2)

The Increasing Importance of Masters-to-PhD Transitions for Underrepresented Students (2.1)

Master's education is a growing enterprise in U.S. colleges and universities. Much of that growth has been attributed to the entrance of groups formerly underrepresented in graduate school enrollments—women and students of color. In the decade between 1990 and 2000, the total number of master's degree recipients increased by 42%. During this same time period, the number of women earning master's degrees increased by 56%, African Americans increased by 132%, American Indians by 101%, and Hispanics by 146% (Syverson 2003).

While growth in underrepresented group access to graduate education is to be lauded, national programs that focus on underrepresented access to graduate education generally have done so with a goal of increasing access to doctoral programs, not master's programs (Lange 2006). Thus, growth in underrepresented group education at the master's level raises questions about the relationship, in practice, between master's and doctoral education. Does access to master's education serve as a gateway to doctoral education for underrepresented students, who are often location-bound or enrolled in master's-only institutions?

Unfortunately, little research has been conducted on graduate degree pathways for underrepresented groups or the transition from master's programs to doctoral programs. A report on research needed to support underrepresented group participation in graduate education (Vining Brown 1994) suggested that more information was needed on the pathways actually taken by underrepresented students to and through graduate school to identify points where students leave the system. This suggestion is reiterated in a report from the American Association for the Advancement of Science (George, Neale, Horne, & Malcom 2001), which noted that more research is needed on pathways taken to doctorates in STEM, and the impact of institutional restructuring of graduate education with particular emphasis on master's certificates, professional master's, terminal master's, and new fields.

A recent study by Lange (2006) provides critical new insight into the role of the master's degree as underrepresented minority students proceed to the doctorate in STEM disciplines. Data from the Survey of Earned Doctorates (SED) was used to examine institutional pathways to the doctorate, and transitions from master's to doctoral programs by race and gender. The study addressed the following questions: (1) Are the pathways to the doctorate significantly different for underrepresented minorities in STEM? (2) Are underrepresented students more likely than majority students to earn master's degrees en route to a doctorate? (3) Are underrepresented minorities more likely to experience institutional transition between the master's and doctorate degrees?

As shown in Figure 1, there are six primary pathways to the doctorate: (1) **BS=MS≠PhD**: Bachelor's degree earned, graduate study begins at same institution,

master's degree is earned, and the student transitions to another institution for the doctorate. (2) **BS=MS=PhD**: Student earns the bachelor's degree, master's degree and doctorate at the same institution. (3) **No MS, BS=PhD**: Student earns the bachelor's degree and doctorate at the same institution. No master's degree is earned en route to the doctorate. (4) **BS≠MS=PhD**: Bachelor's degree earned, graduate study begins at different institution, master's and doctorate granted from same institution. (5) **BS≠MS≠PhD**: Bachelor's degree earned, graduate study begins at different institution, master's degree earned, and the student transitions to a third institution for the doctorate. (6) **No MS, BA≠PhD**: Bachelor's degree earned, graduate study begins at different institution, and no master's degree is earned en route to the doctorate. Statistical analysis performed by Lange (2006) reveals that pathways are significantly different for underrepresented minorities ($\chi 2=49.1$, df=18, $p<0.001$). Slightly more underrepresented minority than White/Asian students earn the bachelor's and master's degrees from the same institution and then transition to another institution for graduate study (BS=MS≠PhD). The two major differences, however, are that White/Asian students are more likely to forgo earning the master's degree en route to the doctorate altogether (No MS, BA≠PhD), and underrepresented minority students are much more likely to earn all three degrees at three different institutions (BS≠MS≠PhD). For underrepresented minorities, pursuit of the master's degree can often be a critical step on the path to the doctorate, though it is a step that is often fraught with the added instability that often attends institutional transition.

The key findings from the Lange (2006) study that have informed our development of the Fisk-Vanderbilt Masters-to-PhD Bridge program are thus:

- Underrepresented minority students are significantly more likely to earn a master's degree en route to the doctorate.
- Underrepresented minority students are more likely to earn the master's and doctoral degrees from different institutions, and thus usually experience institutional transition between the master's and doctoral degree.
- Underrepresented students who experience institutional transition typically do so with no deliberate programmatic structure in place to ease that transition.

The Geographical Concentration of Minority-Serving Institutions (2.2)

As already noted in Section 1, minority-serving institutions are a critical link in the higher education pipeline for underrepresented minority students. In physics, for example, the overwhelming majority of

