2017 GRADUATE EDUCATION CONFERENCE REPORT

A CONFERENCE TO DISCUSS THE STATUS AND FUTURE OF GRADUATE EDUCATION IN PHYSICS

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Geraldine Cochran, Theodore Hodapp, and Erika Brown, editors, *2017 Graduate Education Conference. A Report on the 3rd Graduate Education in Physics Conference* (American Physical Society, College Park, MD, 2018)

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Executive Summary

Directors of graduate studies, department chairs, bridge program directors, and graduate students from 64 institutions joined representatives from the public sector, the private sector, and eight professional societies at a meeting convened in College Park, Maryland from February 10, 2017 to February 12, 2017 for the third Conference on Graduate Education in Physics. The conference was held jointly with the American Physical Society (APS) Bridge Program Meeting. The joint meeting, which built on the 2013 graduate education conference and the 2015 APS National Mentoring Meeting and Bridge Program meeting, was organized by the APS and supported, in part, by the National Science Foundation (NSF).

The theme of this joint conference was **Enhancing Diversity in Physics Graduate Education**. Five plenaries and 15 workshops addressed this theme in various ways. Fifty-five graduate students presented their research through poster presentations. To frame discussions that took place, plenary sessions provided information on:

- The current status and future of graduate education in physics;
- Preparing students for private sector employment; and
- Results of recent research studies on graduate admissions in physics.

Enhancing diversity in graduate physics education requires increasing the representation of graduate students who identify as ethnic or racial minorities. To support departments in these efforts, sessions provided:

- Strategies for recruiting diverse applicants to graduate programs;
- Guidelines for creating graduate admissions practices that enhance diversity and comply with federal and state laws; and
- Tips for creating and sustaining successful bridge programs.

Improving departmental climates for all students is one way to enhance diversity and increase the likelihood that students admitted to graduate programs are successful and retained. Workshops offered participants strategies for:

- Engaging in culturally relevant mentoring;
- Understanding and addressing implicit bias;
- Retaining graduate students through mentoring and academic support; and
- Creating and supporting physics graduate student associations.

Making changes that will enhance diversity in individual programs and institutions requires institutional support and departmental buy-in. To support faculty in garnering support and implementing change within their institutions, sessions addressed ways to:

- Plan programmatic innovations that advance equity and inclusion; and
- Implement and support institutional change.

The concluding plenary discussed ways in which professional societies can support departments in their efforts to enhance diversity. Representatives from APS, the American Institute of Physics, the National Society of Black Physicists, and the National Society of Hispanic Physicists discussed how their organizations support students and faculty.

APS gratefully acknowledges NSF's support in helping make this conference possible. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

Findings from Sessions Framing the Conversation

1.1 Status of Graduate Education in Physics

Session Title: Reflections on the Future of Graduate Education in Physics

Speaker: Cherry Murray (Harvard University)

During her plenary talk, Cherry Murray, who served as Director of the U.S. Department of Energy's Office of Science from December, 2015 to January, 2017, said that in the U.S., "physics graduate education is doing extremely well and will go on into the future." She shared several pieces of evidence to support this statement:

- Many of the top 100 research universities are in the U.S.
- There is no expectation that physics funding will change in the future. The number of physics PhDs tracks the level of physics funding. Of the various physics subfields, condensed matter has the most PhDs and the most funding.
- Physics is a key source of national security; it is relevant to a lot of research conducted for the purposes of national security. So the need for physicists will continue in the future. National labs require employees to be U.S. citizens, so there is a sustained need for U.S.-born or naturalized PhDs. The number of domestic first-year graduate students is now higher than the number of international first-year graduate students.
- Physics graduate students indicate that they are content with their education. Seventy-three percent of physics Ph.D.s who are U.S. citizens said they would go through the process of getting a Ph.D. in physics again (See Murray, Slide 15). Most international students also said they would get the degree again.
- Ph.D. graduates are generally able to find employment (See Murray, Slides 18–19 for college majors most and least likely to lead to unemployment and unemployment rates of science and engineering degree holders).

Despite these positive findings, physics faces major challenges in terms of diversity among faculty and among students at the master's and Ph.D. levels:

- Around 23% of both master's-level and Ph.D. physics graduate students are women.
- Only 5% of U.S. citizens getting physics graduate degrees are African Americans, and only 3% are Hispanic Americans (Murray, Slide 5).

Jobs are available for physics Ph.D. graduates, but the nature of those positions is changing. This has implications for physics graduate education:

- While the number of faculty positions in the U.S. will not likely increase dramatically in the near future, the number of non-tenure-track faculty positions will increase. Graduates interested in faculty positions should be prepared for that reality.

- Increasing the number of master's programs in physics will be necessary. These programs can prepare students for the variety of technical jobs that will become available in the near future and serve as a bridge to Ph.D.-level education.

Overall, physics education is doing well. The underrepresentation of women and ethnic and racial minority students is still a major problem, however. One way to address this problem is through understanding and addressing implicit bias, the topic of section 3.2.

1.2 Preparing Students for Private Sector Employment

Session Title: Preparing Students for Private Sector Employment

Speakers: Liesl Folks (University at Buffalo), Newton Frateschi (University of Campinas), Anthony Johnson (University of Maryland, Baltimore County), Kathy McCormick (Department of Homeland Security), and Steve Rolston (University of Maryland)

As Cherry Murray discussed in her talk on the Current Status and Future of Graduate Education, the number of tenure-track academic positions for physicists in the U.S. is decreasing. Thus, some physics graduate students must also be well prepared for private-sector employment.

The plenary "Preparing Students for Private-Sector Employment" addressed this need. The session began with a panel discussion, followed by an audience question-and-answer period and a large-group discussion of needs. The panelists provided valuable information for graduate students interested in entering the private sector and for faculty preparing graduate students for the private sector.

To prepare students for a variety of careers, panelists suggested that physics faculty take the following actions:

- **Develop relationships with industry partners in your area.** Map out major employers in your region, and determine which companies might hire your students. Invite representatives from those firms to give talks at your university and discuss their needs. As part of this effort, university researchers can also provide training or classes to company employees.
- **Prepare your students for work in hostile workplaces**. Recognize that there are many hostile workplaces, and that your students may end up working in such places. Consider what skills you can provide students to help them cope in such situations and change the culture in a positive way. Training graduate students in cultural competency and inclusion may be one way to accomplish this.
- **Don't try to create a curriculum tailored to each student's future employment.** A student who will work for IBM and a student who will work for a hedge fund will need different skills and experiences. Exposing students to people working in a variety of fields can assist students in gaining those skills. Invite people from government and industry to give talks and have lunch with graduate students and postdocs. This will give students an opportunity to learn about skills needed for a variety of fields, and how they can become proficient in these skills. It can also

help guide students who are unsure about their future career paths. Encourage students to ask visitors what they like about their job and what prepared them most for their career.

- **Offer challenging projects to students preparing for industry**. Students may not get great results or tons of publications, but industry employers are often not interested in papers. They want to know if a potential employee can take on a challenging project and stick with it to completion.

Graduate students preparing for positions in the private sector or government should:

- **Develop a reputation for finishing what you started.** Whether it is a file you need to complete, a report you have to write, or a piece of equipment you need to get to the field, you need to stick with the assigned task and follow a schedule until you complete it.
- **Learn to tailor your message for those without your expertise, and be able to explain your work without sounding condescending.** One way to do this is to write 60 to 100 words explaining your research to a family member who does not have knowledge in your field. Another way is to take advantage of outreach opportunities. Could you help a high school student understand the gist of your research and its scientific impact? What about an eight-year-old?
- **Develop your collaborative skills.** Physicists in industry may have to work on large teams, follow the lead of others, and compromise often. Experience in working efficiently in teams is critical.
- **Recognize that different organizations have different personalities**. Ensure that the company you are considering working for is a good fit for you, and that you are a good fit for it. This often requires getting to know people who already work there.
- **Know what kinds of tasks you are interested in doing.** Understanding what a specific job at a given organization will mean for your everyday routine will help you decide whether it is a job you want. Similar to when you were selecting a graduate program, consider whether you could happily do the essential tasks for a given position on a long-term basis. For example, would you mind doing the same task multiple times even after you have mastered it? Or are you constantly seeking out something new and more challenging? This may determine whether or not you want to go into manufacturing.

To succeed in private-sector employment, physics graduates will need to:

- **Understand what they need to thrive at a particular company.** Does a merit-based system exist? If so, how are employees assessed? Do they need to publish a specific number of papers? Are employees evaluated based on their output?
- **Avoid isolation**. Women and ethnic or racial minorities may find it particularly important to seek out comrades and advocate for themselves who will let people know about their skills and how they can partner. Working with others will create more opportunities to publish, give presentations, and receive recognition for work completed.
- **Learn to work effectively with people from other disciplines.** In private-sector and government organizations, teams are often large and interdisciplinary.

