Astro2020 Statement of the Profession Consideration White Paper

It's Time to Eliminate the GRE and PGRE in All Astronomy & Astrophysics PhD Programs: Motivation, Implementation and Outcomes

Principal Author:
Name: Adam Burgasser
Institution: UC San Diego
Email: aburgasser@ucsd.edu
Phone: +1 858 822 6958

Co-authors:
Alicia Aarnio, U North Carolina Greensboro, anaarnio@uncg.edu
Kevork N. Abazajian, UC Irvine, kevork@uci.edu
Marcel Agüeros, Columbia University, marcel@astro.columbia.edu
Joseph Andrew Barranco, San Francisco State University, barranco@sfsu.edu
Zachory K Berta-Thompson, U Colorado Boulder, Zachory.BertaThompson@Colorado.EDU
Benjamin P Brown, U Colorado Boulder, Benjamin.P.Brown@Colorado.EDU
Caitlin Casey, UT Austin, cmcasey.astro@gmail.com
David Charbonneau, Harvard University, dcharbonneau@cfa.harvard.edu
Kim Coble, San Francisco State University, kcoble@sfsu.edu
Megan Donahue, Michigan State U, donahue@pa.msu.edu
Sarah Gallagher, U Western Ontario, sgalla4@uwo.ca
Jenny Greene, Princeton U, jgreene@astro.princeton.edu
Sarah Horst, Johns Hopkins University, sarah.horst@jhu.edu
Quinn Konopacky, UC San Diego, qkonopacky@ucsd.edu
Casey Miller, RIT, cwmsch@rit.edu
Jackie Monkiewicz, Arizona State University, jmonkiew@gmail.com
Julie Posselt, U Southern California, posselt@rossier.usc.edu
Enrico Ramirez-Ruiz, UC Santa Cruz, enrico@ucolick.org
Emily Rauscher, U Michigan, erausche@umich.edu
Seth Redfield, Wesleyan U, sredfield@wesleyan.edu
Alexander L. Rudolph, Cal Poly Pamona, alrudolph@cpp.edu
Karin Sandstrom, UC San Diego, kmsandstrom@ucsd.edu
Aparna Venkatesan, U San Francisco, avenkatesan@usfca.edu

Key Issue and Overview of Impact on the Field

The General Record Exam (GRE) and Physics Subject GRE (PGRE) are standard admission diagnostics for the majority of Physics and Astronomy graduate programs. Decades of research have shown that GRE and PGRE scores are weakly correlated with first-year academic performance, but have no significant correlation with degree completion, time to degree, publications, post graduate careers, and other key graduate outcomes. These high-stakes, standardized exams do show score differentials for underrepresented groups, notably African Americans, Hispanic Americans, Native Americans, and women of all races, for socio-psychological reasons unrelated to graduate potential. The exams are also difficult to access for many international (and domestic) students and students with disabilities, and are a significant financial burden for applicants. The use (and misuse) of the GRE/PGRE for graduate admissions exacerbates existing inequalities in the field, while providing little predictive power for graduate degree potential. In line with the 2016 policy recommendation by the American Astronomical Society's, we call on all Astronomy and Physics programs to eliminate or make optional the GRE and PGRE in graduate admissions. We summarize the practices and outcomes of those programs that have made this transition.

The GRE & PGRE in Graduate Admissions: What is it Testing?

The General Record Exam (GRE) and Physics Subject GRE (PGRE), produced by the Educational Testing Service (ETS), have long been used as standard admission diagnostics for the majority of Physics and Astronomy graduate programs in the United States (Posselt 2016; Potvin et al. 2017). Approximately 7,000 students take the PGRE annually (ETS 2019), and nearly all Physics Masters and PhD programs, and a plurality of Astronomy graduate programs, currently require or recommend one or both exams as part of their admissions requirements. Moreover, at least 1 in 3 Physics PhD programs use formal cutoff scores on the PGRE (and often the Quantitative GRE, or GRE-Q) to triage their admissions pool (with evidence that a higher fraction do so in practice; Potvich et al. 2017), in spite of ETS's own stated policy that such cutoffs are "contradictory to holistic admissions process" (ETS 2019). For the vast majority of students applying to US graduate programs in Physics and Astronomy, these high-stakes, time-sensitive, multiple-choice exams are a hurdle - and often a barrier - to pursuing advanced degrees. They are also a barrier for programs seeking to recruit the best graduate students.

