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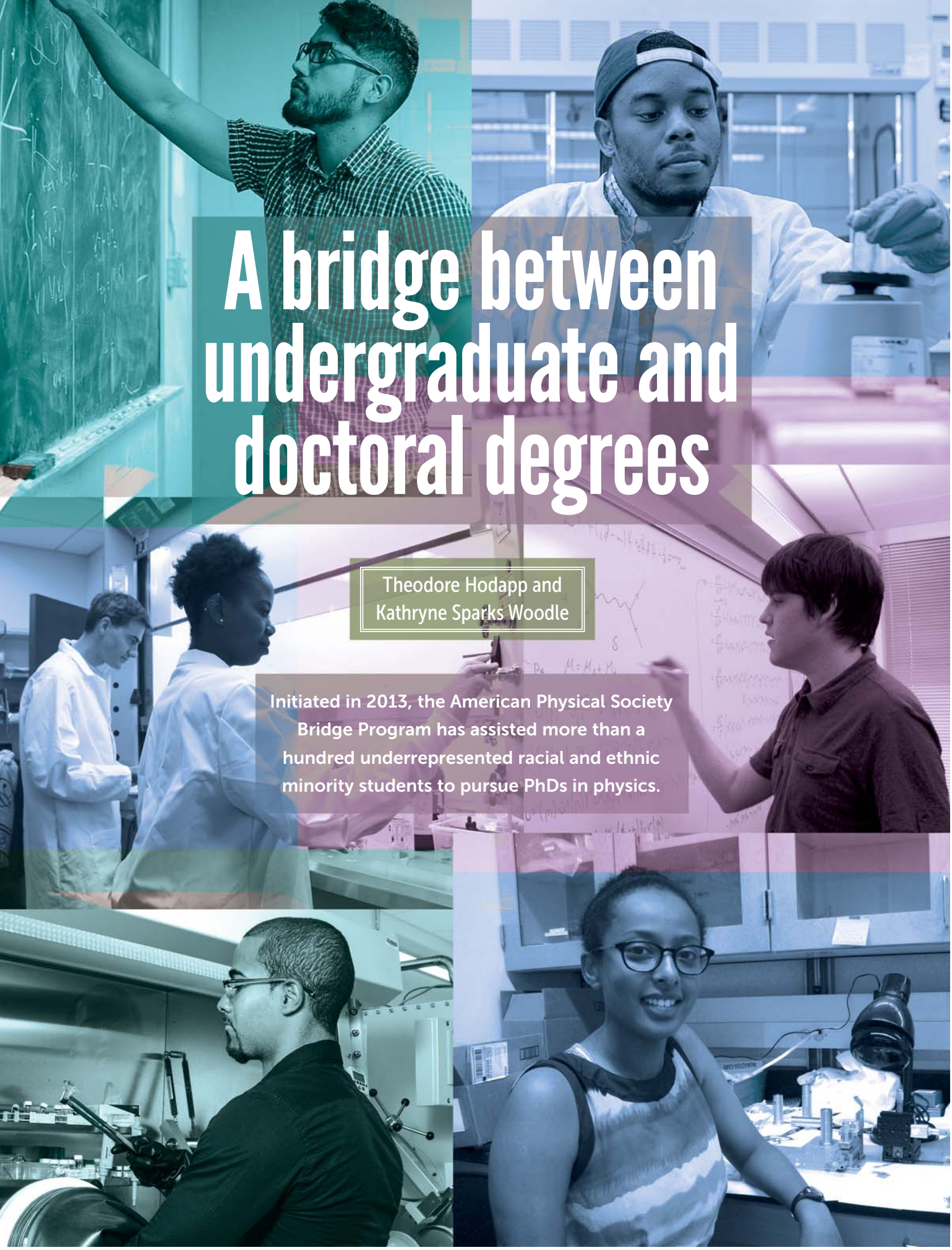

A bridge between undergraduate and doctoral degrees

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Initiated in 2013, the American Physical Society Bridge Program has assisted more than a hundred underrepresented racial and ethnic minority students to pursue PhDs in physics.

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Physics is unflinchingly objective, intellectually difficult, and at times downright confusing. It also stimulates creativity and helps us understand pretty much everything—at least at some levels. None of those traits, or others you might think of as descriptive of a natural science, are intrinsically biased for or against African Americans, Hispanic Americans, or Native Americans. So why do such underrepresented racial and ethnic minorities (URMs) collectively earn a paltry 11% of undergraduate physics degrees in the US and only 6% of its doctoral degrees, as shown in figure 1?