1.3 Supporting the Transition to Graduate School Through Core Courses

Session Title: New Developments in Graduate Core Courses

Speakers: Alexandru Maries (University of Cincinnati), Chris Porter (The Ohio State University), and Chandralekha Singh (University of Pittsburgh)

One major goal of the physis graduate core courses is to help graduate students develop functional understanding of core core physics content so that they can apply them flexibly in their research. In this session, speakers led participants in generating a working list of goals for core courses and considered the extent to which assessment and instruction are aligned with these goals. The speakers also shared promising approaches to improve graduate student learning outcomes being implemented at various institutions, both through presentations and through a mock group work session.

The working list of goals and objectives for core courses included:

1. Assess the extent to which students are prepared for the graduate program.
2. Expand upon knowledge gained in undergraduate courses and help students develop deep conceptual understanding of physics principles and concepts (as well as further develop complex reasoning skills) so that they are prepared for their future courses (and research).
3. Prepare students for research. From taking these courses, students build a toolbox with necessary techniques (e.g., computational) that will be useful in their future research.
4. Help students see connections between different subdisciplines of physics, as well as provide an opportunity for students to explore what they want to work on in their research.

In short, core courses should help students develop a deep conceptual understanding of physics so that they are prepared for future courses as well as future research.

Unfortunately, multiple studies suggest that students who take graduate core courses feel overwhelmed by the fast pace of homework and the mathematical sophistication required in order to solve the majority of the problems assigned [Maries and Singh 2012]. Consequently, the graduate students are sometimes unable to make conceptual connections on their own, leading to less than desirable performance on conceptual questions, even at the advanced undergraduate level [Maries and Singh 2012, Bilak and Singh 2007, Porter et al. 2017, Keebaugh et al. 2017].

Takeaways from the discussion on assessment (See slide 8) included:

- The most typical assessments used, homework and exams, mostly test problem solving ability, more so than conceptual understanding.
- A concern is that students may lose the key idea from a lot of mathematical derivations.

Research suggests [Maries and Singh 2012] that instructors who teach core courses are often aware that they themselves rarely make conceptual connections and most of the time try to make sure students understand the mathematical procedures used. Research by DeVore and Singh [DeVore and Singh 2016] found that students sometimes do not develop complex reasoning skills when doing

research using a very commonly used device (Lock-in amplifier): they show difficulty troubleshooting when the results are not the ones they expect.

The main take-away from this discussion is that if a major goal of core courses is for students to develop deep conceptual understanding, assessment must include conceptual questions. Instructors who teach core courses express concern that they do not have the time to develop them [Maries and Singh 2012], but are willing to use conceptual questions if they are provided (either by other instructors or by textbooks).

Suggestions for improving the outcomes of core courses included:

- A lot of what has been developed by physics education researchers for undergraduate physics can be used in graduate physics. There is some research on the effectiveness of these approaches in graduate courses, such as the tutorial approach [DeVore and Singh 2016, Keebaugh et al. 2017] group work [Porter and Heckler, in preparation], and providing ongoing support and mentorship [Hodapp and Woodle 2017].
- Assessment drives learning, so learning outcomes (conceptual understanding) should influence assessments and vice versa.
- Core courses should use active learning as much as possible (see for example “Jackson by inquiry” developed by Bruce Patton at the Ohio State University, where students learn graduate E&M in a manner similar to the flipped model). Class time can also focus on the physics rather than the mathematics: students should consider questions like “what do you think should be the answer to this problem” or “what features should the answer to this problem have” before launching into long mathematical calculations.
- Graduate students often teach as teaching assistants (TAs), and some programs require all TAs to take a course which introduces them to effective pedagogy, which includes information about how students should engage with physics content in order for effective learning to take place. This can help TAs learn how to learn, which can improve their engagement with and learning in graduate core courses.

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1.4 Reflecting on the Graduate Admissions Process

Session Title: Findings on Graduate Admissions Studies

Speakers: Geoff Potvin (Florida International University) and Casey Miller (Rochester Institute of Technology)

Several conference sessions focused on graduate admissions. During the second plenary, "Findings on Graduate Admissions Studies" Geoff Potvin and Casey Miller described what they found when they investigated several aspects of the physics graduate student admissions process. Some of the major findings and takeaways from presentations and discussions during this plenary are described below:

Geoff Potvin discussed findings from his studies of physics faculty perception and practices related to graduate student admissions, as compared to student perceptions of graduate admissions:

- Faculty perspectives and student perspectives on admissions are very different in some areas. Student perceptions of the admissions process are just as important as the actual admissions process.
- Students will often self-select themselves out of physics graduate school—by not applying to graduate programs—based on their perception of the admissions process. In particular, students may believe that prior research experience is required for graduate admissions, and may choose not to apply if they lack that experience.
- Undergraduate women physics majors in their junior and senior years feel the physics community is much less open to women than to men.
- Black undergraduate physics majors in their junior and senior years feel the physics community is much less open to racial and ethnic minority groups than to White students.
- Experiences of racial and sexual harassment are common barriers that prevent students from applying to graduate physics programs.

Casey Miller shared the results of his study of the role that the GRE plays in physics graduate program admissions and its impact on diversity in physics graduate programs.

- Many departments still use GRE cutoff scores, explicitly or implicitly. In these departments, if an applicant has low GRE scores, then the rest of the application must be stellar for the applicant to be considered for admission.
- GRE scores are weakly correlated with students' long-term outcomes in a physics graduate program.
- A student's GRE score is predictive only of their first-year graduate GPA. The Educational Testing Service, which produces the GRE, has acknowledged this and stated that they do not want their tool to be misused.
- There is a significant gender gap with respect to GRE test performance and test taking nationally and internationally. In only four countries do 30 or more women take the physics GRE test.

- Graduate school application fees are also a barrier that can deter students of low socioeconomic status from applying to graduate physics programs.

Recommendations related to these findings

A series of recommendations were generated as a result of this session:

Physics departments should:

- Encourage faculty on graduate admissions committees to review some of the published research studies that APS has conducted on physics graduate program admissions.
    - Investigating approaches to diversity in a national survey of physics doctoral degree programs: The graduate admissions landscape
    - Fixed and growth mindsets in physics graduate admissions
    - Making physics more inclusive
- Not use a GRE cutoff score in their admissions process.
- Use rubrics and holistic admissions processes to identify diverse groups of candidates capable of succeeding as Ph.D. physicists.
- Encourage graduate admissions committees to base admissions decisions on valid and appropriate factors.
- Contact APS about a workshop for your department or admissions committee, with a focus on creating a holistic graduate student admissions process.

APS should:

- Continue to provide a common graduate school application through the APS Bridge Program. The common application allows multiple departments to consider diverse candidates and for students to have their applications considered by multiple programs without having to pay application fees.

Findings and Recommendations for Increasing the Representation of Ethnic and Racial Minorities in Physics

2.1 Strategies for Recruiting

Session Title: Best Recruitment Practices

Speakers: S. Lance Cooper (University of Illinois at Urbana-Champaign), Ramon Lopez (University of Texas, Arlington), and Kate Scholberg (Duke University)

The third plenary, Best Recruitment Practices, consisted of a panel of faculty from three physics graduate programs that have been successful at recruiting. Each panelist spoke for a few minutes about their respective programs and effective recruiting practices, then took questions from the audience. According to the American Institute of Physics' GradSchoolShopper, some physics graduate programs are seeing increases in applicants (Cooper, Slide 4). Panelists shared recommendations for increasing the number and diversity of applicants, based on practices that have worked at their institutions.

These effective recruiting practices include the following:

- Realize that recruiting quality students is your department's job, not the job of your university's admissions office.
- Maintain an accessible web presence:
    - Keep your department's website up-to-date, accessible, and user-friendly. This is often the first place students look when deciding whether to apply to your program.
    - Keep your department's profile on GradSchoolShopper up-to-date. This is another place where students commonly look for information on physics graduate programs.
    - Students also look to see if institutions have provided information on APS's "female-friendly" web page.
    - Know your department's job placement statistics for recent graduates. Include that information on your website and share it with prospective students.
- Recruit at conferences that students attend, such as the APS March and April meetings. A number of identity-based physics professional organizations also host conferences that serve as great opportunities to connect with underrepresented student physicists:
    - National Society of Black Physicists Annual Conferences
    - Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) National Diversity in STEM Conferences
    - National Society of Hispanic Physicists' *Día de la Fsica* (usually coincides with the SACNAS meeting)
    - Conferences for Undergraduate Women in Physics (CUWiP) in your area
- Respond to emails from interested students. Include lots of detail, if possible. Even if you do not currently have room for new students in your program or research group, the information is still valuable.

- Leverage campus resources.
    - Find out what resources your campus provides to recruit underrepresented students, including fellowships.
    - Determine if your dean will provide additional teaching assistant positions that can be used to recruit students.
    - Advertise your institution's Research Experiences for Undergraduates (REU) or internship programs.
    - Connect to other institutions' physics or math REU programs to create a pipeline to your graduate program.