There is scant evidence that the PGRE & GRE are particularly useful for screening applicants to assure their success in graduate programs in Astronomy and Physics. Numerous studies across multiple fields have found weak correlations between GRE and PGRE scores and performance in first-year courses or qualifying exams. However, no statistically significant correlations with more fundamental degree outcomes such as research productivity, degree completion, and time to degree have been found (Kuncel & Hazlett 2001; Miller & Stassun 2014; Miller et al. 2019). There is also no evidence that the PGRE is a strong predictor of post- graduate success in prize postdoctoral fellowships or first authorship (Levesque et al. 2015, 2017).

These exams are strong predictors for qualities that are irrelevant to graduate study - gender, race and nationality. Research by ETS and others have demonstrated statistically significant score differentials across gender, race, and citizenship, with notably lower scores for African Americans, Hispanic Americans, Native Americans, and women of all races as compared to White and Asian American men (ETS 2019; Miller & Stassun 2014). These score offsets are similar to those seen in other high-stakes standardized exams such as the SAT (Geiser 2015), MCAT (Dixon 2007), and LSAT (Taylor 2019), and can be attributed to broader social-psychological phenomena such as socioeconomic status (Croizet & Dutrévis 2004), imposter

syndrome (Clance & Imes 1978), or stereotype threat (Steele & Aaronson 1995), rather than academic ability or achievement. Such score differentials are particularly harmful combined with GRE/PGRE cutoffs, as they reinforce gender and race inequalities that remain substantial and persistent in both Physics and Astronomy graduate education (Miller & Stassun 2014).

Taking the GRE & PGRE can also involve practical barriers. Current fees for sitting for these exams and distributing scores to graduate programs can exceed $1,000 for most students,[1] on top of graduate school application fees; and applying for GRE fee reductions can be challenging. International students can face barriers getting a seat for a test, or even getting to the test site; there are only 7 test sites in all of India, and 4 in all of Brazil. And not everyone in the US has the same access to PGRE exams. Students in Tucson, AZ, Atlanta, GA, Seattle, WA, Austin, TX, and other major cities only get one exam date for the Fall PGRE exam, rather than the two provided for other locations.

Potential graduate students have options to avoiding these exams: they can get their degree abroad. One colleague reported:

> *"I met a good student at a summer school in Brazil I taught at and initially encouraged her to apply. It turned out that the cost of her taking the GRE would have been several months of income. I tried to find ways to get the fee waived but failed. She eventually decided she wouldn't take it, and went to get her degree in Europe."*

Such outcomes stand in direct opposition to repeated calls by the nation's scientific leadership to "develop, recruit, and retain top students, scientists, and engineers from both the U.S. and abroad" (National Academies 2007).

A Call to Eliminate the GRE & PGRE from Graduate Admissions

In January 2016, the American Astronomical Society endorsed a resolution[2] encouraging Astronomy graduate programs to limit the use of GRE and PGRE scores in admissions, stating:

> *"Given the research indicating that the GRE and PGRE are poor predictors of graduate student success, that their use in graduate admissions has a particularly negative impact on underrepresented groups, and that they represent a financial burden for*

[1] This assumes a typical pattern of taking the GRE once ($205), the PGRE twice ($300) and distributing scores to 10 programs/fellowships ($486).
[2] https://aas.org/governance/society-resolutions#GRE

many students in pursuing advanced degrees in the astronomical sciences, the AAS recommends that graduate programs eliminate or make optional the GRE and PGRE as metrics of evaluation for graduate applicants. If GRE or PGRE scores are used, the AAS recommends that admissions criteria account explicitly for the known systematics in scores as a function of gender, race, and socioeconomic status, and that cutoff scores not be used to eliminate candidates from admission, scholarships/fellowships, or financial support, in accordance with ETS recommendations."