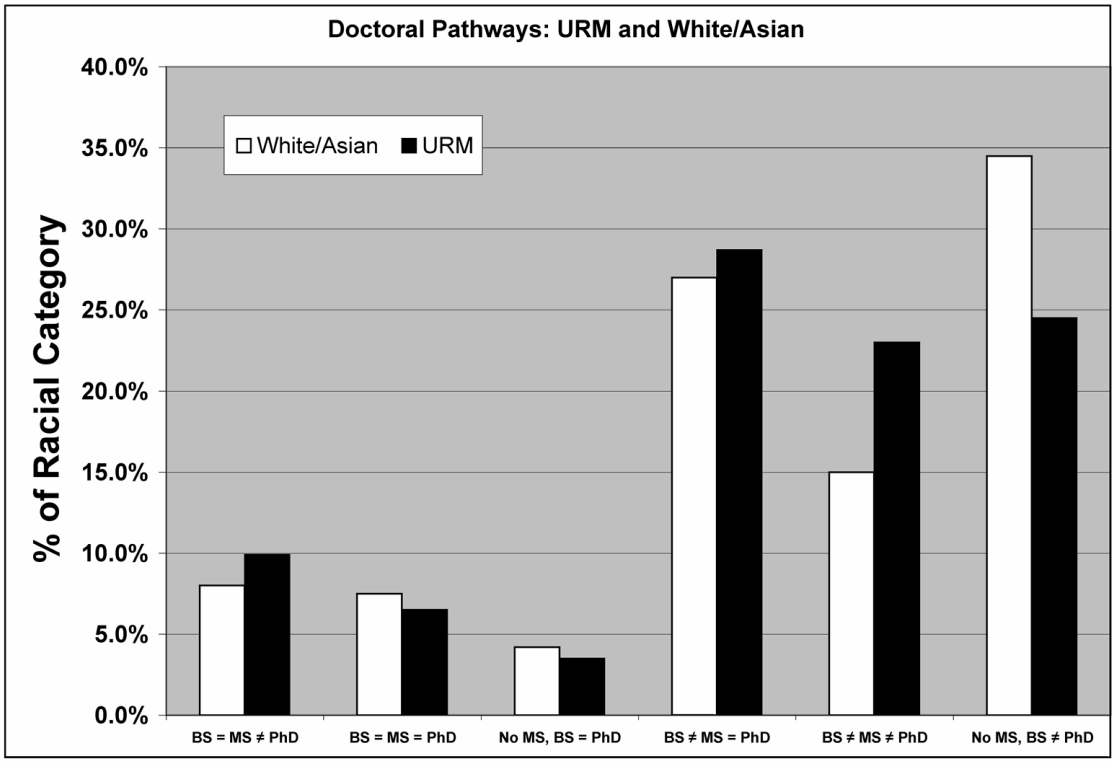

FIGURE 1. Analysis of degree pathways en route to the PhD for underrepresented minority (URM) versus non-minority (White/Asian) students, based on different permutations of the educational pathway to the PhD. An equal sign indicates degrees earned from the same institution. The fourth and sixth comparisons from the left show the "traditional" paths to the PhD, in which the student earns the bachelors degree from institution A, and either receives both the masters degree and the PhD from institution B or else forgoes the masters degree entirely. The fifth comparison from the left shows the case for earning the bachelors degree at institution A, a "terminal" masters degree at institution B, and PhD from institution C. URMs are much more likely to take this latter path than non-URMs. Adapted from Lange (2006), based on analysis of 80,739 PhDs earned in STEM fields, 1998 to 2002.

African American baccalaureate degrees are earned at HBCU's[1]. Tapping the rich pool of minority talent at these institutions is thus highly desirable. However, any programmatic strategy that seeks to partner with these institutions must be cognizant of a key fact: minority-serving institutions are strongly geographically clustered and concentrated. To the extent that students from underrepresented minority backgrounds are often location-bound for familial, cultural, and economic reasons (e.g. Stassun 2003), the issue of engaging, recruiting, retaining, and mentoring these students then necessarily takes on a distinctly geographic and regional character.

Figure 2 illustrates this point in the case of HBCU's, approximately 90% of which are concentrated in the southeastern US. Hispanic Serving Institutions are similarly geographically clustered in the southwestern US, and Tribal Colleges are concentrated in the midwestern and northwestern states (see NSF's www.pathwaystoscience.org for maps similar to Figure 2).

Consequently, research institutions in these regions may be in an advantageous position to develop joint programs and strong relationships with minority-serving institutions.

Implications (2.3)

The differences in pathways to the doctorate for underrepresented minority students, particularly the tendency to earn master's degrees en route, have significant implications for graduate education policy and programmatic development. Institutions and programs interested in increasing the number of underrepresented doctoral recipients must reevaluate their current emphasis on recruiting directly from baccalaureate programs. Certainly, increases in federal funding for master's programs that serve underrepresented students are warranted.