Panelists also shared tips for attracting prospective students once they've applied to your program (Cooper, Slides 9–11):

- Make offers of admission early and encourage prospective students to visit your campus.
- Let prospective students know that you will support them throughout their matriculation and that you are genuinely interested in having them join your department.
- Explain to prospective students how their graduate study would be funded and that they will have health insurance.
- Stay in touch with prospective students and cultivate relationships with them. Maintaining partnerships with pipeline institutions or programs can help with this.
- When prospective students visit, engage current graduate students in recruiting events. Having an active graduate student association can help significantly with this. Make sure your graduate students are engaged and interested in recruiting diverse applicants.
- If your institution offers application fee waivers for financially disadvantaged students, make all prospective students aware of this option.

Presenters emphasized the importance of creating an inclusive environment and ensuring graduate students are happy. Below are some recommendations for making that happen in your department:

- Offer lots of professional development opportunities for graduate students.
- Offer help with National Science Foundation fellowship applications.
- Help graduate students find job opportunities. Create a jobs database. Provide an internship program.
- Fund a Physics Graduate Student Association and make sure it has resources to provide social activities. Provide small incentives for the services the association provides, including hosting prospective students.
- Communicate with faculty regarding graduate student needs.
- Be cognizant of department needs and how recruiting diverse students can serve those needs.

2.2. What You Should Know about Graduate Admissions

Session Title: Enhancing Diversity through Admissions Practices

Speakers: Casey Miller (Rochester Institute of Technology) and Julie Posselt (University of Southern California)

In this workshop, Casey Miller and Julie Posselt of the National Science Foundation-funded APS Inclusive Graduate Education Network discussed research on graduate admissions, legal cases and precedents that affect graduate school admissions, and ways to create admissions practices that may enhance diversity while adhering to national and state laws.

Past legal decisions have a major impact on what is allowable during the graduate admissions process. Multiple Supreme Court cases have considered affirmative action programs at various universities (Miller and Posselt, slide 2–13).

- In the 1978 Bakke decision, the Court stated that race is a permissible "plus factor," but policies must be "narrowly tailored" to achieve diversity.
- In the 2003 Gratz and Grutter decisions, the Court noted that race can be considered as one of many factors in a holistic manner.
- In the 2013 and 2016 Fisher decisions, the Court noted that a college must offer a reasoned, principled explanation for diversity, and race-conscious admissions must be narrowly tailored to achieve diversity goals and withstand strict scrutiny. The Court stated that universities should demonstrate that diversity cannot be achieved through means that don't require the consideration of race.

In some cases, state and institutional decisions regarding affirmative action also dictate what is allowable and what is not in terms of admissions.

- Eight states have banned affirmative action. (Miller and Posselt, Slide 10)
- Some institutions, such as the University of Georgia, have banned affirmative action. (Miller and Posselt, Slide 10).

In states that have not banned affirmative action, key principles from the Bakke decision (Miller and Posselt, Slide 11) must still be adhered to:

- Reserving seats or shares of seats for underrepresented students is not permissible.
- Reviewers should use a common evaluation process for all applicants.
- Race should be just one of several individual characteristics assessed as a "plus factor."
- Every applicant should be evaluated as an individual, not assumed to represent a broader identity category.
- Programs should not single out specific racial or ethnic groups, but consider contributions that all groups make to diversity.

This workshop also covered when and how to discuss race in the admissions process:

- Under specific conditions, race-conscious admissions policies are constitutional, outside the states and institutions that have banned affirmative action.
- Universities and graduate programs must seek diversity in multiple ways and have a "reasoned, principled explanation" for diversity's value in their context.
- Weighing race as an admissions consideration differs from accounting for how the dynamics of race in the U.S. may shape the distributions of applicants' grades, test scores, and institutional affiliations, and the viewpoints that applicants are likely to contribute to an institution or program.
- Admissions committees need not be color-mute, but will be best protected legally if their admissions policies are clearly defined. Ad-hoc policy is hard to defend.

Creating well-defined graduate admissions policies and rubrics that abide by the law and increase the likelihood of admitting students who will be successful in your program can be beneficial. Miller's and Posselt's presentation includes slides on using non-cognitive competencies and rubric development (Miller and Posselt, Slides 29–51). If you are interested in having a workshop on graduate admissions or developing graduate admissions policies and/or rubrics at your institution, APS can connect you with experts offering such workshops.

2.3 Creating and Sustaining Successful Bridge Programs

Session Title: The Nuts and Bolts of Bridge Programs

Speakers: Jay Gupta (The Ohio State University), Kelly Holley-Bocklemann, (Vanderbilt University), Çagliyan Kurdak (University of Michigan), Alexander Rudolph (California State Polytechnic University, Pomona)

Representatives from four successful bridge programs shared some of the practices and structures that make their programs successful, as well as strategies they have developed for working with their unique student populations.

The APS Bridge Program at The Ohio State University has, Since 2013, has admitted 12 bridge students (Gupta, Slides 15–19). The proportion of ethnic and racial minority students in Ohio State's physics Ph.D. program has increased from around 3% prior to 2013 to 17% now, through both the bridge program and regular admissions.

The Fisk-Vanderbilt Masters-to-Ph.D. Bridge Program is a partnership between Fisk University and nearby Vanderbilt University in Nashville, Tennessee (Gupta, Slides 1–14). It was the first bridge program in physics and astronomy, and is one of the most successful. Since the program's inception in 2004, it has accepted 110 bridge students, 55 of whom have transitioned to Vanderbilt's or another institution's Ph.D. program. Vanderbilt has awarded 25 Ph.D.s to bridge alumni, all of whom have gone on to successful careers in science, technology, engineering and mathematics.

The Applied Physics Imes-Moore Fellows Program at the University of Michigan has leveraged the department's diverse faculty (which consists of around 30% ethnic and racial minorities and around 30% women, created a family-like culture, and focused on keeping graduate students happy and preparing them for a broad range of careers. As a result, the program attracts quality students and graduates a significant number of ethnic and racial minority physics Ph.D.s.

The California State University (CSU) system has two bridge programs: the Cal-Bridge Program and CAMPARE (Gupta, Slides 20–27). Cal-Bridge offers students a joint-mentoring program run by CSU and University of California faculty, professional development opportunities, and research experience. Program faculty works closely with community college partners. Program leaders are currently looking for partners outside of California, in order to expand the program nationally.

The CAMPARE program is a summer research program that primarily serves astronomy students. Most participants are first-generation college students. Of the 50 participants who finished their bachelor's degrees, one third went on to Ph.D. programs.

Representatives from the four bridge programs also described some of the benefits that implementing bridge programs has provided to their departments. These include:

- An increase in ethnic and racial minority applicants to the traditional Ph.D. program;
- Greater awareness of climate-related issues, and improved departmental climate as a result of addressing those issues;
- More experience in mentoring and supporting students with mental-health issues;
- Finding ways to create and sustain academic support that benefits all graduate students;
- Learning to support and prepare bridge students for entry into their own doctoral programs; and thus increasing enrollment in their Ph.D. programs;
- Learning to take risks on students who may not "look ideal on paper," but who were passionate and driven and turned out to be high-quality;
- Developing or strengthening relationships with other institutions, including community colleges.

Bridge program representatives shared strategies they have used to build successful programs. Recommended practices include:

- Understand the stresses associated with graduate school and plan ahead for supporting students when issues arise.
- Keep graduate students engaged and interacting with one another through regular social activities.
- Remind students that they are part of a cohort of peers all going after the same thing, to encourage them to work together and support each other.
- Ensure that students choose research advisors wisely, and encourage them to go beyond just looking at a professor's web page when researching a potential mentor.
- Engage mentors at the postdoctoral level. Postdocs can provide practical advice and give students an idea of what their next career stage will be like. Interaction with postdocs can also

give graduate students something immediate to look forward to upon completion of their Ph.D. programs.
- Provide lots of professional development, including seminars on how to find jobs after graduation, how to prepare for industry positions, and how to transition to new jobs.

If you would like to know more about bridge programs, reach out to the APS Bridge Program to learn from—or become part of—a large network of departments improving graduate education. You may also want to view the APS Department of Education and Diversity Graduate Student Induction Manual. This manual is based on reports from a number of bridge programs and includes specific advice on implementing a bridge program, challenges faced by bridge programs, and how these challenges can be overcome.

Findings and Recommendations for Creating Inclusive Environments in Physics Departments

3.1 Engaging in Culturally Relevant Mentoring

Session Title: Culturally Sensitive Mentoring

Speakers: Brian Beckford (University of Michigan), Ximena Cid (California State University Dominguez Hills), Michael Falk (John Hopkins University), and Mel Sabella (Chicago State University)

One of the more popular workshops was entitled "Culturally Sensitive Mentoring." Faculty members from a variety of cultural backgrounds described steps both faculty and graduate students can take to develop meaningful mentoring relationships across cultural lines. Presenters also discussed things that helped them feel supported within the larger physics community.