Partly in response to this call, nearly half of graduate degree programs in Astronomy (including several Planetary Science departments and joint programs) have now either eliminated the PGRE as a requirement or have made reporting of the exam score optional[3] (with different - and confusing - degrees of "recommendedness"). Table 1 shows that only 9 of the top 20 astrophysics degree programs (based on 2010 NRC rankings) now require the PGRE. Of the remaining, 2 recommend it, 7 make it optional, and 2 no longer accept it. Both the NSF Graduate Research Fellowship and the Ford Foundation Fellowship have also dropped the GRE/PGRE from their application requirements. In contrast, only a handful of Physics graduate programs have dropped or made optional the PGRE.

Many of the programs that have reduced PGRE requirements have maintained their GRE requirements. In most cases this requirement has been set by the university's overall graduate program, as GRE scores are used in national graduate program rankings, including those by the National Research Council. Having GRE scores used for program ranking has locked in the use of this exam in many graduate programs, although some universities, such as Stanford[4], Harvard[5], and the University of Michigan,[6] have started to allow departments to waive the general GRE requirement. Student advocacy groups, such as Chicago Biosciences Graduate Recruitment Initiative Team (GRIT[7]), have been notable in pushing for these changes.

Given the limited effectiveness of the GRE & PGRE in evaluating potentially successful students,

---

[3] A curated list of Astrophysics/Physics/Planetary science programs and PGRE requirements is maintained at the following site: https://docs.google.com/spreadsheets/d/19UhYToXOPZkZ3CM469ru3Uwk4584CmzZyAVVwQJJcyc/edit#gid=0

[4] https://www.insidehighered.com/admissions/article/2018/04/16/stanford-adjusts-gre-requirement

[5] https://www.insidehighered.com/admissions/article/2019/03/18/cornell-and-harvard-english-departments-drop-gre-requirement

[6] https://www.sciencemag.org/careers/2017/08/updated-biomedical-phd-program-major-research-university-drops-gre-requirement

[7] https://biosciences.uchicago.edu/diversity/grit

Institution	GRE/PGRE Policy	Institution	GRE/PGRE Policy
Caltech	GRE required PGRE recommended	Johns Hopkins U	GRE required PGRE required
Princeton	GRE required PGRE required	Ohio State U	GRE required PGRE optional
UC Berkeley	GRE required PGRE required	Cornell	GRE not accepted PGRE optional
MIT (Physics & Planetary Science)	GRE required PGRE required	Columbia	GRE required PGRE required
Penn State	GRE required PGRE required	U. Texas Austin	GRE required PGRE not accepted
Harvard	GRE not accepted PGRE optional	U. Wisconsin Madison	GRE required PGRE optional
U. Chicago	GRE recommended PGRE recommended	U. Virginia	GRE required PGRE required
U Washington	GRE required PGRE not accepted	U. Colorado Boulder	GRE required PGRE optional
U. Arizona	GRE required PGRE optional	U. Maryland	GRE required PGRE required
UC Santa Cruz	GRE required PGRE optional	UC Los Angeles	GRE required PGRE required

Table 1: GRE/PGRE requirements for the top 20 Astrophysics degree programs, based on the average of the National Research Council's 2010 S- and R-rankings, using both 5% and 95% ranks. Requirements are as stated on admissions program websites as of July 2019, and are subject to change.

the demographic inequalities they perpetuate, and the negative impact they have in recruiting a broad graduate talent pool (and notwithstanding the fact that most international programs have never required these exams for admissions), **we call on the community to eliminate (or make optional) the GRE and PGRE exams in admissions for all Astronomy and Physics graduate programs.**

Implementations & Outcomes: Case Studies

Even before the AAS Policy Statement, many faculty have tried to change their programs' admissions policies regarding the GRE and PGRE, motivated by the studies listed above. Pushback may range from technical ("our graduate school won't allow us to do this") to pragmatic ("how can we possibly read 300 applications?"), and from seemingly student-centered ("we have to make sure they are prepared for our classes and qualifying exams") to unabashedly faculty-centered ("I don't want to have to deal with poor students"). More troublesome, many faculty are unmotivated by - and even skeptical of - research demonstrating the inequities in standardized exams such as the GRE (Handley et al. 2015). As Coil (2017) notes, "no one wants to believe that they achieved their success, even in some small part, based on their gender or ethnicity. We all want to feel that we deserve the success and accolades that we have received based on our own merit."