Factors such as stereotype threat—a well-documented effect in which individuals underperform at challenging tasks when they feel they might conform to a stereotype of their group[1]—and unconscious bias[2] contribute to the problem. But unknown to many in the physics community are the difficulties that are endemic to a student's background and to the culture of society at large.

All students struggle—that seems to be the nature of graduate work and independent research. But are those struggles primarily associated with understanding the science or with situations that tear one away from a focus on academics and sap creative energies? The latter often come after the loss of a loved one, a breakup, or some other personal crisis that undermines the ability to perform at one's peak. Now imagine what it is like to deal with those kinds of challenges, in addition to racial profiling and other issues. Imagine working at the lab late at night and having a security guard question whether you belong there. For some students, disruptions like those are everyday reality.

In 2008 the American Physical Society (APS) brought together leaders from minority communities to strategize what specific programs might be considered to address inequities. After a year of discussions, conversations with lots of people around the country, and a look at some distinctive, existing programs that showed promise in addressing underrepresentation, APS settled on trying to eliminate the disparity between URM students' participation at undergraduate and doctoral levels. The percentage of physics degrees awarded to URM students at both levels has remained stagnant for the past couple of decades (see figure 1b). A significant gap also remains between the fractions of bachelor's and doctoral degrees awarded to URM students—a loss of URM physicists.

Increasing the number of URM PhDs by about 30 each year would be enough to close the gap between the number of bachelor's and PhD degrees that are earned, on average, by URM students. Thirty PhDs seemed like an achievable goal to those of us in the education and diversity department at the APS. Using knowledge gained through our discussions, we adapted existing program elements and developed new ones to create a "bridge" program designed to help motivated and talented URM students gain acceptance into graduate programs and receive support to enable them to succeed.

In 2013 the first students matriculated into graduate schools through the APS Bridge Program (see figure 2). Although they have yet to earn doctorates, we expect the number of students now in the program to close the gap in percentage of URM degree recipients once they graduate. This article describes the APS program and explains why we think we now understand something about a system that is stacked against students who are talented and motivated but who often have to deal with cultural attitudes, poverty, or just bad advice that keeps them from experiencing the joy of going down the intellectually stimulating road we call physics.

A starting assumption

Our early discussions made us realize that some students, though capable and driven to complete PhD-level work, are, for various reasons, unable to gain admission to a graduate program or, once there, fail to obtain their degree. To counter both problems, we established three significant components of the Bridge Program:

1. Recruit, disseminate, and track applications from students who have not been admitted to graduate studies.
2. Establish "bridge sites"—universities willing to help students make the transition into and ultimately complete graduate studies.
3. Conduct research into underlying factors that contribute to the success or failure of students in attaining doctoral degrees in physics.