Strategies suggested for faculty were broken into three major categories: communication, visibility, and identification of resources.

Communication

- Recognize that your mentee's background may influence the barriers that they see as impeding their success, and give them space to talk about this.
- Recognize that as a physicist, you are probably not trained in counseling or psychology, and you may find mentoring emotionally draining.
- Realize that in a mentoring relationship, two people learn from each other. Take time to learn about the challenges your mentee faces and consider how you can relate to them.
- Understand that students may not share important information with you because of prior negative experiences they may have had as a result sharing information. They may not be comfortable sharing personal situations, even those that affect their academic progress. And they may not want to become emotional in front of their mentors. Mentees may also be reluctant to be open with mentors who also serve as research advisors, out of fear of disappointing their advisor or admitting weakness.
- Understand that sometimes mentoring is just listening. Physicists want to solve problems, but sometimes that is not what is wanted or needed by mentees. Sometimes it is more important to just listen to a situation and how a student is feeling about it.
- Make it explicit to mentees that they will get the support they need to succeed.

Visibility

- Be visible. Let students know where you stand on issues that affect their emotional well-being. For example, when situations arise that gain national attention and could be triggering to students, it may be helpful to check in with students.
- Demonstrating visibility can take many forms. Putting hashtags, signs, or papers signifying issues you care about or matters you believe in, on your door can demonstrate visibility, as can attending or participating in campus events and activities related to Martin Luther King, Jr. Day,

Black History Month, Hispanic Heritage Month, Women's History Month, and/or LGBT History Month.

Identification of Resources

- Support mentees in attending national or international conferences where they will meet physicists and scientists who share their ethnic, racial or gender identities. Examples of organizations holding such conferences include the Society for Advancement of Chicanos/Hispanics and Native Americans in Science, the National Society for Hispanic Physicists, the National Society for Black Physicists, the American Indian Science and Engineering Society, and the International Conference on Women in Physics.
- Help students seek support for emotional or mental health issues from professionals, as needed. Let students know that this need is perfectly normal, and that it is not a sign of weakness. Help them navigate setting up an appointment, if needed. If you or your department have a connection to a mental health professional, it may help to introduce and refer students to that individual.
- Encourage your department to invest time and money in diversity, inclusion, and equity efforts.
- Inform your students about appropriate opportunities for professional development. Then check to make sure they have followed through. Even if a student is interested in an opportunity, they may, for various reasons, believe they do not belong or are not qualified. You may have to encourage them multiple times.

Suggestions for graduate student mentees focused on helping them build and understand their relationship with their mentors. These include:

- Ensure that the person you choose to vent to is comfortable with that role, so you do not cross professional boundaries.
- Share your communication style with your mentor and/or research advisor, and explain how you practice as a physicist.
- Learn who at your institution is a "mandatory reporter" under Title IX, and who is not.

Suggestions for departments focused on developing faculty's mentoring skills. These include:

- Encourage faculty to participate in mentoring workshops that will help them hone mentoring skills and learn strategies for having difficult conversations.
- Support participation in the APS National Mentoring Community (NMC). Although NMC mentees are undergraduate students, this community provides information and workshops on mentoring both undergraduate and graduate students.

Workshop leaders expressed how important it is for APS to take a stance on issues that can make physicists feel less welcome in the community. One example of APS's work in supporting physicists was its stand in 1992 against Colorado's "No Protected Status for Sexual Orientation" amendment. APS decided not to hold meetings in Colorado if the initiative went into effect. This statement signaled that there were physicists who believed the contribution of LGBTQ+ physicists was valid and that they

should be able to do physics anywhere. APS also sponsored a study on the climate for LGBT physicists.

Suggestions for APS:

- Take a stand on political issues that affect its membership.
- Continue to support climate-related studies on issues that its members face.

3.2 Understanding and Addressing Implicit Bias

Session Title: Implicit Bias and Self-Advocacy

Speaker: Angela Johnson (St. Mary's College of Maryland)

Participants came to the Implicit Bias and Self-Advocacy workshop with hopes of identifying biases, exploring their own implicit biases, developing strategies for mediating biases, and learning how to better support students in their departments. Implicit bias refers to unconscious attitudes or stereotypes that affect our understanding of others, actions toward others, and decisions related to others. Participants learned that implicit bias among faculty, students, or others may cause some students to face challenges unrelated to their willingness to work hard and their potential to be successful.

However, there are strategies that can help faculty to address their own biases and support students facing bias-related challenges within their departments (Johnson, Slide 19). These include:

- Stereotype replacement
- Counter-stereotypic imaging
- Individualism
- Perspective taking
- Increased contact

Stereotype replacement requires addressing our own stereotype-related biases head-on. To use this strategy, we first must recognize that a thought we had or a statement we made was motivated not by reality but by a stereotype. Then, we must think about where this thought or statement actually came from. This process can help avoid biased stereotypical thinking or statements in the future.

Counter-stereotypic imaging is a tool for addressing our own implicit bias. Faculty can engage in counter-stereotypic imaging by imagining or reflecting on people who do not conform to negative stereotypes. For example, one might imagine or reflect on a group of women physicists presenting their research at a national conference, to counter the stereotype that women are not good at physics.

Individualism is the practice of intentionally seeing others as individuals rather than as part of a larger group. For example, if we are assessing an African-American student's potential for success in our

research group, we can intentionally think about what we know about that student as an individual and what that says about their potential for success, rather than evaluate them based on what we might think or feel about African-Americans engaged in research.

Perspective taking involves engaging in any activity that presents someone else's perspective. This could include reading a novel about someone from a different background or thinking about how someone from a different background might experience a situation.

Finally, **increased contact** involves increasing the amount of time we spend in our professional and personal lives with people from backgrounds different from our own. Doing this may help us confront our own biases through stereotype replacement and provide examples of counter-stereotypes. We may also find it easier to see people we engage with in our personal lives as individuals rather than as members of identity groups, and we are more likely to encounter and understand their perspectives in different situations. Thus, increased contact with members of marginalized groups will aid us in engaging in all of the previous strategies.

Discussion within the workshop revealed recommendations for both physics departments and APS.

Departments should:

- Encourage faculty to participate in workshops on implicit bias, to learn more about the strategies above and how they can be implemented in their departments.

APS should:

- Help coordinate workshops on implicit bias, facilitated by physicists and physics education researchers, for interested departments.

3.3 Retaining Graduate Students through Mentoring and Academic Support

Session Title: Best Retention Practices

Speakers: Brian Beckford (University of Michigan), Geraldine Cochran (Rutgers University), Casey Miller (Rochester Institute of Technology)

Some APS Bridge Program sites boast retention rates as high as 90%. What can we learn from these programs? In the Best Retention Practices workshop, Brian Beckford and Geraldine Cochran, former APS Bridge Program managers, and Casey Miller a former bridge program site leader, shared what they have learned from evaluating and supporting a number of bridge programs nationally.

Beckford said that a holistic admissions process is the first step toward achieving high retention rates. (See Miller, Cochran and Beckford, Slide 9; See Miller and Posselt presentation fr discussion of holistic admissions.) Presenters recommended that physics departments incorporate the following best practices in their admissions process:

- **Consider strategies not traditionally used for graduate student admissions.** For example, in interviews, ask students about the personal context for why they are interested in graduate school. For more examples on admissions practices that support diversity, see Julie Posselt's and Casey Miller's presentation, "Enhancing Diversity Through Admissions Practices."
- **Find out what fields students are interested in and why.** This will help clarify whether your program a good match for particular students' interests, and whether your program can provide appropriate research opportunities.
- **Determine how invested potential students are in getting the Ph.D.** If this is not discussed in an interview, it could be included as an application essay question.
- **Help students do an accurate self-assessment of their preparation.** Such a self-assessment includes much more than a student's GPA. For example, ask what courses a student took as an undergraduate, what textbooks they used, and how far they got in the textbooks. How comfortable did they feel with the material presented? APS Bridge Program sites have found that giving potential students content assessments or tests prior to admissions has not helped students self-assess, and that asking the right questions during pre-admissions interviews is key. (For further discussion and suggestions on questions to include in student interviews, please refer to the APS Bridge Program Graduate Student Induction Manual).