So how have programs that previously required the PGRE & GRE exams managed to deal with both real and imaginary barriers?

Case Study 1: Boulder

In 2018, CU Boulder's Astrophysical and Planetary Sciences program made the PGRE optional. This change took sustained effort and consensus building over a period of about five years, with early discussions beginning within the Admissions committee. In the 2016/2017 cycle, the committee brought a motion to the faculty to remove the PGRE, which was deferred with no action taken. Advocates continued discussions on the data and research surrounding the PGRE, and in the 2017/2018 admissions cycle, the committee decided to internally treat the PGRE as optional, disregarding it in nearly all cases and only including it in discussion if the PGRE score offset a low GPA. The committee presented the data on the admitted pool to the faculty for a second time and moved to either drop the PGRE or make it optional; the latter was approved. The adoption was not unanimous and remains somewhat controversial within the department. To clarify the "optional" status, specific language was included on the "Prospective Student" web page (see below) .

The following 2018/2019 admissions cycle saw an increase of about 48% in applications over the previous year, a 60% acceleration in growth over the previous year (30%) when the PGRE was required. All applications were evaluated by the admissions committee (notably half faculty and half graduate students), resulting in a heavy service load for committee members. About half of the committee utilized a shared rubric, while the other half did not.

Case Study 2: Harvard

In 2016, Harvard's Astronomy faculty voted to drop the GRE from their admissions criteria and made the PGRE optional. The subsequent application cycle in 2017 saw a 76% increase in applications from *all* groups, with statistically district increases in applications from historically underrepresented minorities (169% increase) and non-US women (112% increase). Indeed, the fraction of applications from minorities rose from 12% to 19% of applications. Applications from non-US women and non-US colleges also more than doubled. The elevated application rate persisted in 2018.

Recognizing the need to deal with an increased number of applications, rather than having a subset of the faculty (the Admissions Committee) evaluate applications, all (non-sabbatical) faculty were required to do a first round evaluation, and the Admissions Committee made the second round cut . Currently, Harvard Astronomy graduate students are 50% women and 30% underrepresented minorities. It is also notable that the Astronomy department's request to drop the GRE encouraged Harvard to invite all departments to reconsider the requirement, and several programs have followed suit.

Strategic Plan for Moving Beyond the GRE and PGRE

As these two cases illustrate, there are challenges in removing standardized exams from admissions procedures; yet the research-based evidence of benefits in competitiveness (at both institutional and national levels), accuracy of evaluation, and equity argue against the use of these exams in graduate admissions. Drawing on the recommendations of the 2018 AAS Task Force on Diversity and Inclusion in Astronomy Graduate Education (Rudolph et al. 2019), 2015 Inclusive Astronomy Nashville Recommendations[8], multiple research studies and the practices of graduate programs that have changed their admissions policies, we offer the following strategies for removing the GRE/PGRE from graduate admission requirements while retaining a competitive and equitable admissions process.

1. First develop departmental consensus on what the goals of your graduate program are. Faculty's views on the necessary preparation for graduate study can differ substantially. Some faculty are looking for elite students who can explore difficult theoretical problems. Others may be looking for students with laboratory or research skills who can jump into a complex experiment. Both types of applicants are ideal graduate students for these respective faculty, but likely possess differing degrees of preparation or background. How does your graduate program evaluate students with a broad range of training? Is the first-year course sequence used as an opportunity to bring students "up to speed" (student-centered) or to identify and

[8] https://aas.org/posts/news/2017/02/inclusive-astronomy-nashville-recommendations

remove weak students from the program (faculty-centered)? Do you expect your students to know the curriculum (fixed mindset) or learn the curriculum (growth mindset)? What are the diversity goals of your graduate program?

