Resource Letter: GP-1: Gender and Physics

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RESOURCE LETTER

Resource Letter: GP-1: Gender and Physics

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This Resource Letter introduces issues which influence the representation and participation of women in physics. It is intended for all physicists, regardless of subfield, who teach, advise, or work in research groups with other people. We start with reports, statistics, and literature reviews, give a theoretical framework, and address the intersection of gender with additional identities. Then, we review several factors that impact the participation of women at all levels. We continue with the literature about scientific careers and then talk about "what works" and how women can be supported as physics students and as physicists. We conclude with a call to action.
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I. INTRODUCTION

In this letter, we give an overview of research results and teaching resources on gender in physics. There are a number of arguments for why this topic is important. One argument is that physics programs continue to do a poor job of recruiting and retaining women; only about 20% of the physics undergraduate degrees in the United States go to women, a number that has stalled during a time when biology, chemistry, and mathematics have made large gains. When any field is dominated for too long by a homogeneous group of people, the intellectual richness and rigor of that field are affected, and it underperforms its potential. If groups of talented people are systematically excluded from areas of science where fundamental research occurs, that science is failing to serve society.[1] For the sake of physics and our students, it is worth digging into the question of gender in physics.

Defining "gender" is nuanced, because it is a culturally rooted concept that shifts in time—including in the last several decades—so that not all resources in this letter use the word in the same way. We will borrow from previous work[3] and give an operational definition that holds gender distinct from sex. "Sex" is rooted in biology, in the physiological characteristics of a person (though not as cut-and-dried as is commonly assumed; see Resources 18 and 19). Gender is currently understood to describe identity that may or may not overlap with assigned sex. It can be external, as a combination of "clothing, accessories, outward appearance, or behaviors to signify masculinity and femininity that are validated (or not) by other members of society."[3] Or it can be an internal perception of identity that is not outwardly expressed. A person's gender identity is not necessarily constant through their life.

In this letter, we approach this large topic from several angles. Section II begins with a "bird's eye view" of statistics, reports, and literature reviews of various lengths and densities. Section III gives some theoretical framing, digging deeper into questions like "how is gender defined?" (and also "why should we care about gender in science?"). Section IV addresses intersectionality, the ways that other identity facets such as race interact with gender. Section V gives selections from the vast literature about what affects the participation of women and girls in physics at all levels. Section VI focuses on careers, and Sec. VII highlights "what works" resources with an emphasis on teaching. Section VIII concludes with some thoughts about the future.

There are several important topics that are not treated with the depth that they deserve in this letter. We look at interactions of race and gender in Sec. III and as it comes up in various resources throughout. A subsequent Resource Letter will address race in physics as its own topic. The intersection of

LGBTQIA+ identity and gender and the intersection of disability and gender are only just starting to be explored in a physics context. (LGBTQIA+ is an abbreviation to describe sexual and gender minorities. It includes Lesbian, Gay, Bisexual, and Transgender, as well as Queer or Questioning, Intersex, and Asexual identities. To be inclusive of other sexual and gender identities (e.g., agender and pansexual), the + is added. We use LGBTQIA+ in this letter but follow the authors' usage for specific resources that use other abbreviations.) We will point to these resources where available. Finally, many (though far from all) of these references were developed in the United States, and all are in English. We acknowledge that these constraints have limited the scope of this letter.

1. "**The challenges of educating the next generation of the professoriate**," S. Tilghman, Killam Lecture (2003), transcript at https://www.princeton.edu/president/tilghman/speeches/20031023/ (accessed January 31, 2019). Outlines several reasons to care about diversity in science; see especially the comments beginning, "Attracting the best and the brightest into a life in science…" (E)
2. "**Vantage point: Look to future of women in science and engineering**," J. Hennessy, S. Hockfield, and S. Tilghman, Stanford Report (February 11, 2005), online at https://news.stanford.edu/news/2005/february16/henop-021605.html (accessed April 26, 2019). Commentary from the presidents of Stanford, MIT, and Princeton supporting the benefits of gender equity in STEM education. (E)
3. "Enriching gender in physics education research: A binary past and a complex future," A. L. Traxler, X. C. Cid, J. Blue, and R. Barthelemy, Phys. Rev. Phys. Educ. Res. **12**(2), 020114-1–15 (2016). Reviews trends and suggests new directions for physics education research on gender. (I)