Workshop leaders also indicated that admitted students will benefit from support prior to their arrival and matriculation on campus. The following are important things to consider:

- **Ensure students have information on appropriate housing.** Living far from campus can make it hard to attending office hours, work regular hours in the lab, and attend peer study groups. Students may also need help finding affordable housing. Financial stress resulting from expensive housing have forced some students to take on extra jobs, creating academic challenges.
- **Help students connect to cultural spaces on campus and in their community before classes start.** A strong support system is essential to graduate students' success. If first-year courses prove challenging, students are less likely to seek out support systems after classes start. However, if they make these connections before classes start, such systems can often support and retain students through a challenging first or second year. Current graduate students can help in these efforts. A Physics Graduate Student Association, in particular, can collect resources and help incoming students make connections. (See Creating and Sustaining a Physics Graduate Student Association)
- **Create a formal peer-mentoring structure or program.** Students will relate to their peers differently from how they relate to faculty, and will often open up to their peers about their needs and challenges in ways that they will not with their research advisors or faculty mentors.
- **Use assessments to place students in appropriate courses.** Accurate course placement influences a student's self-esteem and their content knowledge. Underestimating or overestimating student readiness can lead to both academic and affective challenges. Transparency in this process is also extremely important. Students who feel that their department has unwarranted low expectations for them are not likely to be retained. If students are placed in undergraduate courses, they should know why. This is especially important if their

peers are placed in different classes. Having new students speak with other graduate students who have benefited from taking some undergraduate courses can also help.

Presenters also noted that early interventions, have the largest effects. That means problems need to be identified early. Effective mentoring can increase the likelihood that problems are addressed early. Specific suggestions related to mentoring include:

- **Formalize faculty-student mentoring programs.** Some departments have found it beneficial to hold mixers at the beginning of the semester. This provides students and faculty with an opportunity to get to know each other in an informal, low-pressure environment. In this setting, mentoring relationships form organically. Note that some students find it difficult to have their research advisor(s) as mentors. They do not feel comfortable discussing their challenges with advisors, because they want to make good impressions. It may be appropriate to ensure students have additional faculty mentors who are not their research advisors.
- **Early on, schedule individual mentor meetings regularly and often.** Presenters recommended starting with weekly meetings. As time passes, they may be needed less frequently.
- **During mentoring meetings, ask students about how they are doing overall, not just in relation to coursework.** This is especially important early on, to build trust and mutual understanding. Ask students how they like the location where they are living, if they have any family in the area, and if they are affiliated with any religious groups. It is important to discuss academics tas well, but this will likely come up naturally and organically. It should be apparent that mentors care about their students as a whole person, and not just in terms of their success in the program. This is especially important for women and ethnic and racial minority students who may have been tokenized in the past.
- **During initial mentoring meetings, ensure that students are aware of the department's expectations.** Be aware that what students need to be successful in your program may differ drastically from what they needed to do to be successful at their undergraduate institutions. For example, students need to know whether they are expected to attend department seminars, and when and how long should they be in the lab.. Do not assume that students are on the same page as their advisors when it comes to this. Have this discussion explicitly, and follow up in writing to ensure that communication is clear. Some programs provide students with contracts that detail expectations.
- **Ensure that students know the milestones built into in the program, and are given regular feedback regarding where they need to improve, and where they are doing well.** Be specific when it comes to commendation. "You're doing great!" is not helpful. "I like how you thought about possible solutions before presenting the problem to me," might be more helpful. Students need to know exactly what they are doing right and should continue doing.
- **Consider setting up group mentoring meetings.** Meetings of specific groups of students (e.g. cohorts of graduate students, or bridge students) should be mandatory from the beginning. Otherwise, students will check out, particularly as their workload increases throughout the semester.
- **Use group mentoring sessions to capitalize on the strengths of high achievers.** Is one student particularly good at coding? Have that student lead a coding session for their peers.

This will advance the knowledge of the entire group, provide positive feedback to the high-achieving student, and boost confidence. Understand that students may excel in some areas and struggle in others. To the extent possible, capitalize on and highlight the areas in which individual students excel. This will help students overcome self-doubt resulting from challenges they have in other areas.

- **Recognize your limitations as a mentor.** One person cannot provide for every student's mentoring needs. Students may need more support than you are able to provide, or specific kinds of support that you are unable to provide. Is there a network of other professionals on campus to which you can refer students? Build a network of potential mentors for your students.
- **Be transparent with students when information that is discussed in mentoring meetings will be shared.** Sharing a student's personal information without permission may be perceived as a violation of trust. Be explicit about what information might be shared with whom and why.
- **Encourage students to participate in organizations in which they can make cultural and social connections on campus.** This includes multicultural centers, Q or LGBTQ centers, and religious student organizations.
- **Encourage students to participate in identity-based professional organizations.** Organizations like the National Society of Black Physicists, the National Society of Hispanic Physicists, the Society for Advancement of Chicanos/Hispanics and Native Americans in Science, and the American Indian Science and Engineering Society are great for building student support systems and for professional development opportunities. It is important for students to realize that there are physicists and scientists who look like them and can relate to them in ways that people in the department may not. (See What Professional Societies Can Do)

For a more detailed discussion of best practices for retaining graduate students, please refer to the APS Bridge Program Graduate Student Induction Manual. The manual documents effective practices for inducting new students into graduate programs, as identified and described by APS Bridge Program sites. It also includes specific strategies for developing a solid foundation for students before and after their arrival on campus.

You can download a pdf copy of the entire manual or browse section-by-section on the APS Bridge Program website.

3.4 Creating and Supporting Physics Graduate Student Associations

Session Title: How to Create and Sustain a Physics Graduate Student Association and How to Support a Physics Graduate Student Association

Speakers: Adewale Akinfaderin (Florida State University), Sara Mueller (The Ohio State University), Ashlee Wilkins (University of Maryland, College Park), Garrett Matthews (University of South Florida), and Jon Pelz (The Ohio State University)

A number of physics departments have found that Physics Graduate Student Associations (PGSAs) can improve the overall climate for graduate students. In a two-part workshop, graduate student leaders and faculty shared advice on how to create and sustain PGSAs and explained how PGSAs have benefited their departments.

First, in "How to Create and Sustain a Physics Graduate Student Association," PGSA members at Florida State University (FSU), the Ohio State University, and the University of Maryland, College Park described best practices for developing PGSAs. They outlined a step-by-step process for creating a PGSA:

1. Find committed students with leadership potential who are interested in forming a PGSA.
2. Form a constitution committee.
3. Meet with stakeholders including students, the graduate director, and the department chair, to discuss how the PGSA and department can support one another.
4. Meet to ratify the constitution and elect PGSA leadership.
5. Choose a faculty advisor. This should be someone who cares about students.
6. Contact PGSAs at other universities to get tips and advice.
7. Apply to become a recognized student organization at the university.
8. Seek funding from stakeholders.
9. Carefully plan the first organized event or meeting. Making a good first impression is very important.
10. Develop a feasible advocacy plan. Survey students to find out what they think is important and how they want this organization to advocate for change.
11. Set goals for the PGSA. Discuss what the organization's role be within the department, and what it will do for students.
12. Delegate work among many people, but in a very structured way.

For more details and an example objective statement for a PGSA, please see Akinfaderin, Slides 4–5.

The student presenters also discussed ways that PGSAs have fulfilled their objectives in supporting physics departments (Akinfaderin, Slides 7–11):

PGSAs have supported graduate student recruitment efforts by:

- Hosting potential students in members' homes during departmental open houses;
- Creating career and professional development resources that are attractive to potential students; and
- Improving the climate of the department.

PGSAs have supported graduate student retention by:

- **Creating a peer-mentoring "buddy" system that matches incoming first-year students with current graduate students.** Peer mentoring helps incoming students acclimate to their new environment, both academically and socially. At FSU, this relationship often starts before students arrive on campus. Buddies have picked up incoming students from the airport, helped them locate housing and build networks within the local community, and identified mental health and financial resources available on campus.
- **Providing practical advice for fellow graduate students in a written "survival guide."**
- **Organizing and facilitating seminar series and workshops** on topics including finding a graduate mentor, joining a research group, and improving time-management skills. PGSAs have also organized practice sessions for research presentations.
- **Improving the overall climate of the department by facilitating conversations between students and faculty.**
- **Providing academic support to peers in the form of tutoring for first-year courses and preparation for qualifying exams.**

Despite all of their benefits, sustaining a PGSA can be challenging for a number of reasons. Workshop leaders provided strategies for overcoming these challenges:

- **Create a budget that details how funds will be spent and the impact of each PGSA activity.** Finding sustained funding to support a PGSA can be difficult. A written budget can be used to submit proposals to the physics department chair or college dean, and to apply for support from university-wide sources and student organizations or activities offices.
- **Develop an organizational structure that allows for passing of the torch.** It is recommended that leaders, particularly presidents, commit to a two- or three-year term as president-elect, president, and past-president, so that organizational knowledge is passed along.
- **Seek out multiple faculty advocates.** If faculty don't value a PGSA, students will not put time and effort into the organization. This will make recruiting difficult, and low membership will result in a heavier burden on members, which can lead to burnout.
- **Highlight the benefits for students participating in the program.** In addition to leadership skills, student participants can also gain experience in valuable career skills such as proposal writing, budgeting, project management, and collaborating with diverse teams.

