- *Programmatics:* Could be done as an institutional program in campuses around the country.

- **NSF, NASA, DOE, and Academic Institutions**
  - *Method:* The panel suggests that agencies and institutions design and fund training that focuses on cultural humility and bystander-intervention. While cultural competency focuses on providing practitioners the ability to understand, communicate with, and effectively interact with people across cultures,[171] cultural humility is a way of being with ourselves, others, and the institutions we inhabit.[172] It asks not only that we assess our environments and engage them in an unbiased and nonviolent manner but also that we reflect deeply on who we are and how we show up for others.
  - *Impact:* Changes discriminatory evaluation and decision-making processes within the Profession through training to reduce inequities in participation and leadership within the field.
  - *Programmatics:* Minimal cost. Could be implemented in 1–2 years.
- **NSF, NASA, and DOE, and Institutions**
  - *Method:* Because lack of access is a form of discrimination, the panel suggests that institutions consider developing accessibility plans to identify the current state of facilities and plans for increasing access.
  - *Impact:* Accessible spaces encourage equal participation.
  - *Programmatics:* Accessibility plans can be implemented in 1–2 years.

N.6.5 Goal 5: Removing Barriers

Modernize practices that have disparate impact on access to education, training, and advancement.

Scientific excellence depends on ensuring that each generation of scientists can thrive within the environments in which they learn and work, and requires equitable access to education, advancement opportunities, funding, and facilities. Astronomy is a dynamic field, both culturally and technologically, and training (including teaching practices, curriculum, and technical/professional development) that reflects the current state of evidence-based, inclusive practice is needed. Physics and mathematics instruction is the gateway to the Profession and must be modernized nationwide. Inequities in career advancement and access to the tools of the Profession must be addressed so that the entire workforce is engaged. See also the driving motivation for SEA Change,[173] an effort of the American Association for the Advancement of Science to effect sustainable change with regard to diversity, equity, and inclusion in STEMM[174] at U.S. institutions of higher education.

N.6.5.1 Work with Physics Departments to Incentivize the Widespread Adoption of Research-Based Instructional Strategies and Inclusive Pedagogy in First-Year Physics

The first-year sequence in physics is among the most influential in a student's chances to continue not only in astronomy but also in all STEM fields. This sequence, along with calculus, have drop, fail, or withdrawal (DFW) rates of 30 percent or more, and first-generation (First Gen), Pell-eligible

[171] T.L. Cross, B.J. Bazron, K.W. Dennis, and M.R. Isaacs, 1989, Towards a Culturally Competent System of Care, *NCJRS*: 12439.

[172] R. Danso, 2018, Cultural competence and cultural humility: A critical reflection on key cultural diversity concepts, *Journal of Social Work*, 18(4):410–430, doi:10.1177/1468017316654341.

[173] See https://seachange.aaas.org/.

[174] Science, technology, engineering, mathematics, and medicine (STEMM).

and minoritized students, particularly those with intersectional identities, can have nearly double the DFW rates of majority non-Pell, non-First Gen students.[175] Retention and degree completion is strongly tied to D and F grades in the first term.[176] The increased DFW rate at the course level with URM students leads to the loss of URM students presented in the earlier sections. Physics Education Research and Astronomy Education Research (PER, AER) shows that there are specific instructional practices that consistently achieve better student course outcomes and retention than traditional lectures.[177] Collectively known as "interactive engagement," these methods include student-centered instruction and discovery-based learning practices such as peer instruction.[178] Sociology and psychology research further demonstrates the importance of student belonging and the impact of stereotype threat, and provides proven classroom methods that improve student performance.[179] The low rates at which these methods are applied in STEM courses reduces the production of science and technology graduates, and contributes to the loss of diversity among those that do graduate. Moreover, the documented reduction of gender and racial/ethnic performance gaps[180,181] in courses taught with Research-Based Instructional Strategies (RBIS) makes the continued use of lecture-based teaching in first-year physics and calculus courses tantamount to discriminatory practices.