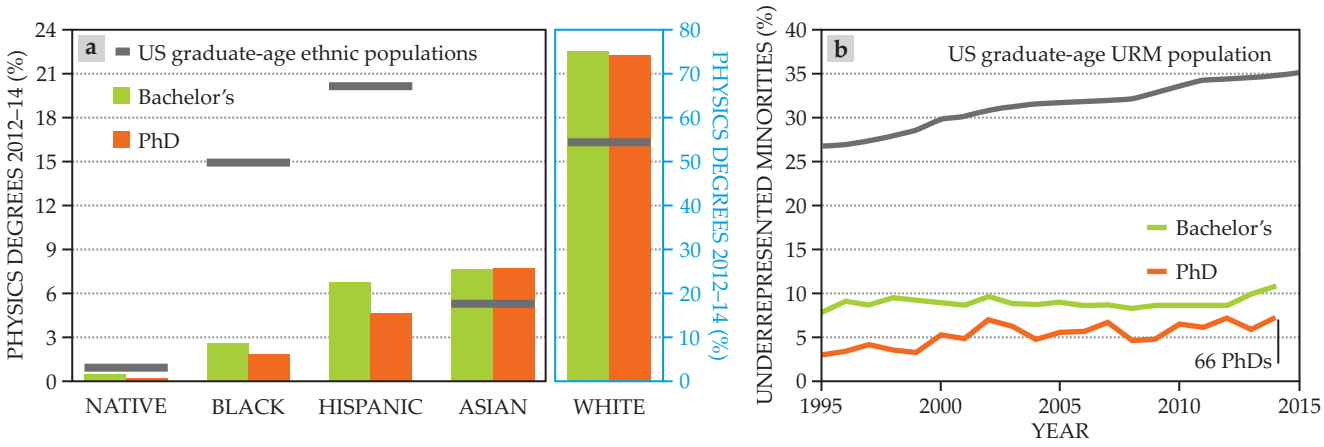

FIGURE 1. UNDERREPRESENTED RACIAL AND ETHNIC MINORITIES (URMs) in US physics programs include Native Americans, African Americans, and Hispanic Americans, whose fractional representation as bachelor's (green) or PhD (orange) degree recipients is disproportionally less than each group's representation in the total university-age population (gray bars). **(a)** For example, Hispanic Americans represent 20% of the US population but earn less than 5% of the PhDs awarded to US citizens or permanent residents. White and Asian Americans, by contrast, are overrepresented as degree earners in a similar analysis. The percentage of bachelor's degrees attained by those two racial/ethnic groups is also roughly the same as their percentage of PhDs. **(b)** By contrast, an achievement gap of about 5% exists between the percentage of URMs who received bachelor's degrees and the percentage who received PhDs. The gap has persisted for more than two decades.

Since beginning our program, we have found that about two-thirds of all applicants to the program were turned down at every graduate school to which they had applied, and the remaining third never even applied. A chief explanation we hear from the latter group is either a low score on the physics graduate record exam (GRE) or grades. This reason is particularly common to URM students, as the GRE has documented differentiation in scores based on gender and URM status. When broken down by race and gender, the distribution of GRE scores is, on average, lower for minorities and women.[3]

One result of a low score is that students often don't even bother to apply to graduate school, believing that they would be wasting their money trying to gain admission—a process that can set them back roughly $1500 in applying to 8–10 schools. To increase the number of URM students transitioning into physics PhD programs, we connect these students with programs that are willing to look beyond GRE scores and that recognize (and foster) potential rather than just accomplishment. A permanent solution will require departments and faculty to consider systemic changes to admissions and other longstanding practices—a longer-term goal of the project.

National recruiting

While enabling URM students to succeed is at the heart of bridge programs, finding these can be a frustrating and time-consuming occupation for a physics department. Fortunately, APS is in a unique position in the physics community. We can do what most universities cannot: advocate for everyone. We can ask every department to nominate students they think would be successful if given the right opportunity. We can ask graduate departments to identify applicants to whom their own programs are unable to extend an offer and then to encourage those students to apply to the APS Bridge Program. We also do not let departments review applications until after 15 April, the standard deadline for students to accept graduate program offers, as we do not want to move students between programs. We want to make sure students who did not receive an offer but have the potential to complete a PhD get that opportunity.

The APS-facilitated process offers several advantages. First, for each student we effectively "apply" to dozens of universities, including lesser-known ones of which most are unaware. (The US has about 185 PhD-granting and 60 MS-granting departments.) Second, our process is free for students—we do not require application fees, official transcripts, or their official GRE score.

The response to this recruiting effort has far exceeded our original expectations (see figure 2). In 2016 we received applications from 90 students—far more than our bridge sites, described below, could accept (they took 24 this year). Our solution was to vet additional "partnership" institutions willing to embody the principles behind the Bridge Program. With the help of the APS Committee on Minorities in Physics, we have now recognized 27 such departments, with the number rising by about 10 each year. The committee review process provides important feedback to each physics department and gives us confidence that an institution is committed to establishing conditions needed for URM students to succeed.

To date, we have placed 106 students into bridge sites, partnership institutions, and several other affiliated programs. Figure 3 shows the geographic distribution of sites hosting bridge students (red, blue, and green dots) and institutions that support the ideals of the APS Bridge Program (black dots). Ultimately, we intend to limit applications to vetted departments to ensure a supportive environment for all students coming through the APS process.

Figure 2 shows the increasing numbers of students entering graduate studies through the APS Bridge Program, along with those who have since left, resulting in a retention rate of 92% (the national physics graduate student retention rate is 59%).[4] Many more students have been accepted than can be directly supported through project funding. The fact that the remainder are directly funded by institutions demonstrates a route to sustaining this effort into the future.