The faculty-focused session "How to Support a Physics Graduate Student Association" was led by Garrett Matthews and Jon Pelz, both APS Bridge Program site leaders at institutions that support

PGSAs. Matthews and Pelz shared a number of ways that faculty can support the creation and maintenance of PGSAs (See Pelz and Matthews, and Akinfaderin, Slide 4):

- Identify diverse groups of students who would benefit from participating in PGSA.
- Provide funding to support PGSA activities.
- Meet with the PGSA regularly to get a sense of the organization's priorities and progress.
- Provide dedicating faculty and staff to support and advise the organization.
- Acknowledge, and, if possible, reward financially student leaders whose efforts have a positive impact on the department.
- Address students concerns in appropriate and timely ways.
- Include students in faculty meetings and on faculty committees.

Support for Faculty Implementing Change within Their Institution

4.1 Planning Programmatic Innovations that Advance Equity and Inclusion

Session Title: Planning Programmatic Innovations that Advance Equity and Inclusion

Speaker: Sheila Kannappan (University of North Carolina at Chapel Hill)

This workshop provided participants with practice in planning changes in their own program. The presenter started by describing the situation at her institution, the University of North Carolina at Chapel Hill (UNC–Chapel Hill), just four years prior. The graduate student body in the physics department was far less diverse than what the faculty wanted. Women and ethnic and racial minorities were severely underrepresented in the graduate program, and the retention rate of all graduate students needed improvement. However, after department faculty made several changes, the representation of women in the graduate program climbed from 14% to 32%, the representation of underrepresented ethnic and racial minority students grew from 0% to 8%, and graduate student retention increased from 75% to 96%.

Dr. Kannappan described some of the effective changes her department made:

- Offering training for faculty on topics such as unconscious bias, sexual harassment, and LGBTQ awareness.

- Modifying admissions policies and procedures, to encourage diversity in the student body:
    - **Admissions committee members began using holistic admissions practices in evaluating applicants.** Specifically, committees instituted rubric-based grading, weighed the GRE less heavily, and paid attention to non-cognitive variables. Committee members also began paying greater attention to contributions to diversity in their post-admissions recruiting.
    - **Graduate application essay instructions were revised.** The new application instructions requested that applicants submit at least one page explaining past experience, personal reasons for interest in graduate study in physics and astronomy, and additional information the applicant would like the committee to know.
    - **UNC–Chapel Hill became an APS Bridge Program Partnership Institution.** This allowed the department to recruit from the program's diverse student application pool.

- Changing policies, procedures, and support mechanisms for current graduate students.
    - A first-year advising team was created to provide direction to first year students.
    - The first-year seminar was revamped to focus on topics including non-academic careers, imposter syndrome (a situation in which individuals have difficulty internalizing their accomplishments and fear being exposed as a fraud or imposter), test anxiety, finding advisors, computing basics, and applying to the National Science Foundation Graduate Research Fellowship Program.

    - Senior graduate students offered preparation for the qualifying exam to first-year students.
    - Department policies were changed to allow one qualifying exam deferral and one first-try fail.
    - A departmental diversity committee and a graduate student diversity liaison position were created.

After discussing the implementation and successes of some of these initiatives, participants in this workshop identified initiatives to implement in their departments and designed plans for doing so. To design these plans, participants used the following process:

- **Categorize innovations:** Determine if each initiative will have a major impact or a minor impact on the department and on graduate students, and if it requires a short-term or long-term effort.
- **Specify contexts:** Write down the optimal context for making each initiative happen (for example, a discussion with the department chair, work with a committee, implementation in the classroom, a department meeting, obtaining institutional approval).
- **Identify allies:** Write down the names of people or the institutional roles you could tap to support your proposed innovations.
- **Plan for lasting change:** Think about how to make the desired innovations sustainable. Can you formalize roles and changes in policies or procedures?
- **Set priorities:** Decide which innovations you want to tackle first. Include some short-term efforts to avoid burnout while pursuing long-term goals.

4.2 Institutional Change Tactics

Session Title: Institutional Change Tactics

Speakers: Lance Cooper (University of Illinois at Urbana–Champaign), Scott Franklin (Rochester Institute of Technology), Jon Pelz (The Ohio State University), Stuart Vogel (University of Maryland, College Park)

In this workshop on Institutional Change Tactics, four presenters shared changes that were made at their institutions and the tactics they used in catalyzing those changes.

Lance Cooper shared details about a variety of changes that improved graduation education in his department (Cooper, Slides 1–7). His suggestions included:

- Get inspired to make change. Find out who has already tried and succeeded, and what strategies they used.
- Assemble a group of advocates to assist with the process. Share the workload and get people on your side.

- Listen to and understand doubts and challenges from colleagues. Find ways to address these doubts.
- Take advantage of opportunities to get help, and ask for a commitment. (For examples of this and the preceding three suggestions in action, and see Pelz, Slide 14).
- Share supportive data with skeptics.
- Capitalize on student interest to support changes. (For examples of student-supported initiatives, see Vogel, Slides 19–21).
- Foster grassroots efforts while garnering support from your administration and and other campus decision makers.
- Track success, document support, and evaluate progress continually.

Scott Franklin shared a model of systemic change in university science, technology, engineering and mathematics education (See Franklin, Slide 11). He also discussed "middle-out change," a theory of change wherein a champion implements and advocates for change, with the goal of convincing peers and/or administration. Outside-in change, by contrast, occurs when an outside facilitator promotes regular communication across scales (eg from faculty to an administrator) and frames narrative (or tells a story) (See Franklin, Slide 12).

Jon Pelz gave specific examples on how to get inspired to make changes, assemble a group of advocates to support the change, address challenges to implementing change, leverage existing resources to support change (See Pelz, Slides 13-18).

Stuart Vogel discussed how the GRAD Map program has been instrumental in instituting changes at the University of Maryland. (See Vogel, Slides 19-22)

4.3 What Physics Professional Societies Can Do to Help

Session Title: What Can Physics Societies Do For You?

Speakers: Trina Coleman (National Society of Black Physicists), Theodore Hodapp (American Physical Society), Cathy O'Riordan (American Institute of Physics), Jesus Pando (National Society of Hispanic Physicists)

The plenary session What can Physics Societies do for you? addressed how physics professional societies can support efforts to better prepare students and broaden participation in the field. Representatives from four physics societies provided brief descriptions of their organizations and the resources they provide to members and the larger physics community, and then participated in a panel discussion.

The American Physical Society (APS) is an organization whose membership consists of some 54,000 physicists. APS's organizational structure includes divisions, units, topical groups, forums, and sections. Section meetings, which are organized geographically, are great places for faculty and

students to present their research. APS's Forum on Graduate Student Affairs enables graduate students to connect and have their voices heard. APS also runs committees and task forces, including an LGBT task force.

APS provides to its members and the physics community at large:

- **Access to data resources.** APS compiles data on physics graduate school admissions, recruitment, and retention. The APS website also provides access to education data from the American Institute of Physics and the federal government.
- **Statements.** APS periodically issues public statements on issues of importance to the physics community. The society has issued statements encouraging increased diversity and supporting women in physics. Statements have also been issued in support of individual departments. APS is currently considering a statement that would encourage departments to rely less on the GRE for graduate admissions.
- **Documentation of discussions of policy.** APS produces conference reports such as this one. APS committees, particularly the Committee on Education, the Committee on the Status of Women in Physics, and the Committee on Minorities, also have policy-oriented subcommittees.

The American Institute of Physics (AIP), which includes a federation of 10 scientific societies (one of which is APS), engages in activities designed to support its individual societies. In particular, AIP:

- Archives member societies' papers;
- Serves as a journal publisher, mainly in applied physics;
- Works in science policy;
- Is home to the Society of Physics Students (SPS) and Sigma Pi Sigma organizations.

Undergraduates are inducted into Sigma Pi Sigma annually. Five hundred SPS chapters also have Sigma Pi Sigma chapters. There are 18 geographic zones that host regular meetings. Travel awards to zone meetings are offered.

AIP has a several initiatives designed to encourage diversity within physics. With support from the National Science Foundation and APS, AIP has awarded travel grants to 73 students who identify as ethnic and racial minorities, to encourage their participation in the Sigma Pi Sigma Congress. AIP also created a Liaison Committee on Underrepresented Minorities that supports initiatives involving multiple member societies.

AIP also provides a number of resources on its website:

- **A careers toolbox**, with tools for physicist at a variety of levels;
- **Physics trends reports**, in a series entitled "Focus On";
- **Grad School Shopper**, a website focused on physics graduate school admissions;
- **A professional/faculty job board**, which is advertised through AIP and APS, as well as an SPS job board for undergraduate opportunities;
- **"Hidden Physicists,"** a column that highlights people of different professions who began their careers in physics.