Perhaps most importantly, college and university

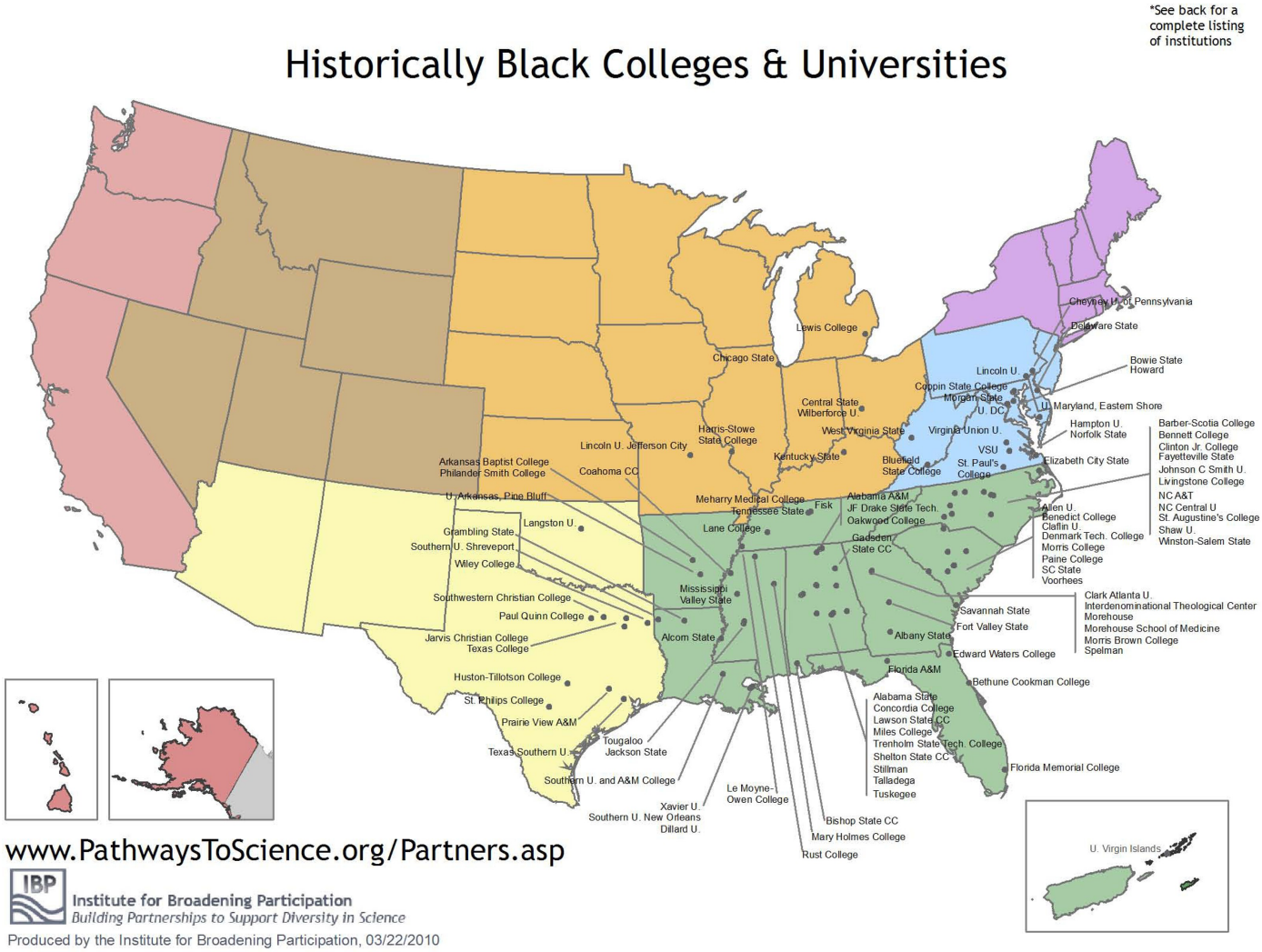

FIGURE 2. Geographic concentration of HBCU's in the southeastern US. Hispanic Serving Institutions and Tribal Colleges are similarly concentrated in other parts of the country (not shown here). Reproduced from the Institute for Broadening Participation; a comprehensive list of institutions associated with this map can be found at www.pathwaystoscience.org.

faculty, particularly at PhD-granting institutions, need to reassess the value placed on master's education and its role in broadening participation specifically. The research suggests that underrepresented minority students use the master's degree as a stepping stone toward success at the PhD level. Unfortunately, too often the transition from the master's degree to the PhD is one that students must navigate on their own, with little or no active mentorship.

Finally, the geographical concentration of minority-serving institutions (e.g. HBCU's in the southeastern states) should impel research universities situated in these regions to assume leadership in fostering joint programs and strong relationships with their neighboring minority-serving institutions.

THE FISK-VANDERBILT MASTERS-TO-PHD PROGRAM (3)

Programmatic Structure and Design Considerations (3.1)

The Fisk-Vanderbilt Masters-to-PhD Bridge Program was initially designed by physics faculty at Fisk and Vanderbilt dedicated to expanding opportunities for students to succeed in earning a PhD. The program has since grown to include four participating Vanderbilt PhD departments and programs, all fed by the Fisk MA program in physics, representing a variety of PhD degree options: (1) Department of Physics & Astronomy (www.vanderbilt.edu/physics), (2) Interdisciplinary Program in Materials Science and Nanophysics (An NSF-funded IGERT program, see ims.vanderbilt.edu), (3) Biophysical Sciences (Includes Chemical & Physical Biology, Structural Biology, Biophysics. See bret.mc.vanderbilt.edu/bret), and (4) Imaging Science (Includes Cellular and Molecular Imaging, Functional and Structural Neuro-Imaging, Physics of Imaging and Spectroscopy. See www.vuiis.vanderbilt.edu). In this section, we describe in detail the program's structure with the aim of elucidating key design considerations. These principles are informed by, and build upon, several strategies that have begun to emerge in the literature (see, e.g., Huntoon & Lane 2007 in the geosciences context, and Pyrtle & Williamson-Whitney 2007 in the earth science context). These precepts include: the importance of developing partnerships among multiple stakeholders to reduce 'leaks' in the education pipeline, and enabling strong mentoring relationship between students and key faculty.