Establishing a consensus on graduate program goals, particularly as it pertains to student preparation and performance, is essential before making changes to admissions processes, such as removing the GRE/PGRE. The AAS Graduate Taskforce Study recommends a multi-stage, iterative process to engage a department in reaching consensus on change, including:

1. Engage in genuine, open, and sometimes difficult conversations;
2. Conduct assessments to identify areas of need or opportunities;
3. Create short- and long-term actionable department plans with measurable outcomes that address the goals of diversity and inclusion;
4. Incentivize and support professional development in the support of the five (5) program goals;
5. Take actions based on the departmental plan and monitor progress toward outcomes, employing inclusive processes; and
6. Encourage ongoing improvements toward inclusiveness by iterating through the process represented in steps 1-5.

2. Recognize that the GRE and PGRE are not the best diagnostics of physics knowledge.
Despite their broad use, the GRE-Q and PGRE are rather poor assessments of physics knowledge as it is taught in most US undergraduate programs. The GRE-Q is a very low-level mathematics exam, testing arithmetic, algebra, geometry, and data analysis, but not trigonometry or calculus. [9] On the other hand, much of the subject material of the PGRE, junior- and senior-level undergraduate physics, is often taken by students during or after the Fall terms of their senior year[10]. Moreover, the format of these exams - high-speed, multiple choice questions - is inconsistent with assessments used in nearly all Physics major courses, which generally emphasize quantitative reasoning and problem solving. Often a "decent" score on the PGRE can be obtained with just basic high-stakes test strategies - estimation, unit analysis, limits - without any need to understand the underlying physics principles (conversely, students who know their physics may simply run out of time having not been prepped on the nature of the exam). Other metrics such as graduate courses taken or appropriate research experience are likely better measures of the preparation of a graduate student. Even undergraduate GPA is a better predictor of graduate success (Miller et al. 2019).

[9] https://www.ets.org/gre/revised_general/prepare/quantitative_reasoning/; the median score for self-identified physics/astronomy majors is 83rd percentile.
[10] About 40% of Bachelors degrees in physics are awarded from small colleges, including minority serving institutions. In these places, and others, curriculum is often out of phase with the test's content. Students may be taking the PGRE concurrently or before the physics courses they need to succeed on the exam..

3. Make sure everyone has access to the research. Like any specialized topic, faculty may not be aware of the body of research that has been conducted examining correlations between GRE and PGRE scores and outcomes, particularly for traditionally underrepresented groups. Regular equity discussion groups that are inclusive of faculty, postdocs, students and staff are an excellent venue for reviewing and discussing the literature. Maintaining documentation of the pros and cons arising from these discussions[11] can help prevent repeated arguments.

4. Evaluate your own program's outcomes. While the statistical power of large studies such as Miller et al. (2019) provide an evidence-based rationale for eliminating the GRE/PGRE, a self-study of admissions practices and outcomes can be particularly effective in guiding policy. A self-study by the University of Texas, Austin (UT) found that, despite accepting students with higher PGRE scores than those of the applicant pool, the PGRE scores of prize fellowship recipients were distributed according to the original applicant pool. This was one factor in their decision to stop accepting PGRE scores from applicants starting in Fall 2016. On the other end of the spectrum, one of the coauthor's institutions recently mandated a PGRE cutoff of 55%, resulting in a class that was only 8% women, had no underrepresented minorities, and rejected an NSF Graduate Research Fellowship recipient. It is important to honestly reflect on whether these are the kind of outcomes that benefit your program.