II. STATISTICS, REPORTS, AND LITERATURE REVIEWS

In this section, we include reviews of the literature and reports that allow the reader to orient themselves regarding what is known regarding gender and physics. The following statistical reports, reviews of literature, and research critiques are beneficial for framing the conversation on gender and physics. These works reveal that women are underrepresented in physics and many STEM fields; there exists a higher attrition rate for women in STEM, and the existing STEM wage gap negatively impacts women. We have chosen to use terminology in the summary sentences which mirrors the terminology used in the reports. This includes the use of binary gender terms (men and women, male and female, boys and girls) in some instances. The 1-2-word sentences are brief summary statements of the findings or what is contained in the report and do not include an evaluation or judgement of the report design or findings.

A. Reports and statistics

4. **Women, Minorities, and Persons with Disabilities in Science and Engineering: 2017**, Special Report NSF 17.310 (National Science Foundation, National Center for Science and Engineering Statistics, Arlington, VA, 2017). This biannual statistical report focuses on women, ethnic/racial minorities, and persons with disabilities in science and engineering with a focus on enrollment, field of degree, occupation, employment status, and early career doctorate holders. (E)
5. **Women in STEM: A gender gap to innovation**, D. N. Beede, T. A. Julian, D. Langdon, G. McKittrick, B. Khan, and M. E. Doms (US. Department of Commerce, Economics and Statistics Administration, Issue Brief #04-11, 2011). This report published by the U.S. Department of Commerce used data from 2000 to 2009 to find that US women are underrepresented in STEM degree attainment and the STEM workforce, and that there exists a gender wage gap among workers in STEM occupations. (E)
6. **STEM Inclusion Study Organization Report: AAPT**, E. Cech and T. Waidzunas (University of Michigan, Ann Arbor, 2017). This report and Ref. 7 are part of a large-scale, national-level study examining the experiences of women, racial and ethnic minorities, persons with disabilities, and lesbian, gay, bisexual, transgender, and queer members of two professional societies, the American Association of Physics Teachers and the American Physical Society, using survey data. (E)
7. **STEM Inclusion Study Organization Report: APS**, E. Cech and T. Waidzunas (University of Michigan, Ann Arbor, 2018). See comment to Ref. 6. (E)
8. **STEM Attrition: College Students' Paths into and out of STEM Fields: Statistical Analysis Report**. NCES 2014-001, X. Chen and M. Soldner (National Center for Education Statistics, Washington, DC, 2013). This statistical analysis report identifies characteristics of students who leave STEM fields and identifies factors associated with STEM attrition, finding that female STEM entrants were more likely to switch out of the STEM major than their male counterparts at the associate-degree level when a multinomial probit model was applied, and at all levels when using bivariate analysis. (E)
9. **LGBT Climate in Physics: Building an Inclusive Community**, T. J. Atherton, R. S. Barthelemy, W. Deconinck, M. L. Falk, S. Garmon, E. Long, M. Plisch, E. H. Simmons, and K. Reeves (American Physical Society, College Park, MD, 2016). This report commissioned by the American Physical Society provides an assessment of barriers to inclusion in the physics community for LGBT physicists based on focus groups, a detailed climate survey, and in-depth interviews with self-identified LGBT physicists. (E)
10. **African American, Hispanic, and Native American Women among Bachelors in Physical Sciences and Engineering: Results from 2003–2013 Data of the National Center for Education Statistics**, L. Merner and J. Tyler (American Institute of Physics, College Park: 2017). This statistical report focuses on the underrepresentation of African American, Hispanic, and Native American Women in Physical Sciences and Engineering, finding that there was growth in bachelor's degrees awarded to African American, Hispanic, and Native American women, but very little growth in bachelor's degrees in physical science and engineering. (E)
11. **Women in Physics: 6th IUPAP International Conference on Women in Physics.** G. Cochran, C. Singh, and N. Wilkin, Editors, AIP Conference Proceedings 2109 (2019). These are the most recently published proceedings from the International Union of Pure and Applied

Physics' International Conference on Women in Physics, which happens every three years. This a good starting place to learn more about the issues women in physics face outside the US and includes information on several topics discussed later in this resource letter. More proceedings will be forthcoming here: https://aip.scitation.org/toc/apc/2109/1?expanded=2109. (E)