Sadly, evidence abounds that despite efforts to train faculty to move from teacher-centered lecture to learner-centered course design, the majority of faculty trained (75 percent) in workshops continue to use lecture-based pedagogy.[182] Recently, new initiatives that promote the use of RBIS are grounded in robust theories of change, such as supporting networks or learning communities of faculty, called Communities of Practice and Research-Practice Partnerships. Learning communities allow cultural and work-related shifts to happen on the part of both researchers and practitioners engaging in this work to implement and spread reform.[183] A non-exhaustive list includes the Accelerating Systemic Change Network,[184] AAC&U TIDES,[185] the AAU Undergraduate STEM education Initiative,[186] and Kaleidoscope.[187] Private foundations have supported the advancement of such communities, such as the Research Corporation for Science Advancement's contributions to the American Physical Society's NSF Funded Workshop for New Physics and Astronomy Faculty. New funding from federal agencies is required to implement these new, innovative means for increasing the adoption of RBIS. This will require enriched engagement with education researchers in designing professional and department-level training and mentoring in RBIS.

Goal 5, Suggestion 1: The panel suggests that the Profession adopt and promote inclusive pedagogy and RBIS in the classroom through engagement with experts from the PER and AER

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[175] See https://www.aplu.org/library/powered-by-publics-learning-memo-the-big-ten-academic-alliance-cluster/file.

[176] [176] See https://www.aplu.org/library/powered-by-publics-learning-memo-the-big-ten-academic-alliance-cluster/file.

[177] Freeman et al., 2014, *PNAS*, 111(23):8410–8415.

[178] Turpen et al., 2016, *Phys. Rev. Phys. Educ. Res.*, 12:010116.

[179] C. Verschelden, 2017, *Bandwidth Recovery: Helping Students Reclaim Cognitive Resources Lost to Poverty, Racism, and Social Marginalization*, Stylus Publishing.

[180] Eddy and Hogan, 2017, *CBE-Life Sciences Education*, 13:3.

[181] Theobald, et al., 2020, *PNAS*, 117:6476.

[182] Ebert-May, et al., 2011, *What We Say Is Not What We Do: Effective Evaluation of Faculty Professional Development Programs*, *BioScience*, 61:550–558, doi: 10.1525/bio.2011.61.7.9.

[183] Kezar et al., 2015, Implicit theories of change as a barrier to change on college campuses: An examination of STEM reform, *Review of Higher Education*, 38(4):479–506, doi: 10.1353/rhe.2015.0026.

[184] Accelerating Systemic Change Network, https://ascnhighered.org/index.html.

[185] AAC&U TIDES, https://www.aacu.org/2021-TIDES.

[186] The AAU Undergraduate STEM Education Initiative, https://www.aau.edu/education-community-impact/undergraduate-education/undergraduate-stem-education-initiative.

[187] Kaleidoscope, https://www.aacu.org/pkal.

community to design professional and department-level training in modern teaching practices at all career stages. To achieve transformational change at a national scale, the panel suggests that federal agencies increase funding in PER and AER.

Method, impact, and programmatics and cost to achieve this suggestion:

- **NSF-MPS, NASA STEM-Engagement**
  - *Method:* Expand funding for research-practice partnerships based on Physics and Astronomy Education Research in order to promote the adoption of evidence-based inclusive pedagogy. Funding supports grants for conferences, training for current and future instructors (master's, doctoral students, and postdoctorates). Private foundations can also support program development.
  - *Impact:* Expanded use of RBIS and inclusive pedagogy in gateway courses will increase retention of all students pursuing astrophysics, particularly underrepresented students.
  - *Programmatics:* $3 million/year NSF-MPS; $2 million/year NASA STEM-Engage.[188]

N.6.5.2 Invest in Programs and Practices to Increase Inclusion and Persistence of Scientists from Groups Historically Underrepresented