Admission to the Fisk-Vanderbilt Bridge program (3.1.1)

Admission begins with application to the Fisk MA program in physics, which includes undergraduate transcripts, letters of recommendation, a personal statement, and general GRE scores (Note that while the subject GRE is not required for entrance into the Bridge program, it is ultimately required for formal admission to the Vanderbilt PhD program. Thus the Bridge program includes GRE study and tutoring sessions as one of its key components; see Sec. 3.3). The applicant indicates on the application that they wish to be considered for the Bridge program and submits an additional Bridge program information form. Once admission to the Fisk MA program has been formally decided by the Fisk faculty following Fisk's standard admissions procedures, admission to the Bridge program is determined by the Bridge program steering committee, consisting of three faculty members each from Fisk and Vanderbilt: the Chair of the Physics Department at Fisk, the Chair of the Physics & Astronomy Department at Vanderbilt, the Fisk representative to the Vanderbilt Interdisciplinary Program in Materials Science, the Fisk representative to the Vanderbilt Medical Center's Biomedical Research Program, and the Vanderbilt Director of Graduate Studies. Upon the recommendation of this steering committee, the successful applicant is formally designated as a Bridge student.

A comment is in order on the meaning of conferral of "Bridge status". Officially speaking, admission to the Bridge program does not constitute admission to the Vanderbilt PhD program, nor does it carry with it a formal promise of admission to Vanderbilt in the future. We did not want to create the appearance of a "back door" into the PhD program, and we were furthermore concerned that a guarantee of admission at the outset might encourage passivity both in the students admitted and in the faculty mentors responsible for preparing them.

But this does not mean that the program makes no promises. On the contrary, Bridge students are guaranteed support and mentorship in a number of concrete forms, as described below. More importantly, Bridge students receive an explicit commitment that they will receive the personalized attention, guidance, and one-on-one mentoring relationships that will allow them to develop—and to demonstrate—their full scientific talent and potential. We explicitly promise the Bridge students that we will work with them to help ensure their successful admission to the PhD program, and the program has adopted the view that failures in student retention are programmatic failures. This philosophy is more than a platitude; the program has been formulated with the direct oversight by the appropriate Deans of both universities, who hold the program's directors accountable for its success. Of course, the proof is not in promises made but in real student outcomes (see Sec. 3.4).

At this point the reader may also understandably wonder about the specifics of how the admissions decision is made: By what metrics does one judge promise for success when applicants so often have non-traditional backgrounds and/or attended unfamiliar undergraduate institutions, and thus many of the traditional measures used in admissions decisions may be missing (e.g. no subject GRE scores, course grades from undergraduate institutions whose academic rigor may be unfamiliar, and recommendation letters from faculty mentors who are not known personally by the graduate admissions committee)? To our mind, this may be one of the most important questions that PhD departments seeking to form bridges to minority-serving institutions must confront. We revisit this important issue in more detail below (Sec. 3.2.2).

Facilitating a Successful Transition to the PhD (3.1.2)

The vehicle by which successful transitions to the Vanderbilt PhD program are realized is through carefully orchestrated student-faculty mentoring relationships. We have found that the extent to which a student is successful in developing one-on-one relationships with faculty mentors—mentors who may very well become the student's PhD advisor—is the single most reliable predictor of the student's eventual admission into the Vanderbilt PhD program. Faculty mentors not only provide key guidance on course selection and research topics, they also become the student's most important advocates in the PhD admissions process. The fact is that a student who is well known to the faculty of the admitting department is more likely to have their potential for success evaluated holistically and on the basis of direct faculty interaction, and not simply on how the student appears "on paper".

It is thus the explicit goal of the Bridge program that its students will be well known by the Vanderbilt faculty by the time that they are ready to apply to the Vanderbilt PhD program of their choice. Indeed, *fostering individual mentoring relationships between Fisk students and Vanderbilt faculty is at the very heart of the Bridge program, and is the guiding principle for all other programmatic design considerations*. To that end, the Bridge program includes the following key elements, requirements, and benefits:

- Provision of full financial support in an amount that is standard for full-time graduate research assistants at Fisk University. Rationale: Financial burden should not be an impediment to full participation and satisfactory progress. Funding is provided through a combination of institutional support (e.g. tuition waivers) and extramural support, as appropriate, for a minimum of two years leading to the conferral of the MA degree. Core funding partners to date have included the National Science Foundation, NASA, and NIH.
- Assignment of both a primary Fisk advisor and a secondary Vanderbilt advisor. Rationale: Joint mentoring is the best way to track student progress and to ensure student readiness for PhD-level work. For students who are certain of the area of research interest, every attempt is made to match the secondary advisor to that interest. The role of the secondary advisor is to serve as a mentor, an expert on the rules and procedures at Vanderbilt, and as advocate during the eventual PhD application process.
- Scheduling of at least two meetings per year (in approximately December and August) with the Bridge program steering committee to review progress and receive guidance, in addition to the day-to-day interactions with primary and secondary advisors. Rationale: Keeping key personnel, particularly the directors/liaisons of the participating PhD programs, abreast of student progress helps to keep each Bridge student on the PhD program's "radar screen" and helps PhD program directors in planning the needs of each year's incoming PhD class.
- Participation in supervised research, at Fisk or Vanderbilt (or both), during at least the second academic year of the program, and participation in supervised research at Vanderbilt (or at a Vanderbilt-affiliated research site) during at least each summer of the program. Rationale: Demonstrating research promise, skill, and maturity in the lab of a potential PhD adviser is the single most effective way for students to develop relationships with faculty who can serve as recommenders and advocates. Students are required to publish their research and to successfully defend a Masters thesis.
- Requirement of at least B grades in all graduate courses, with at least one of these courses being a core PhD course taken at Vanderbilt. Rationale: Demonstrating competency in a core PhD course is essential to demonstrating promise for PhD study. Typically, Bridge students take several core PhD courses at Vanderbilt. Together with a judicious selection of courses taken in fulfillment of the MA degree at Fisk, many Bridge students complete most of the course requirements for the PhD by the time they apply to the Vanderbilt PhD program. Being close to PhD candidacy upon entering the PhD program makes the student more attractive to potential PhD advisers and places the student close to an equivalent third-year student in the PhD program. As a result, the total time to degree for Bridge students is typically only one year longer than for students entering the PhD program directly.
- Provision of: cross-registration privileges for Vanderbilt courses through a memorandum of understanding between the two universities; Vanderbilt parking permit; Vanderbilt photo ID card, email account, and library access. Rationale: These privileges and benefits support the programmatic goals and elements listed above, and specifically enable course attendance and research participation. In addition, these services provide Bridge students with a sense of welcoming and belonging at the institution that they strive to call their home, and thus serve a critical retention function as well (see also Sec. 3.3).

Recruitment Strategies (3.2)

Recruitment for the Bridge program has two interrelated dimensions. The first is logistical and practical: How and where to identify qualified minority students? The second is strategic and maybe even philosophical: Who is the ideal Bridge student?

Practical considerations: How and where to find and attract students? (3.2.1)

The primary recruitment vehicle of the Bridge program is faculty emissaries at minority-serving institutions and at national meetings of professional societies of underrepresented students. The Bridge program is aggressively and broadly advertised. We have developed both print and online advertising materials (see Figure 3) that are broadly distributed and made highly visible through personal connections with minority-serving institutions and professional societies of minority scientists. While we make regular use of electronic distribution mechanisms (listserves, newsletters, etc), we rely primarily on research faculty to personally visit

nearby institutions and to participate in national conferences. The recruiting function is too important to be relegated only to non-academic staff; in our experience, it is faculty—faculty who are positioned to convey the excitement of their research, who have discretionary authority to offer opportunities in their labs, and who are able to communicate their commitment to student success—who make the most effective recruiters.

A key way by which we effectively advertise the Bridge program and to specifically target minority students is to make use of faculty and current Bridge students attending the meetings of professional societies that represent minority scientists and engineers. We have developed very close ties to three of these organizations in particular. The Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) holds an annual meeting in October, and Fisk and Vanderbilt faculty are very active in the organization of these meetings. They regularly organize scientific sessions, participate in the Board meeting of the National Society of Hispanic Physicists (NSHP) held jointly with the annual SACNAS meeting, participate in student mentoring sessions, judge student posters, etc. These activities provide a means for effectively advertising the program at this meeting and, more importantly, for personally recruiting students in attendance. Presently, the National Society of Black Physicists (NSBP), NSHP, and the Fisk-Vanderbilt Masters-to-PhD Bridge Program share a recruiting booth at this meeting.

NSBP and NSHP hold an annual meeting in February which Fisk and Vanderbilt faculty regularly attend. Again, faculty participate in mentoring sessions and judging posters. NSBP and NSHP also participate in the fall meetings of the Southeast Section of the American Physical Society (SESAPS) and the Texas Section of the American Physical Society (TESAPS). This provides another opportunity to bring the Bridge program to the attention of interested students. We are in the process of building relationships similar to the ones described above with other minority professional societies so that they and their annual meeting can serve as a conduit of information to prospective students and mentors. These societies include the National Society of Black Engineers (NSBE), National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBECCHE), Society of Hispanic Professional Engineers (SHPE), American Indian Science and Engineering Society (AISES), Society of Mexican American Engineers and Scientists (MAES), Coalition to Diversify Computing (CDC), Institute for African American e-Culture (IAAEC), and the National Association for Black Geologists and Geophysicists (NABGG).

Another way of recruiting which focuses on minority students is to work through the Committee on Minorities of professional societies, when they have one. We have developed strong connections with the Committee on Minorities of the American Physical Society and the Committee on the Status of Minorities of the American Astronomical Society, the latter of which one of us presently serves as chair.