B. Review of the literature

12. "Women in physics: A comparison to science, technology, engineering, and math education over four decades," L. J. Sax, K. J. Lehman, R. S. Barthelemy, and G. Lim, Phys. Rev. Phys. Educ. Res. **12**(2), 020108-1–17 (2016). Reviews the literature on themes related to gender gaps in STEM, examines how women's intention to major in physics has changed over time, and provides a profile of women likely to major in physics. (I)

13. "Women in physics: A review," L. McCullough, Phys. Teach. **40**(2), 86–91 (2002). This review discusses the underrepresentation of women in physics at various levels, factors causing women to leave physics, and suggestions for addressing the problem. Concise, very readable, and not nearly as out of date as one might hope after more than 15 years. (E)

14. **Women and Physics**, L. McCullough (Morgan and Claypool Publishers, San Rafael, CA, USA, 2016). A longer and updated review of the themes introduced in Resource 13. (I)

15. "Beneath the numbers: A review of gender disparities in undergraduate education across science, technology, engineering, and math disciplines," S. L. Eddy and S. E. Brownell, Phys. Rev. Phys. Educ. Res. **12**(2), 020106-1–20 (2016). Reviews studies on gender across STEM disciplines with an emphasis on measures correlated with retention, such as academic performance, engagement, self-efficacy, belonging, and identity. (I)

16. "Increasing achievement and higher-education representation of under-represented groups in science, technology, engineering, and mathematics fields: A review of current K-12 intervention programs," J. M. Valla and W. M. Williams, J. Women minorities Sci. Eng. **18**(1), 21–53 (2012). This review focuses on K-12 program interventions designed to increase representation in STEM fields with a focus on program structures and components. (A)

III. THEORY

A deep dive into feminist theory is beyond the scope of this letter, but "what's going on with gender in our classrooms?" is a question that needs this expertise. Even distinguishing gender from sex is a useful first step,[17] but educators should also be aware of the power of Western cultural norms about gender. These norms have acted (and still do) to steer women away from the rigorous practice of science, but this is overlooked by statements like "girls just aren't as interested in science" that imply a free and unbiased choice by those girls. The pieces in this section are useful for unearthing and questioning assumptions about what gender means, and how much of the male-dominated composition of physics is just "the way things are."

A. Gender theory

17. The Genderbread Person <https://www.genderbread.org/resource/genderbread-person-v4-0>. Diagram that breaks gender identity, expression, sexuality, and more into bite-sized pieces. (E)

18. "The five sexes: Why male and female are not enough," A. Fausto-Sterling, Science **33**(2), 20–25 (1993). Introduction to intersexuality, which breaks down the idea that there are only two strictly defined biological sexes. (E)

19. "Sex redefined," C. Ainsworth, Nature **518**(7539), 288–291 (2015). News update in Nature that reviews the current scientific model of the spectrum of biological sex. (E)

20. "Performative acts and gender constitution: An essay in phenomenology and feminist theory," J. Butler, Theatre J. **40**(4), 519–531 (1988). An article-length introduction to some of Butler's arguments about the continuously performed nature of gender. (A)

B. Feminist science studies

21. **Has Feminism Changed Science?** L. Schiebinger (Harvard U. P., Cambridge, 2001). Development of modern-day scientific disciplines, the gendered nature of their power structures, and feminist critiques of women's underrepresentation in these fields. (E)

22. "Has Feminism Changed Physics?" A. Bug, Signs **28**(3), 881–899 (2003). Discusses gender in physics beyond numbers representation. Notes connection between physics education research and feminist studies, both existing work and areas that should be explored. (I)

23. "(Baby) Steps Toward Feminist Physics," B. L. Whitten, J. Minorities Women Sci. Eng. **18**(2) 115–134 (2012). Reflects on feminist developments in other sciences and suggests nine categories of feminist (or potentially so) physics projects. (E)

24. "The history and philosophy of women in science: A review essay," L. Schiebinger, Signs **12**(2), 305–322 (1987). Compares four approaches to studying "women in science"—the encyclopedia approach, critiques of institutional barriers, biological determinism arguments, and feminist critiques of science norms. (E)

25. **Reflections on Gender and Science**, E. F. Keller (Yale U. P., New Haven, 1985). Essays on cultural stereotypes around gender binaries and how these stereotypes have shaped the history and present-day practice of science. (A)

26. **The Science Question in Feminism**, S. Harding (Cornell U. P., Ithaca/London, 1986). Critically examines the foundations of how social gender schema affect the structure of science, including connections to race and class structure. An influential outline of several feminist science critiques that are still playing out today. (A)

C. Education

Several of the resources already listed above touch on education but primarily in broad statistics. The following five resources illustrate how theoretical perspectives about gender can influence how we teach as well as the structure and kind of questions we ask in education research.