5. Make an advanced plan for modifying admissions criteria and processes. As noted in the case studies, one positive - and challenging - outcome of removing GRE and PGRE requirements may be a substantial increase in applications. Engaging all of the faculty in a first-round evaluation (ala Harvard) may reduce the burden on an Admissions Committee; so can including graduate students on the Admissions Committee (ala U. Colorado), which additionally increases the transparency of the process and agency by the graduate students. To assure all evaluators are on the same page, committees or departments should develop and use consensus rubrics well before applications are received. These rubrics should include a broad range of student qualities, including socio-emotional competencies such as perseverance, creativity, conscientiousness, realistic self-appraisal, and leadership, among others (Sedlacek 2004; Boyatzis 2008). Rubrics should be revisited annually to assure evaluations are matched to outcomes. Example rubrics are compiled in the AAS Graduate Taskforce Study, while the Fisk-Vanderbilt Master's-to-PhD Bridge Program has developed an extensively-researched admissions toolkit.[12]

6. Clearly advertise your GRE/PGRE policy and rationale for it. This is especially important for programs that decide to make the GRE/PGRE optional or recommended, which may cause

[11] For example, see U. Michigan's white paper reflecting pros and cons on using the GRE: https://docs.google.com/document/d/1fqKVFsVHBzi8y5yd5C6yOPTL9Kh97vV5cV8g1D1fdWs/mobilebasic

[12] http://fisk-vanderbilt-bridge.org/tool-kit

confusion from applicants. A good example comes from the University of Colorado's Astronomy and Planetary Science (APS) program, which states on its website[13]:

> *"The Graduate Record Examination general aptitude tests are required for application to our department. The APS Department does not employ any quantitative cutoff for these scores, and the GRE is only one facet out of many which the admission committee uses to review each student's application. The Physics subject test may be submitted, but is no longer required. Data show that Physics GRE scores are biased, and that performance is correlated more strongly with axes of the test-taker's identity such as race and gender than physics knowledge/skill alone. As a result, submission of your physics GRE scores is optional and will only be considered in the context of your complete application. For example, if you feel your performance in your upper-level physics classes does not accurately reflect your mastery of the material, but your score on the Physics GRE does, you may choose to submit your Physics GRE score to bolster your application. If you feel your physics GRE score does not accurately reflect your mastery of physics, evaluation of your application will not be affected by electing to withhold those scores."*

7. Accept that the transition away from the GRE/PGRE may be a multi-stage process. The case of the University of Colorado Boulder illustrates two reasons for this: convincing skeptical faculty that "quality" will not be lost (the significant increase in applications may assure this) and developing an admissions process that is effective and not burdensome. As scientists, we should embrace evidence-based experimentation in developing admissions procedures. For example, the University of Illinois at Urbana-Champaign Astrophysics PhD program (which makes the PGRE optional) is currently evaluating GRE-blind review as a way to bring skeptical faculty on board. Making the GRE/PGRE optional may be sufficient to realize equity and recruitment goals.

Request to Funding Agencies

Despite the considerable body of research on admissions practices, studies such as the AAS Graduate Taskforce Study, and toolkits produced by programs such as Fisk-Vanderbilt Master's-to-PhD Bridge Program, there are few resources available for programs to conduct self-studies on their admissions practices, long-term tracking of applicants who matriculate into or complete (or not) graduate programs, and training of admissions committees on best practices of holistic admissions. We encourage the NSF to expand funding programs such as ADVANCE, AGEP, INCLUDES and TCUP to allow institutions to conduct such studies, and to support the collection and dissemination of institutional admissions practices and outcomes with the aim for designing, evaluating, and encouraging the adoption of inclusive practices.

[13] https://www.colorado.edu/aps/prospective-students

References

R. E. Boyatzis, (2008). Competencies in the 21st century. Journal of Management Development, 27(1), 5-12.

P. R. Clance & S. A Imes, Suzanne A. (1978). The Impostor Phenomenon in High Achieving Women: Dynamics and Therapeutic Intervention. Psychotherapy Theory, Research and Practice 15 (3): 241–247.