The stated purpose of the National Society of Hispanic Physicists (NSHP) is "to promote the professional well-being and recognize the accomplishments of Hispanic physicists within the scientific community of the United States and within society at large." Former NSHP president Jesus Pando described the society as "providing a place for Hispanic folks to network with people who look like them, and are part of the same community or have similar backgrounds. At NSHP, members do not have to prove themselves any more than their credentials have already, and they can be empowered take on leadership roles and effect change".

For undergraduate members, NSHP offers:

- **Mentorship.** NSHP members are often able to relate to students in ways that physicists at their home institutions may not, and can provide advice on personal as well as professional issues.
- **Social capital.** Faculty members demonstrate to students how to conduct themselves professionally and how to collaborate with others. NSHP members help students become a part of the field and serves as role models, especially with respect to balancing physicist and Hispanic identities.
- **Research opportunities.** NSHP serves as a clearing house for students interested in doing undergraduate research. The society also offers funding opportunities, including the Victor Blanco Undergraduate Research Fellowship. NSHP partners with institutions that have Research Experiences for Undergraduates sites, in order to connect students with experiences. The society also has partnerships at LIGO and Fermilab.

NSHP supports faculty at various stages in their careers. NSHP helps new faculty widen their networks, and supports faculty at all career stages navigate work-life issues. When faculty are able, they are asked to help NSHP. Members are asked to let people know that NSHP exists and that there is a vibrant community of capable Hispanic physicists.

Being part of a community allows for targeted advocacy. After Arizona passed a law that could allow for discrimination against Hispanic Americans, NSHP wrote a strong statement that they would not hold meetings in Arizona. When Texas cut programs at mostly Hispanic Serving Institutions, NSHP partnered with APS to send letters protesting the cuts.

NSHP is a 501(c)3 non-profit organization with no staff. Therefore, NSHP often partners with APS and the Society for Advancement of Chicanos/Hispanics and Native Americans in Science.

The National Society of Black Physicists (NSBP) engages in similar community-support activities to those of NSHP. At the time of the conference, NSBP was in its 40th year. NSBP is an organization built around the necessity to bring together Black physicists and provide them space to cohesively present their work. NSBP is needed because of the discrimination that Black physicists face in the field. It is important for African-American physicists to see other physicists who look like them, and who are invested in supporting their career development.

NSBP offers a number of benefits to its members:

- **Mentorship.** NSBP student members know that they are not alone.
- **Funding opportunities and scholarships.** NSBP provides scholarships directly to students.

- **A job board.** Members can upload their resumes to the NSBP job board, which is very active.
- **A professional network.** Students can connect with each other and form bonds and relationships that last a lifetime.
- **A safe space.** If students have challenges or issues in their departments, they can get advice and guidance from experienced professionals.
- **A number of social media spaces**, including a space for Black women in physics and astronomy.
- **A newsletter.** Information is disseminated to the membership through this newsletter.
- **Professional development.** NSBP answers questions students may have, such as “What does it mean to be a faculty member or a postdoc?” The society helps students build confidence, feel comfortable asking questions, and address imposter syndrome.

NSBP provides a space where Black physicists can engage without judgment. Members often feel more comfortable at NSBP meetings than in other professional settings because they do not have to prove themselves. They can just engage with one another. They can simply talk about physics.

Summary and Next Steps

At the 2017 Graduate Education in Physics Conference, which was held jointly with the APS Bridge Program Meeting, it became clear that since the 2008 Graduate Education in Physics Conference, some physics departments have, by implementing bridge programs, made significant changes in many aspects of graduate education. Furthermore, the APS Bridge Program has carried out a number of studies that provide a comprehensive perspective on how departments make graduate student admissions decisions. These include a national research study on approaches to diversity in physics doctoral degree programs, focused on the admissions landscape [1]; and a study on the perspectives of faculty involved in physics graduate admissions and how these perspectives relate to the inclusion or exclusion of women and people from traditionally marginalized racial and ethnic groups [2]. APS also continues to provide resources such as the Graduate Student Induction Manual [3] to help faculty improve the climate of physics departments and increase retention of all graduate students.

This report recommends additional changes in several areas. These areas include how physics departments recruit graduate students, how they retain and support graduate students through Physics Graduate Student Associations and mentoring programs, and how they prepare graduate students for private sector employment.

It is now time to collect and analyze data to evaluate departments' progress in these areas. Understanding the effects of these changes will help us continue to diversify the field of physics through broadening participation in physics graduate programs. It will also help us improve the climate in physics departments and, through inclusive practices and career preparation, the overall graduate student experience.

We anticipate a fourth conference on graduate education in physics in 2020, at which participants will disseminate research results, share departmental efforts and progress, and determine best practices and next steps for physics graduate education.

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[1] Potvin, G., Chari, D., & Hodapp, T. (2017). Investigating approaches to diversity in a national survey of physics doctoral degree programs: The graduate admissions landscape. *Physical Review Physics Education Research*, *13*(2), 020142.

[2] Scherr, R. E., Plisch, M., Gray, K. E., Potvin, G., & Hodapp, T. (2017). Fixed and growth mindsets in physics graduate admissions. *Physical Review Physics Education Research*, *13*(2), 020133.

[3] Cochran, G., Hodapp, T., & Brown, E. (2017). Graduate Student Induction Manual. Retrieved from http://www.apsbridgeprogram.org/resources/manual/CombinedInductionManualv3.pdf.

Appendices

Appendix I: Recommendations from the 2013 Committee

The following key findings emerged from discussions and presentations at the 2013 Conference on Graduate Education. They include input and feedback from the participating graduate students, whose active engagement contributed to the success of the conference. The recommendations built upon, and in some cases reiterate, the observations and recommendations from the 2006 report of the Joint AAPT-APS Task Force on Graduate Education in Physics and the report from the 2008 Graduate Education in Physics Conference: "Graduate Education in Physics: Which Way Forward?"

Develop an identity for your graduate program
In order to develop a coherent strategy, faculty must know the strengths of their department and the goals for their particular graduate program. These strengths should then be appropriately advertised, so that students can make informed decisions about graduate school based on their own goals, skills, and ambitions.

Strive to achieve diversity in recruitment and admissions
Effective recruiting of women and minorities is critical if U.S. graduate physics programs want to stay competitive with other disciplines and attract the brightest minds in the country and the rest of the world. Participants at the conference reported that recruiting increasingly requires more personal faculty attention to students, and cannot be left to administrators.

Create cohorts and bridge programs to promote diversity
Departments can also promote diversity by facilitating community among graduate students. For some departments, it may be effective to construct diverse cohorts, with attention to a "critical mass" of underrepresented students, since cohorts can prevent isolation and provide students an opportunity to support each other. To reduce feelings of isolation and build community, departments can plan events to connect students with campus groups, or encourage the formation of a graduate student club or social committee. Some departments reported that instituting defined times and places for core course study groups helps to integrate all students regardless of race, gender, ethnicity, or national origin.

Adopt an exam structure that is effective and fair
In the 2006 Joint Task Force Report5, the overwhelming majority of departments reported that they require a classical comprehensive style exam that was at least partly based on material from graduate courses. The informal impression at the 2013 conference was that this was no longer true. Some departments reportedly have shifted to different exam types. A number of departments have removed the time constraints in their exams in response to reports that timed exams may discriminate unfairly against women and minorities.

Provide social/cultural resources and support for graduate students
During their time in a graduate program, students will inevitably face many professional and personal challenges. A welcoming and helpful climate is crucial for overcoming these challenges successfully. Departments should take responsibility for establishing supportive relationships with graduate students as soon as they arrive on campus. This should be the responsibility of graduate student advisors, department chairs, other faculty, and graduate student groups.

Mentor and monitor student progress
Quite often the terms “advisor” and “mentor” are used interchangeably. Although an advisor can and should also serve as a mentor, many students need additional advice and guidance, especially when their thesis advisors are unable to provide appropriate support. Most importantly, departments must ensure students get help before a problem becomes unsolvable. Many departments report that they are already instituting formal mentoring programs, some based upon the mentoring resources that APS has on its website. Departments should consider whether to require faculty members to take mentor training.

Add flexibility to the graduate curriculum
What constitutes a “core curriculum” and what de nes a “physicist” remain challenging questions for physics departments. Conference participants agreed that everybody with a PhD in physics should be expert in understanding and applying the core upper-level undergraduate physics curriculum: quantum mechanics, electricity and magnetism, classical mechanics, and statistical mechanics. However, the increasing number of interdisciplinary programs in which physics graduate students participate require that departments offer more flexibility than in the past. Each department must decide what graduate courses are necessary to enable its students to have a successful career as a physicist.

Focus on career development and professional training
The success of a graduate student is not guaranteed with the passing of the core courses or a comprehensive exam. Physics graduate school should prepare students for a successful career in which they apply the knowledge and skills gained during their studies and research. In addition to mastering a broad physics background, students should be given the opportunity to learn and perform the many aspects of independent research as well as to become proficient in professional skills. Departments should have a department-wide plan to ensure that graduate students have sufficient opportunity to develop professional skills such as oral and written communication, teamwork, leadership and management, and mentoring.