27. **Failing at Fairness: How America's Schools Cheat Girls**, M. Sadker and D. Sadker (Charles Scribner's Sons, New York, 1994). This book reports the results of 20 years of research that show how differently boys and girls are treated in the (pre-college) classroom. This unfair treatment has implications for how young women will choose majors and careers, as well as how they will act in the college classroom. (E)

28. **The Science Education of American Girls: A Historical Perspective**, K. Tolley (Routledge, London, 2002). This book traces the pre-college science education of American girls from the 17th through the 20th century, discussing the changes in curriculum and its delivery that resulted in the inequitable education that we have now. (E)

29. "Gender-inclusive science teaching: A feminist-constructivist approach," A. Roychoudhury, D. J. Tippins, and S. E. Nichols, J. Res. Sci. Teach. **32**, 897–924 (1995). Applies feminist science critiques to education reform, including a case study of a physical science class that incorporated principles from feminist standpoint theory. (I)

30. "Impact of equity models and statistical measures on interpretations of educational reform," I. Rodriguez, E. Brewe, V. Sawtelle, and L. J. Kramer, Phys. Rev. Phys. Educ. Res. **8**(2), 020103-1–7 (2012). Contrasts three models of equity used in education research and how model choice affects interpretation of results. (E)

31. "Embodying science: A feminist perspective on learning," N. Brickhouse, J. Res. Sci. Teach. **38**(3), 282–295 (2001). Discusses how learning theories in science align (or do not align) with feminist research on equity. (I)

IV. INTERSECTIONALITY

Gender is only one of many socio-demographic identities that impact an individual's experience. Intersectionality is the understanding that people have multiple identities that interact in ways that influence power and access, providing unique experiences for individuals who may share some identities. In this section, we have included papers on intersectionality that explain the historical roots of the movement and how it has been used in research. We also include in this section a paper that used an intersectional approach, prior to the coining of the term intersectionality, focused particularly on Women of Color in STEM and a more recent work focusing on the same intersection. (The authors have chosen to capitalize the term "Women of Color" throughout this document as it is used as a racial identity group. The authors have also capitalized all other racial identity groups in this document. For references supporting this decision, see https://consciousstyleguide.com/capitalizing-for-equality/, https://www.nytimes.com/2014/11/19/opinion/the-case-for-black-with-a-capital-b.html, and https://www.press.umich.edu/9843/color_of_privilege). With the exception of those two reviews,[35,36] we have made the decision to include studies that disaggregate data by the intersections of race and gender throughout this resource letter rather than to include them in this category. We have also made the decision to include studies focused on the intersection of particular identities (i.e., Women of Color), in the sections most related to the topic of the study/paper rather than in this section.

32. **Black Feminist Thought: Knowledge, Consciousness, and the Politics of Empowerment.** P. H. Collins (Routledge, 2002). This book provides an overview of Black Feminist thought that explores intersecting oppressions of race, class, and gender. (I)

33. "Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics," K. Crenshaw, The University of Chicago Legal Forum, 139–167 (1989). Explains how single-axis frameworks, failing to utilize an intersectional framework, marginalize Black women. (A)

34. "Toward a field of intersectionality studies: Theory, applications, and praxis," S. Cho, K. W. Crenshaw, and L. McCall, Signs **38**(4), 785–810 (2013). Discusses what it means to engage in intersectionality studies and includes identification of three fields of inquiry in intersectionality and a brief history of the intersectionality movement. (A)

35. **The double bind: The price of being a minority woman in science**, S. M. Malcom, P. Q. Hall, and J. W. Brown (American Association for the Advancement of Science, Washington, DC, 1976). This report, based on a conference, focused on the intersections of gender and race by focusing on Women of Color in STEM before the term intersectionality was coined and the intersectionality movement started. (I)

36. "Inside the double bind: A synthesis of empirical research on undergraduate and graduate women of color in science, technology, engineering, and mathematics," M. Ong, C. Wright, L. Espinosa, and G. Orfield, Harvard Educ. Rev. **81**(2), 172–209 (2011). A thorough review and synthesis of research on Women of Color in STEM focused on undergraduate, graduate, and policy levels. (I)