Creating supportive environments

Bridge programs have existed for many years at all levels of higher education. Today, numerous programs help high school students transition to college or college students get into medical school, but few exist to aid undergraduates progressing to graduate school. In 2009, after we realized that the gap between undergraduate and graduate participation among URM students was potentially fixable, we set out to visit existing physics bridge programs. The best known was (and still is) the Fisk–Vanderbilt Master's-to-PhD Bridge Program.[5] Enabled by the close proximity of the two institutes' campuses, this highly successful program inducts students into Fisk University, a small master's degree-granting HBCU (historically black college or university), and helps them transition into the PhD program at Vanderbilt. We also visited Columbia University's Bridge to the PhD Program; the Imes-Moore Fellows Program at the University of Michigan; the Meyerhoff Scholars Program at the University of Maryland, Baltimore County; and others. All those programs are taking thoughtful approaches to improving diversity and can offer lessons that impact diversity and improve education for all students.

Following in the footsteps of those programs and with funding from NSF, APS established six bridge sites: at the Ohio State University, the University of South Florida, Florida State University, California State University Long Beach, Indiana University, and the University of Central Florida (the red dots in figure 3). Those institutions typically use the first year to help students make the transition ("bridge") to graduate studies with undergraduate or graduate coursework as needed and provide mentoring and close attention.

During the second year, students are often well into their graduate coursework, with financial support provided by the university. At that point, they are in good shape to apply for admission into a PhD program. Of the 22 students accepted at bridge sites as members of the classes starting in 2013 and 2014, 15 are progressing toward a PhD, 11 at their original bridge sites.

Retention of students is a focal point of bridge programs, including ours. The tremendous effort to recruit and attract students into graduate school is wasted if they leave for reasons that can fairly easily be remedied. Key components of all bridge programs include financial support, induction, mentoring, and progress monitoring.

Financial support

Many students entering bridge programs cannot afford to self-finance their graduate studies, and most physics doctoral programs do not expect that of their students. The reality, however, is that URM students are more likely[6] than majority students to begin their graduate education in a master's program. And many such programs offer considerably lower financial support for their students than doctoral programs do, a reflection of the decreasing amount of state support for higher education at many institutions.[7] For some students, especially those struggling academically, the distraction of working a part-time job often dooms their academic studies.

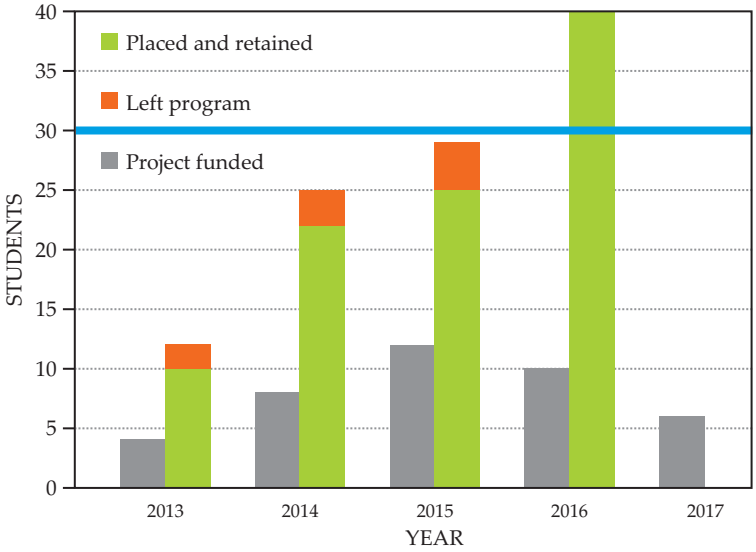

FIGURE 2. STUDENTS being placed into graduate programs (green) and leaving without a PhD (orange) from the American Physical Society Bridge Program for each year of the project. Gray bars indicate the number of students supported by APS project funding. To date, 210 students have applied to the program, 106 have been admitted, and 9 are no longer in it. The blue line represents the number of PhDs needed to equalize the percentages of doctoral and bachelor's degrees awarded to underrepresented ethnic and racial minority students.

One student in our program represents a case in point. She reported that she was unable to gain admission to graduate school because of a low undergraduate grade-point average. But once fully supported in a PhD program through an application to the APS Bridge Program, she excelled at coursework. Although she had received Bs or lower in her core undergraduate physics courses, she earned As in the graduate-level versions of the same courses. What accounts for the difference? She had to work several jobs as an undergraduate to put herself through college and lacked the time to properly study. She has now passed her qualifying exams and is on the way to a PhD.