Prepare students for diverse careers
Most physics graduate programs do not prepare students well for a career outside academia, presumably because professors are poorly informed about non-academic careers. To address this shortcoming, faculty should educate themselves and advise students about careers outside of academia, and provide speci c and integrated training in broadly valued skills such as communication, time and project management, and leadership. Departments should invite seminar or colloquium speakers from local industries or from their alumni who work in industry, and ensure that speakers have ample time to interact with students during their visit.

Incorporate Feedback from Alumni to Improve Graduate Program
Departments should track the placement of their PhD students over time and periodically solicit feedback from them in order to improve their graduate programs and make them more relevant to students entering the current job market. Currently such tracking is piecemeal, with some faculty members doing an excellent job, and others failing to do so.

Appendix II: Acknowledgements of Steering Committee

This report describes the results of the third conference on Graduate Education in Physics organized by the American Physical Society. The conference received support from the National Science Foundation under Award PHY-1644885.

We would like to thank Kathleen McCloud, the NSF funding agency representative, for her support. In addition, we wish to express our appreciation to the following American Physical Society (APS) staff members: Kate Kirby, Executive Officer, Theodore Hodapp, Director of Project Development, Senior Advisor to the Department of Education and Diversity, Kathryne Sparks Woodle, Education and Diversity Programs Manager, Erika Brown, Bridge Program Manager, and Brian Clash, Bridge Program Coordinator, who generously contributed their time and skills. Their assistance was invaluable. We also thank Geraldine Cochran, Rutgers University, who led the effort in preparing this conference report. We would also like to thank Gabriel Popkin, Erika Brown, and Shandy Destin for editing this report.

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- *Elaine Lalanne,* Faculty Associate for PhysMoVan – Physics outreach project to South African high schools, Team leader for the US delegation to the 5th International Conference on Women in Physics, US Navy, elalanne@umbc.edu
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- *Beth Thacker*, Member of COE and Chair of the COE Graduate Education Subcommittee, Texas Tech University,

2017 Joint Graduate Education and Bridge Program Conference Agenda

Friday, February 10, 2017			
12:00 - 3:00 PM Chesapeake Ballroom Foyer	Registration Opens (Chesapeake Ballroom Foyer)		
3:00 - 5:00 PM Chesapeake Ballroom Foyer	Poster Session: Graduate Education Programs		
5:00 - 5:15 PM Chesapeake Ballroom	Welcome Remarks from APS Ted Hodapp, APS Director of Project Development		
5:15 - 8:00 PM Chesapeake Ballroom	**Plenary I with Dinner: Preparing Students for Private Sector Employment:** *Liesl Folks, University at Buffalo; Newton Frateschi, University of Campinas; Anthony Johnson, University of Maryland-Baltimore County; Kathy McCormick, Department of Homeland Security; Steve Rolston, University of Maryland*		
8:00 - 9:00 PM	Optional Student Social Activity		
Saturday, February 11, 2017			
7:00 - 8:00 AM Chesapeake Ballroom Foyer	Registration		
8:00 - 10:00 AM Chesapeake Salon	**Plenary II with Breakfast: Findings on Graduate Admissions Studies** *Casey Miller, Rochester Institute of Technology; Geoff Potvin, Florida International University*		
10:00 - 10:15 AM Chesapeake Ballroom Foyer	Break		
10:15 AM - 12:00 PM	Parallel Sessions		
	Workshop 1A Chesapeake Salon A	Workshop 1B Chesapeake Salon B	Workshop 1C Chesapeake Salon C
	Holistic Admissions *Julie Posselt, University of Southern California; Casey Miller, Rochester Institute of Technology*	**How to Write a CV/Resume** *Crystal Bailey, APS* **Time Management and Work-Life Balance** *Marquita Qualls, Entropia*	**Culturally Sensitive Mentoring** *Brian Beckford, University of Michigan; Ximena Cid, California State University-Dominguez Hills, National Society of Hispanic Physicists; Michael Falk, Johns Hopkins University; Mel Sabella, Chicago State University*
12:00-12:05 PM Chesapeake Ballroom Foyer	Break		
12:05 - 2:05 PM Chesapeake Ballroom	**Plenary III with Lunch: Best Recruitment Practices** *Kate Scholberg, Duke University; Ramon Lopez, University of Texas-Arlington; Lance Cooper, University of Illinois at Urbana-Champaign*		
2:05 - 2:15 PM Chesapeake Ballroom Foyer	Break		
2:15 - 4:00 PM	Parallel Sessions		
	Workshop 2A Chesapeake Salon A	Workshop 2B Chesapeake Salon B	Workshop 2C Chesapeake Salon C
	Programmatic Innovations *Sheila Kannappan, University of North Carolina-Chapel Hill*	**Implicit Bias and Self Advocacy** *Angela Johnson, St. Mary's College of Maryland*	**Mental Health in Physics Graduate School: Support Roles and Obligations of Faculty** *Mercedes Ebanks, Howard University*
	Institutional Change Tactics *Lance Cooper, University of Illinois at Urbana-Champaign; Scott Franklin, Rochester Institute of Technology; Jon Pelz, The Ohio State University; Chandra Turpen (Moderator), University of Maryland; Stuart Vogel, University of Maryland*	**Guided Reflection to Enable Persistence** *Dimitri Dounas-Frazer, University of Colorado-Boulder*	**Mental Health in Physics Graduate School: Student Perspectives and Resources** *Gina Quan, University of Maryland; Zachary Eldredge, University of Maryland*
4:00 - 4:30 PM Chesapeake Ballroom Foyer	Poster Setup and Break		
4:30 - 6:00 PM Chesapeake Ballroom Foyer	Poster Session: Graduate Student Research		
6:00 - 9:00 PM Chesapeake Ballroom	**Plenary IV with Dinner: Reflections on the Future of Graduate Education in Physics** *Cherry Murray, Department of Energy*		
9:00 - 10:00 PM	Optional Student Social Activity		

The APS Bridge Program is supported in part by the National Science Foundation and the American Physical Society.

2017 Joint Graduate Education and Bridge Program Conference Agenda

<table>
<tr><th colspan="4">Sunday, February 12, 2017</th></tr>
<tr><td>8:00 - 10:00 AM
Chesapeake Ballroom</td><td colspan="3">Plenary V with Breakfast: Nuts & Bolts of Bridge Programs
Jay Gupta, The Ohio State University, Kelly Holley-Bocklemann, Vanderbilt University; Cagliyan Kurdak, University of Michigan; Alex Rudolph, California State Polytechnic University</td></tr>
<tr><td>10:00 - 10:15 AM
Chesapeake Ballroom Foyer</td><td colspan="3">Break</td></tr>
<tr><td>10:15 - 11:55 AM</td><td colspan="3">Parallel Sessions</td></tr>
<tr><td></td><td>Workshop 3A
Chesapeake Salon A</td><td>Workshop 3B
Chesapeake Salon B</td><td>Workshop 3C
Chesapeake Salon C</td></tr>
<tr><td></td><td rowspan="3">Retention Best Practices
Brian Beckford, University of Michigan; Geraldine Cochran, Rutgers University; Casey Miller, Rochester Institute of Technology; Monica Plisch, APS</td><td>Graduate Program Assessment
Simon Capstick, Florida State University, Michael Pechan, Miami University (Ohio); Talat Rahman, University of Central Florida</td><td>How to Create and Sustain a Physics Graduate Student Association
Adewale Akinfaderin, Florida State University; Sara Mueller, The Ohio State University; Ashlee Wilkins, University of Maryland</td></tr>
<tr><td></td><td rowspan="2">New Developments in Graduate Core Courses
Alexandru Maries, University of Cincinnati; Chris Porter, The Ohio State University; Chandralekha Singh, University of Pittsburgh</td><td rowspan="2">How to Support a Physics Graduate Student Association
Garrett Matthews, University of South Florida; Jon Pelz, The Ohio State University</td></tr>
<tr><td></td></tr>
<tr><td>11:55 AM-12:00 PM
Chesapeake Ballroom Foyer</td><td colspan="3">Break</td></tr>
<tr><td>12:00 - 2:00 PM
Chesapeake Ballroom</td><td colspan="3">Report Out/Feedback with Lunch: What can Physics Societies do for you?
Ted Hodapp, APS Director of Project Development; Renee Horton, NASA, National Society for Black Physicists; Cathy O'Riordan, American Institute of Physics; Jesús Pando, National Society for Hispanic Physicists</td></tr>
<tr><td>2:00- 2:15 PM
Chesapeake Ballroom</td><td colspan="3">Closing Remarks and wrap-up</td></tr>
</table>

The APS Bridge Program is supported in part by the National Science Foundation and the American Physical Society.

Appendix IV: Program Participant List

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