Strategic and philosophical considerations: What type of student to recruit? (3.2.2)

Passively waiting for that rare candidate who stands out by all of the usual metrics on paper will not net a high yield of promising new recruits. As discussed by Dr. Richard Tapia in his 1999 address to an NSF-sponsored summit on "Promoting National Minority Leadership in Science and Engineering," a business as usual approach, particularly in admissions, simply does not achieve the goal of truly broadening participation:

> *There are underrepresented minority students who have had first-rate educations who look like majority students, and in every way are as capable and as sophisticated. It really isn't an issue if they go to Stanford, Berkeley, Caltech, or Cornell. They're going to do well. But that's not the bulk of the underrepresented minority population. And for schools that say, "we're going to fight for that first pool," I ask, what are you contributing to the nation's representation with that tactic? If you fight for members of the first pool by offering more money or more perks, you really haven't done anything to address the issue of underrepresentation. You've made your school look better. You can say, "oh look we're leading the nation," or whatever you want to say, but what have you done for the global pool, what have you done for the underrepresentation crisis? You haven't done anything.*

In his remarks, Dr. Tapia goes on to suggest that instead of simply competing with other highly-ranked schools for the best students, truly broadening participation requires that we identify and support the 'second pool,' the "diamonds-in-the-rough that don't look like traditional candidates." This second pool consists of individuals who are certainly talented and capable, and can succeed given proper guidance, but who either have not been properly developed or properly evaluated. It is this second pool that our traditional graduate programs have been missing. As Dr. Tapia points out, "They take special effort. They require mentoring, guiding, and sometimes remediation. They may make a slower start."

The Bridge program is in a very real way predicated on the premise that dipping into this 'second pool' can be done fruitfully and successfully. In formulating an admissions strategy for the Bridge program, we have been forced to abandon the usual mindset of filtering applicants on the basis of *proven ability* to one of identifying applicants with *unrealized potential* that can be honed and nurtured.

Recognizing potential can take a number of forms, and often plays out differently for each student. One student's undergraduate transcript might show a low GPA that, on closer inspection, is the result of a slow start but a clear upward trajectory. Another may have an excellent GPA but missing upper-level courses in the major because they were simply not available at the undergraduate institution. Still another may simply have made a strong positive impression on a faculty recruiter during a poster presentation at a national conference.

Perhaps most importantly, in the course of developing the Bridge program we have formed strong, positive relationships with colleagues at numerous minority-

serving institutions. These relationships serve two critical functions. First, as we get to know these undergraduate feeder programs better, we are able to make better and more informed evaluations about the specific strengths and weaknesses in the academic preparation of incoming students. Second, by earning the trust of our faculty colleagues at these institutions, we enhance the likelihood that they will work with us to encourage their mentees to consider our graduate programs. Indeed, in a report studying strategies for building effective partnerships with minority-serving institutions, Stassun (2003) found that undergraduate mentors at these institutions take a very active role in advising their students, and that they will actively steer their students away from graduate programs that they do not trust will nurture their students' success.

More than one colleague has commented that this approach to recruiting and admissions is analogous to that of minor-league (or "farm") teams in baseball: Rather than build a team by recruiting only "starters," the idea is to develop an infrastructure that scouts early talent while it is still rough, that provides the resources and training to allow that talent to blossom and mature without lowering standards or expectations, and that thereby sustains the future vitality of the team.