The timeliness of financial support is important as well. Some students are unable to afford moving expenses, rental deposits, or their first month's rent. Starting the first semester of graduate school while already in financial straits makes it even more difficult, and stipends are often paid only at the end of the first month. To remove that hardship, APS advances funds to students before they arrive on campus. Some bridge sites also provide financial guidance because students who are unaccustomed to receiving a regular stipend are occasionally not familiar with how to effectively manage money. The guidance helps ensure that students are not handicapped by choices they made before beginning their studies. The problems are easy to solve, but for some students, they can spell the difference between success and failure.

Induction

The first few weeks of a student's experience in graduate school can be traumatic: a new location with little or no support

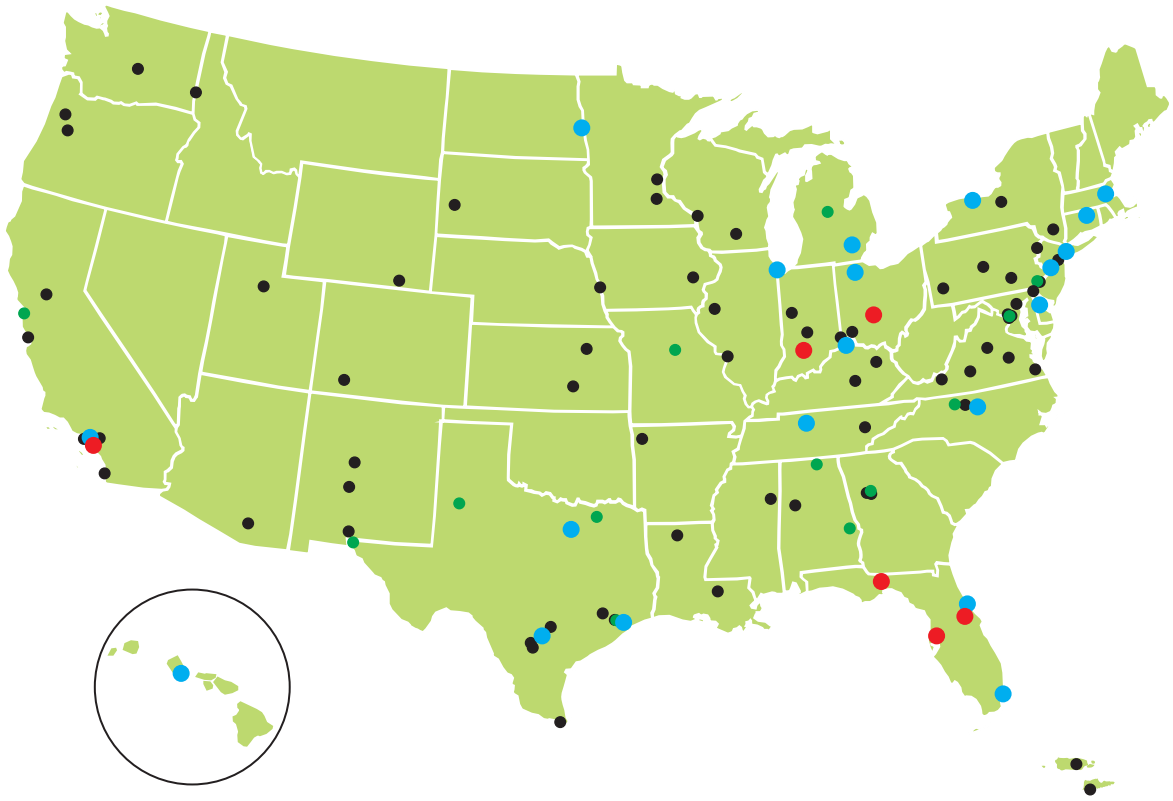

FIGURE 3. THE AMERICAN PHYSICAL SOCIETY BRIDGE PROGRAM currently comprises more than 100 participating institutions (all dots)—universities that support the APS's program ideals. They include six bridge sites selected by APS (red); "partnership" institutions, which have been vetted and officially endorsed by the society (blue); and "affiliated" institutions, which have not yet been vetted, but have accepted students (green).

networks, new living situations, and coursework at a level significantly above undergraduate courses. Those changes can be more daunting if English is not the students' first language or if their undergraduate coursework did not prepare them for the next level. Bridge programs address these issues in several ways, often beginning with diagnostic exams to probe a student's preparation. Although it is not always possible to convince students of their readiness for graduate E&M, scheduling undergraduate and graduate sections of the course at the same time gives students the option to switch a level, either up or down, a few weeks into the term, if that's necessary.