Federal funding has created multiple programs to recruit, retain, and advance historically underrepresented people within the Profession, including Bridge Programs (Fisk-Vanderbilt, Columbia, Cal-Bridge, IGEN Bridge); terminal master's programs (e.g., Wesleyan); and summer research programs (REUs, CAMPARE[189]). NSF is funding APS and AAPT's new program, Effective Practices for Physics Programs (EP3) for responding to challenges and engaging in systematic improvements.[190] DOE is funding a Visiting Faculty Program[191] (VFP, formerly known as FaST) to increase faculty and students at institutions historically underrepresented in research areas important to DOE. Last, the National Society of Black Physicists (NSBP), funded by NASA, NIST, NSF, and several national and private research institutions and organizations, has a growing list of student chapters. Such programs and organizations enhance access to doctoral education, as well as a sense of belonging and identity for physics students from underrepresented groups, which increase their persistence and success. However, agencies no longer offer funding for long-term sustainability nor institutional or agency accountability for the continuation of past successful programs. For example, PAARE[192] and MUCERPI[193] are no longer receiving proposals. Investments for programs that have shown progress in increasing the persistence of historically underrepresented groups are most successful if they are not time-limited but are supported for as long as they are effective.

In addition to support for such programs, there is a clear need to remove racial, gender, and other barriers to doctoral education in astronomy and physics, including those created through predominant admissions practices to doctoral education. For example, misuse of the general Graduate Record Exam (GRE) and physics subject GRE (PGRE) in admissions decisions leads to disproportionate exclusion of

[188] Fund 30 groups per year to use complex theories of change to train instructors in RBIS and inclusive pedagogy.

[189] See https://www.cpp.edu/calbridge/summer-research.shtml.

[190] Effective Practices for Physics Programs, https://ep3guide.org/.

[191] DOE VFP, https://science.osti.gov/wdts/vfp.

[192] K.G. Stassun, 2011, The Fisk-Vanderbilt Master's-to-Ph.D. Bridge Program, *American Journal of Physics*, 79:374.

[193] P.J. Sakimoto, and J.D. Rosenthal, 2005, *Physics Today*, September:49–53. [[RSO: PLEASE PROVIDE FULL CITATIONS FOR 181, 184, 185, 186]]

scholars from underrepresented groups, especially women of color.[194,195] These tests have large score gaps by race and gender identities of test takers, yet evidence shows that high scores do not help students to stand out in admission, only penalize otherwise competitive applicants.[196] Further, PGRE scores are not correlated with Ph.D. degree completion[197] nor do they foretell postdoctoral success.[198] Increasingly, astronomy Ph.D.-granting programs are removing GRE and PGRE requirements with no reported negative impact on the academic success of the admitted students.[199]

Goal 5, Suggestion 2: The panel suggests the Profession remove barriers that impede student advancement and renew funding of previous programs with a strong record of retention and advancement of individuals from underrepresented groups.

Method, impact, and programmatics and cost to achieve this suggestion:

- **NSF-PHY, -AST**
  - *Method:* Provide new (or renewed) funds for programs that recruit, retain, and advance historically underrepresented people to support entry into the Profession. Review impact and internal processes from past funded programs (e.g., PAARE, Fisk-Vanderbilt) to determine if their record in advancing individuals from underrepresented groups merits refunding and/or refinement.
  - *Impact:* Increase program longevity and sustain PI commitment.
  - *Programmatics:* $3 million per year to fund nine sites.[200]
- **Academic Departments**
  - *Method:* Provide funds to reduce or eliminate application fees for low-income and historically marginalized applicants. Eliminate requirements for the GRE and PGRE in admissions to astronomy and physics graduate programs.[201] Replace the traditional admissions process with one that embodies the ideals of equity-advancing holistic review.[202]
  - *Impact:* Increase diversity in graduate programs.
  - *Programmatics:* Marginal department cost of effort to devise and implement holistic admissions process and cover application fees for targeted individuals.

N.6.5.3 Provide Broader Opportunity and Continual Training in State-of-the-Art Techniques

To ensure innovation at an emergent level, technical training programs in computational methods and instrumentation are needed for astronomers throughout their careers. Computational and data

[194] C. Miller and K. Stassun, 2014, A test that fails, *Nature*, 510:303–304.

[195] J. Posselt, 2016, *Inside Graduate Admissions: Merit, Diversity, and Faculty Gatekeeping*, Cambridge, MA: Harvard University Press.

[196] N.T. Young and M.D. Caballero, 2020, The physics GRE does not help applicants "stand out," arXiv:2008.10712.

[197] Miller, et al., 2019, *Science Advances*, 5(1).