A. Coil (2017) Why Men Don't Believe the Data on Gender Bias in Science. WIRED Magazine, August 25, 2017

J-C. Croizet & M Dutrévis (2004) Socioeconomic Status and Intelligence: Why Test Scores Do Not Equal Merit, Journal of Poverty, 8:3, 91-107

D. Dixon (2007) Gender Differences in Academic Qualifications and Medical School Performance of Osteopathic Medical Students, Journal of the International Association of Medical Science Educators 19 (1), 33

ETS: GRE Guide to the Use of Scores 2019-2020: https://www.ets.org/s/gre/pdf/gre_guide.pdf

S. Geiser 2015 "The Growing Correlation Between Race And SAT Scores: New Findings From California" Research & Occasional Paper Series: CSHE.10.15

D. R. Hancock (2001). Effects of test anxiety and evaluative threat on students' achievement and motivation. J. Educ. Res. 94, 284–290

I. M. Handley, E. R. Brown, C. A. Moss-Racusin, & J. L. Smith (2015) Quality of evidence revealing subtle gender biases in science is in the eye of the beholder. PNAS 112, 43

N. R. Kuncel, S. A. Hezlett, & D. S. Ones (2001). A comprehensive meta-analysis of the predictive validity of the graduate record examinations: Implications for graduate student selection and performance. Psychol. Bull. 127, 162–181.

E. M. Levesque, R. Bezanson, G. R. Tremblay (2015). Physics GRE Scores of Prize Postdoctoral Fellows in Astronomy, arXiv:1512.03709

E. M. Levesque, R. Bezanson, G. R. Tremblay (2017). Why astronomy programs are moving on from the physics GRE, Physics Today, 31 Mar 2017, Commentary & Reviews

C. W. Miller (2013). Admissions criteria and diversity in graduate school. APS News, 2, The Back Page.

C. W. Miller & K. Stassun (2014) A test that fails: A standard test for admission to graduate school misses potential winners. Nature Careers 510, 303.

C. W. Miller, B, M. Zwickl, J. R. Posselt, R. T. Silvestrini, & T. Hodapp (2019). Typical physics Ph.D. admissions criteria limit access to underrepresented groups but
fail to predict doctoral completion. Sci. Adv. 2019 **5**, eaat7550

The National Academy of Engineering, and Institute of Medicine (2007). Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. (Washington, DC: The National Academies Press).

S. L. Peterson, E. S. Erenrich, D. L. Levine, J. Vigoreaux, & K. Gile (2018). Multi-institutional study of GRE scores as predictors of STEM PhD degree completion: GRE gets a low mark. PLOS ONE 13(10), e0206570

A.M. Porter & R. Ivie (2019) AIP SRC Report: Women in Physics and Astronomy

J. R. Posselt (2016) Inside Graduate Admissions: Merit, Diversity, and Faculty Gatekeeping (Harvard Univ. Press,).

G. Potvin, D. Chari, & T. Hodapp (2017). Investigating approaches to diversity in a national survey of physics doctoral degree programs: The graduate admissions landscape. Phys. Rev. Phys. Educ. Res. 13, 020142.

A. Rudolph, et al. (2019). Final Report of the 2018 AAS Task Force on Diversity and Inclusion in Astronomy Graduate Education. Bulletin of the American Astronomical Society, Vol. 51, Issue 1, id. 0101

W. E. Sedlacek (2004). Beyond the Big Test: Noncognitive Assessment in Higher Education. (Indiana: Jossey-Bass, An Imprint of Wiley)

L. Smith-Doerr, S. Alegria, S., & T. Sacco, (2017). How diversity matters in the UD Science and Engineering Workforce: A critical review considering integration in teams, fields, and organizational contexts. Engaging Science, Technology, and Society, 3, 139-153.

C. M. Steele & J. Aronson (1995). Stereotype threat and the intellectual test performance of African Americans. J. Pers. Soc. Psychol. 69, 797–811

A. N. Taylor (2019) The Marginalization of Black Aspiring Lawyers, 13 FIU L. Rev. 489

G. M. Walton, & S. J. Spencer (2009) "Latent Ability Grades and Test Scores Systematically Underestimate the Intellectual Ability of Negatively Stereotyped Students" Psychological Science 20, 9

R. Zwick (2002) Fair Game?: The Use of Standardized Admissions Tests in Higher Education (Psychology Press).