Social adjustments can be just as important as academic ones. One bridge site has its new students begin their first month on campus rooming with more senior graduate students. They learn about good housing options, limit their initial financial exposure, and begin to form friendships. Supporting many of those activities are physics graduate student associations, which are relatively low-cost organizations, now established at nearly every bridge site, in which students can forge social and professional networks (see box 1).

Mentoring

Students are more likely to thrive if they have different sources of support within easy reach when problems arise. Such support might include a trusted staff member in the departmental office, a student's research adviser, or a favorite instructor. This multiple-mentor model, sometimes referred to as constellation mentoring,[8] encompasses several team mentors who can approach problems from different perspectives and spot trouble more rapidly than a single individual can. To be effective, such a team of mentors must also be educated about mental-health professionals, housing services, and other campus resources. The mentors must also understand their responsibility to be aware of a student's progress or lack thereof. We recommend that the team meet regularly and that it poll the instructors of a student's core courses to gauge his or her involvement in class—for example, attendance, use of office hours, active engagement in discussions, and homework quality. Using this distributed mentoring model, bridge sites have been able to intervene quickly when difficulties arise (for a specific example, see box 2), locate resources, and solve simple problems that otherwise might derail a student.

In one example of effective mentoring, a bridge student left a large and vibrant Hispanic community, where he had enjoyed broad personal support, for a small college town. Once there, the site leaders spent time making sure he felt a part of the new community, and he is now progressing well toward a PhD. However, the availability of resources is not always enough. Students need to be reminded of them regularly, and special care should be taken when interpersonal issues underlie difficulties students are experiencing.

Progress monitoring

This last component is really just an extension of mentoring, but it is important enough that we call it out separately. At its

core, progress monitoring is another example of basic attention paid to graduate students. We ask all sites to check on their students regularly, especially in the first year. Evaluating their progress around week two of the first semester is extremely important: Are they attending and attentive in class? Handing in homework? Are they working in isolation or forming study groups with others? If red flags are raised, there is time to quickly step in and work to solve the problem. Maybe they are in the wrong-level course, or an outside influence may be a distraction. If so, the problems can often be resolved using resources of which they are unaware.

Week two is a great time to fix problems, because waiting until midterm essentially dooms a student. The time is well spent—especially if the correction is simple and its application reinforces and builds students' confidence while keeping them on track toward a degree. For example, one student at an APS bridge site had failing grades in the first semester, but not because he was incapable of the work. It turned out he was sick and did not know how to seek medical attention. English was not his first language and the culture in the locale of the bridge site was a significant change from where he had spent his entire life. The Bridge Program site leader discovered he was having trouble navigating the campus healthcare system and arranged for him to seek treatment.

He has now completed his courses and is on his way to a PhD—he just needed a little more attention than students are sometimes offered. The Bridge Program does not coddle students, but it is designed to head off easily fixed problems that many physicists, often from well-supported backgrounds or positions of privilege, may not encounter or even notice. Failing to see class distinctions associated with finances, race, gender, and other factors can result in biases working against students.

What did we learn?

Establishing the APS Bridge Program was motivated by a glaring gap in educational attainment for underrepresented racial and ethnic minority students and by the knowledge that a small-scale solution had been successfully implemented at a few universities. There was a clear place for a professional society to provide the community with a service that would address the gap and bring the solution to scale. We did not anticipate the degree to which physics departments across the country would step up to the challenge of supporting bridge students. Sustaining those efforts is key to a long-term solution, we believe.

Central to the success of all bridge programs, and ultimately of any student who may need help in the transition into graduate school, is a rethinking of admissions and student support. Through our many discussions with students and faculty mentors, and more recently by gathering data from graduate programs across the US, we have come to a clearer understanding of the limitations of the physics GRE and other measures used in the admissions process. Many faculty already implicitly understand the limitations of these measures, but that knowledge is neither ubiquitous nor backed by peer-reviewed data to help influence the actions of cautious admissions committees. We realized early on that there was substantial demand for a more thorough investigation into discovering what application data are really telling graduate admissions committees.