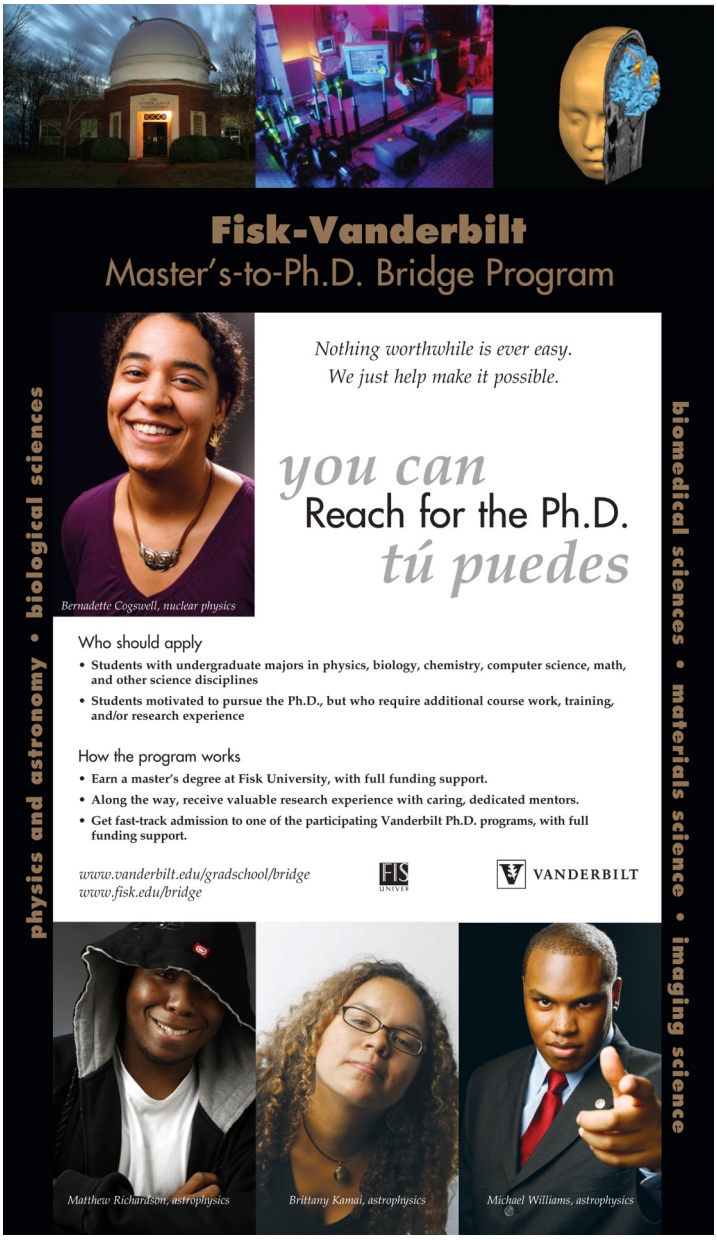

FIGURE 3. Recruitment poster and brochure for the Fisk-Vanderbilt Masters-to-PhD Bridge program. The program website is www.vanderbilt.edu/gradschool/bridge.

Retention Strategies (3.3)

In addition to providing Bridge students with the one-on-one mentoring, coursework, and research experiences that form the program's core, a variety of ancillary programmatic elements have been implemented to form a scaffold of support that helps to ensure student retention and satisfactory progress. These include:

- Annual program orientation and kickoff. A mandatory, all-hands meeting each Fall serves to welcome and initiate new Bridge students with a celebratory and community-building event. New students are given guidelines on how the program works, important milestones and deadlines, and are formally introduced to their faculty and peer mentors.
- Social support structure. We have helped the students organize an informal social group (the "Bridge Club") with student officers who serve as a conduit for program information between faculty and students. An electronic calendar system keeps students reminded of departmental events (colloquia, journal clubs, etc) and of important deadlines (e.g. course registration). More importantly, the club provides a relaxed, informal venue for Bridge students to get to know one another, to study together, and to generally develop a sense of belonging to a larger community and group identity. The club includes senior Bridge students as well as Vanderbilt graduate student mentors who can share their experiences and provide access to social networks at Vanderbilt. We have found that this tiered, peer mentorship approach is extremely helpful in making sure that Bridge students remain connected and emotionally supported.
- GRE preparation study sessions and tutoring. The subject GRE is but one component of the whole system of assessments by which Bridge students are holistically evaluated for admission to the Vanderbilt PhD program. Nonetheless, it is a formal requirement, and we want to help students perform to the maximum of their ability. Study sessions and tutoring by advanced graduate students helps to familiarize students with the exam's structure and contents, and thereby helps to alleviate the intense exam anxiety that can adversely affect performance.
- Early identification of course difficulties, and proactive intervention. For most students in the Bridge program, the question is not *whether* they will encounter course difficulties, but *when*. We have learned that identifying these difficulties early, and intervening quickly and positively, is essential to bolstering success in the critical

core graduate courses that form an essential component of student retention. We track the courses that Bridge enroll in as part of the advising process, and then actively monitor their progress by asking their instructors to promptly notify us at the first signs of concern. One-on-one tutoring is provided, as needed, by advanced graduate students (or postdocs in rare cases), and course-load adjustments are made mid-stream if it is determined that remedial instruction is required before re-enrolling in the course.

- Encouragement in fellowship applications and conference participation. We require all Bridge students to apply for national fellowships and to submit abstracts to national conferences. This provides critical skills in grants development, communication, and professional networking. Bridge students have awarded fellowships from the NASA Harriett Jenkins program, the QEM Science and Technology Centers program, and others. These successes provide in-house expertise in developing successful applications, and help to motivate other Bridge students, all of which helps to build a positive culture of success.

Outcomes (3.4)

Since its inception in 2004, the Fisk-Vanderbilt Masters-to-PhD Bridge program has attracted a total of 35 students, 32 of them underrepresented minorities, 60% female. Of the 35 admitted students, 32 have either already transitioned to the Vanderbilt PhD program of their choice (or to a PhD program of their choice at another institution), or are making satisfactory progress toward that goal; this is a retention rate to date of approximately 91%. Students in the program have received the top graduate fellowships from NSF (NSF Graduate Fellowship, IGERT), and from NASA (NASA Graduate Research Fellowship, Harriett Jenkins Fellowship). We believe these initial outcomes reinforce the efficacy of our approach and suggest that the program may well serve as a model for other programs built on active partnerships with minority-serving institutions.

To be sure, the Fisk-Vanderbilt Bridge program is not for all students, nor is it intended to be. Students with strong undergraduate backgrounds will usually want to enter a Ph.D. program directly, and will not seek nor require this type of bridging opportunity. In these cases, the Bridge program can play an important recruiting role, conveying as it does a serious commitment to student success. Indeed, in the time since partnering with Fisk to develop the Bridge program, Vanderbilt University has witnessed a significant increase in the number of strong minority students applying—and gaining admission—directly to the Ph.D. program. The message for us has been that a true commitment to diversity pays dividends in unexpected ways.