[198] E.M. Levesque, E.M. et al., 2015, *Physics GRE Scores of Prize Postdoctoral Fellows in Astronomy*, arXiv:1512.03709.

[199] Due in part to COVID-19, GRE and pGRE were eliminated from most admission requirements this cycle.

[200] Estimates based on previous PAARE funding ($1 million/site for 3 years).

[201] Also recommended by numerous previous reports, most recently the Nashville Recommendations: https://tiki.aas.org/tiki-index.php?page=Inclusive_Astronomy_The_Nashville_Recommendations.

[202] J.D. Kent and M.T. McCarthy, 2016 *Holistic Review in Graduate Admissions: A Report from the Council of Graduate Schools*,. Washington, DC: Council of Graduate Schools.

summer/winter schools[203] and internships are logical training grounds, but some have been defunded (e.g., NSF Blue Waters Summer Internship), and they typically focus on the technical skills of early-career scientists.

Research experiences are a critical component of graduate school applications, yet access depends on institutional resources and faculty, which vary widely. Meanwhile, REU programs have become increasingly oversubscribed, necessitating selection criteria that balance previous research experience with how much an applicant has to gain from the opportunity.[204] More technical and research opportunities are needed for students from Primarily Undergraduate Institutions (PUI), Minority Serving Institutions (MSI; this includes Historically Black Colleges and Universities [HBCU], Hispanic Serving Institutions [his], and Tribal Colleges and Universities [TCU]), and Women's Colleges (WC), where many students study but fewer options exist, to increase their retention, graduation, and progression to graduate school and STEM careers.

Professional development is needed to keep astronomers current in the Profession's changing technical and career landscape. The current lack of "computational [training], knowledge, and access across the nation is a critical hindrance to the diversity and therefore the success of the field"[205] and a serious national security issue. Modern astrophysics demands computational literacy as a core competency, parallel in priority to math. Opportunities for observational training at modern facilities or developing technical skills to build state-of-the-art instrumentation are also limited. Training programs that address the planning, constructing, testing, and calibrating of new instruments are needed if complex projects are to be completed on time and at cost. More than 40 percent of astronomy Ph.D. recipients in 2015–2016 did not take postdoctoral positions, and many went into private sector jobs.[206] The Profession must respond to this trend and support a broad set of career pathways with an updated curriculum to include skills that are in demand.[207,208]

Goal 5, Suggestion 3: The panel suggests that the agencies fund PUI, MSI, and WC faculty and students in collaborations and research opportunities to access and engage in cutting-edge technological and data advancements, and that the Profession invest in expanded technical training pathways for all career levels.

Method, impact, and programmatics and cost to achieve this suggestion:

- **NSF-AST, NASA-APD/SMD, DOE-OoS**
  - *Method:* Create partnerships or training programs at MSI, PUI, and WC that facilitate long-lasting (5-year grants with administrative support) collaborations with major facilities (e.g., LSST, DESI), including National Laboratories (Fermilab or HPC facilities). Increase agency-funded REU programs and paid internships through partnerships with local industry (e.g., Metcalf program at the University of Chicago, TIMESTEP program at the University of Arizona).

[203] LSST Data Science Fellowship Program, LANL summer computational physics programs, Astro Hack weeks.

[204] McDevitt et al., 2020, *Ecology and Evolution*, 10(6):2710–2738.

[205] G. Besla, D. Huppenkothen, N. Lloyd-Ronning, E. Schneider, P. Behroozi, B. Burkhart, C.K. Chan, et al., 2019, Astro2020: Training the future generations of computational researchers, white paper submitted to the Astro2020 Decadal Survey, https://arxiv.org/abs/1907.04460.

[206] P. Mulvey and J. Pold, "Astronomy Degree Recipients One Year After Degree" https://www.aip.org/statistics/reports/astronomy-degree-recipients-one-year-after-degree, accessed 26 August 2020.

[207] P. Heron and L. McNeil, 2016, "A Report by the Joint Task Force on Undergraduate Physics Programs," http://www.compadre.org/JTUPP/docs/J-Tupp_Report.pdf.

[208] APS/AAPT Effective Practices in Physics Programs, Career Preparation, https://ep3guide.org/guide-overview/career-preparation.