To address that demand, we gathered data on a large fraction of physics graduate students and found that many of the

BOX 1. PHYSICS GRADUATE STUDENT ASSOCIATIONS

If your department is looking for a great way to help retain students, consider what is perhaps the most powerful concept we have seen—a physics graduate student association (PGSA). Analogous to undergraduate physics student clubs, such associations are more prevalent at PhD-granting institutions than at universities whose terminal physics degree is a master's. Nonetheless, PGSAs can work in all settings. They are inexpensive for a department to support, provide advice that entering students trust and understand, and build bonds that help students adjust to new and intellectually challenging environments.

To ensure sustained leadership and yet allow student leaders to maintain focus on their research, PGSAs such as the one shown here at Ohio State often have a rotating chair line, where students cycle through positions in successive years, avoiding burnout and building leadership skills. At almost every university where we have visited and discussed the concept, students have overwhelmingly been in favor of a PGSA, and they quickly start one if none existed beforehand. In addition to providing peer mentoring and social functions for graduate students, PGSAs can provide students' perspectives to faculty committees. Representation at that level can go a long way toward helping students advance professionally. (Photo courtesy of Michael Poirier.)

BOX 2. AN ADMISSIONS AND MENTORING CASE STUDY

Admission difficulties

Fernand Eliud Torres Dávila, pictured here with one of his mentors, Ahlam Al-Rawi, is driven to get a physics PhD. While an undergraduate, he carried out research both in Puerto Rico and at the University of Nebraska–Lincoln, where he demonstrated a firm grasp of the concepts and his dedication to research. Despite that success, Torres Dávila received no offers of admission to PhD programs when he applied. However, faculty leaders at the University of Central Florida (UCF) saw promise and accepted him into their bridge program in 2015.

Early struggles

It became clear that Torres Dávila needed to take a few undergraduate courses on his arrival at UCF. But even in those courses he was not ready to proceed unassisted. Poor performance on the first homework set was flagged by UCF mentors. His problem was time management and an inability to effectively interact with course instructors. From then on he met with a mentor on a weekly basis to ensure that he remained on track, sought help from course instructors when needed, and kept up with the rest of the class. With a little supervision and hard work on his part, he was able to focus and receive passing grades.

Success!

Early intervention by UCF mentors helped Torres Dávila adjust to graduate school. He is now doing well as an MS student and ready to move on to a PhD program. He completed the 2015–16 academic year with two graduate-level core courses and four upper-division undergraduate courses to his credit and will complete all graduate core courses next spring. During his first year in the Bridge Program, he also carried out research in an interdisciplinary materials-research group, made a poster presentation, and was a coauthor on a manuscript submitted for publication.

UCF site leader Talat Rahman says, "Without the Bridge Program, he might not have made it. At this point Fernand is self-assured, engaged in helping others, and moving on with his own goals. He has been very helpful to new bridge students." (Photo by Talat Rahman.)

numeric measures used in admissions, including undergraduate grade point average (GPA) and GRE scores, are not always reliable predictors of success. If used, they should be considered carefully alongside other indicators, but never as a cutoff. The object lesson is that while the way our community practices admissions may yield qualified candidates, it is also inadvertently introducing bias—obscuring a number of individuals who could be successful. Since departments are less likely to admit these students using traditional admissions rubrics, an unseen bias is introduced into the process. This idea is one significant reason why NSF no longer requires the GRE for its prestigious Graduate Research Fellowships.

If we, as a community, want to make sure there are opportunities for everyone, then we need to recognize that some of the problems we must overcome are found outside J. D. Jackson's *Classical Electrodynamics*. Some problems affect students in ways that we probably cannot immediately perceive. Fortunately, once we are made aware of them, many of these issues can be overcome relatively easily using resources and providing attention to students. Supporting students who didn't get the same encouragement that many of us did and adopting a more nuanced approach during admissions, looking at potential rather than just accomplishments, are practices that will benefit everyone. URM students may not immediately see themselves as a part of our community, but with a little tweaking of our practices, they can join us in this exciting pursuit we call physics.

The APS Bridge Program is one way to do this, and hopefully it can reveal some of the ways we can make that path better for all students to come.

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