While we celebrate these early successes, we have nonetheless paused to reflect deeply on the circumstances surrounding the cases of failed retention. These cases have helped to reveal some shortcomings in our program support structure, specifically with respect to socialization and professionalization, and we have since acted to correct these, as we now discuss.

QUESTIONS FOR FUTURE STUDY (4)

As we proceed to execute the Bridge program and make course corrections on the basis of formative evaluation, we have the opportunity to better understand why the Masters degree is such an important stepping stone for minorities in the sciences. To be sure, we now have good evidence that the Bridge program works as a recruitment and retention strategy, but a number of policy -related questions remain. Here we highlight two specific issues that have arisen in the context of student attrition.

First, how might socialization toward academic careers be geared to begin at the Masters level? The majority of our incoming Bridge program students indicate an intent to pursue an academic career upon completion of the PhD. Increasingly, students who aspire to academic careers are turning to programs that provide professional development and early experiences in preparation for the professoriate (e.g. Preparing Future Faculty). Indeed, one of our early attrition cases was the result of a failure to recognize the student's need to "see and feel" that they were receiving skills and training toward an academic career beyond research (e.g. teaching, outreach, etc). While we were initially hesitant to allow students to become overwhelmed with too many activities and responsibilities, we have in fact found that integrating "future faculty" experiences into the Bridge program can actually help to further socialize some students for a successful transition to the PhD, and can help to further motivate and incentivize them to persist in the program. To this end, we have recently partnered with the NSF-supported Graduate Teaching Fellows program at Vanderbilt.

Second, since academic and social integration is essential to persistence in doctoral programs (Tinto 1997), are there strategies that help ensure academic and social integration for students in bridge programs? One of our early attrition cases revolved around a failure to recognize that a student's poor academic performance was in fact linked to under-developed integration into the culture and milieu of the department. We have since worked with the Bridge students to organize a social group (see Sec. 3.3) and have additionally instituted a semester-long "professionalization course" in which students meet weekly with a faculty mentor to discuss issues of "academic culture" (expectations with respect to work habits, communication styles, etc).

We anticipate that addressing these and other research questions will be an important outcome of our continued development of the Bridge program.

SUMMARY (5)

In remarks given at the 2004 meeting of the American Association for the Advancement of Science, Dr. Shirley Jackson described "a perfect storm" of converging societal factors that threaten our nation's competitiveness, as the science, technology, engineering and mathematics (STEM) workforce ages, fewer students pursue STEM degrees, and foreign-born students either choose to study in their own countries or return home to work after earning a degree in U.S. colleges and universities (Jackson 2004). When coupled with demographic shifts in the U.S. whereby the

label "minority" will no longer be accurate for ethnic minorities (Feagin 2002), the factors she describes lend an urgency to efforts to recruit and retain underrepresented minorities in STEM-related programs and professions.

We have developed the Fisk-Vanderbilt Masters-to-PhD Bridge program to (a) leverage the market forces that are driving underrepresented students in STEM fields to increasingly pursue a master's degree en route to the PhD, and (b) provide a path to the PhD that includes deliberate mentorship as students cross the critical junctures that attend institutional transitions. Students are identified through strategic, faculty-led recruiting coupled with a paradigm shift in admissions decisions: We adopt an approach of developing an infrastructure that scouts early talent while it is still rough, that provides the resources and training to allow that talent to blossom and mature without lowering standards or expectations, and that thereby sustains the future vitality of the program. Bridge students receive the personalized attention, guidance, and one-on-one mentoring relationships that will allow them to develop—and to demonstrate—their full scientific talent and potential. We have learned valuable lessons, and have made corrections, from deep reflection on a few early programmatic failures. Overall, program outcomes have been extremely positive: Since its inception in 2004, the program has attracted a total of 35 students, 32 of them underrepresented minority students, 60% female, with a retention rate of 91%.

Key programmatic design considerations can be summarized as follows:

- Focus on retention. Direct programmatic efforts toward fostering one-on-one mentoring relationships between students and potential PhD advisers, through enrollment in core PhD courses and through research assistantships in PhD faculty labs. When faculty know a student personally, and can vouch for their performance in coursework and in the laboratory, they can effectively and persuasively advocate for the student based on a holistic evaluation of the student's ability.
- Focus on recruitment, not competition. Direct recruitment efforts on truly broadening participation by emphasizing *potential* instead of already proven ability. Be willing to take risks in admissions, and then erect scaffolds of support to ensure success. Competing with other selective institutions for the few highly sought applicants who stand out in traditional metrics does little to address the needs of the national STEM workforce.
- Involve key decision-makers in programmatic design and oversight. Faculty who lead graduate admissions must be active stakeholders in the process of matriculating, supporting, and monitoring students. Deans who oversee academic units must commit to work with—and place accountability on—programs that fail to retain students.

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