37. "Broadening the science of broadening participation in STEM through critical mixed methodologies and intersectionality frameworks," H. Metcalf, D. Russell, and C. Hill, Am. Behav. Sci. **62**(5), 580–599 (2018). This paper introduces critical mixed-methodological approaches and intersectionality frameworks and how their use can improve research on broadening participation in STEM. (A)

V. IMPACTS ON PARTICIPATION AND EXPERIENCES FOR WOMEN AT ALL LEVELS

A common explanation for the lack of women in physics is that girls "just aren't interested" in the field. There are many assumptions baked into this idea: that children's interests develop in a vacuum (perhaps frictionless, populated by spherical cows); that they are not filtered through the years by messages from teachers, peers, and family; and that on entering a field, people of the same ability will have similar experiences regardless of their gender. However, this model of pure interest and aptitude is thoroughly unsupported by evidence. In this section, we inventory some of the ways that our social and cultural fabric—in which all science is embedded—shapes interest, who is perceived as belonging to science, and how newcomers are treated. We have used subsections to highlight topics, but there is frequent overlap between them—for example, implicit bias and microaggressions and identity are often intertwined.

A. Implicit bias and stereotype threat

Implicit or unconscious biases are stereotypes that people carry about other groups, which may be at odds with their conscious beliefs. In most social settings, we react with subtle but measurable differences to others depending on their social identities; even people who share a marginalized identity may be biased against one another.[38] Understanding these biases, and the effects they have on our behavior, is crucial to move past knee-jerk responses such as "I'm not a sexist!"

38. Blindspot: Hidden Biases of Good People, M. R. Banaji and A. G. Greenwald (Delacorte Press, New York, 2013). Uses the Implicit Association Test as a framework to discuss how common unconscious biases are. (E)

39. "Stereotypic images of the scientist: The Draw-a-Scientist Test," D. W. Chambers, Sci. Educ. **67**(2), 255–265 (1983). A classic (data taken 1966–1977) study of the DAST, which found that elementary school children know a typical image of a scientist (which includes maleness). (I)

40. "Drawing a scientist: What we do and do not know after fifty years of drawings," K. D. Finson, School Sci. Math. **102**(7), 335–345 (2002). A review of studies of the DAST. Even after 50 years, most students are still drawing White male scientists (though fewer mad scientists, and Frankenstein types than they had in the 1950s). (E)

41. "Expectations of brilliance underlie gender distributions across academic disciplines," S. Leslie, A. Cimpian, M. Meyer, and E. Freeland, Science **347**(6219), 262–265 (2015). Both women and African Americans are more underrepresented in fields more associated with brilliance. (E)

42. "Stereotype threat and women's math performance," S. J. Spencer, C. M. Steele, and D. M. Quinn, J. Exp. Social Psychol. **35**(1), 4–28 (1999). Women underperform on math tests—more when told that the test produces gender differences, but less when told that the test is gender neutral. (I)

43. "Student evaluations of physics teachers: On the stability and persistence of gender bias," G. Potvin and Z. Hazari, Phys. Rev. Phys. Educ. Res. **12**(2), 020107-1–9 (2016). Students under-rate their female (but not male) high school physics teachers. The higher the student's physics identity, the higher their gender bias. (I)

44. "Science faculty's subtle gender biases favor male students," C. A. Moss-Racusin, J. F. Dovidio, V. L. Brescoll, M. J. Graham, and J. Handelsman, Proc. Natl. Acad. Sci. **109**(41), 16474–16479 (2012). Faculty (regardless of gender) were more likely to hire, mentor, and better pay the male-named applicant from identical applications for a lab position. (E)

45. "Penalties for success: Reactions to women who succeed at male gender-typed tasks," M. W. Heilman, A. S. Wallen, D. Fuchs, and M. M. Tamkins, J. Appl. Psychol. **89**(3), 416–427 (2004). Participants rated profiles of managers for competence and likability. In stereotypically male jobs, where competence cues were ambiguous, women were rated as significantly less competent than men; when high competence was clear, women were rated as significantly less likable. (I)

B. Microaggressions and macroaggressions

Microaggressions are small interactions that appear (and are often intended to be) harmless, but which accumulate into a pattern of exclusion. Examples might include interrogating an Asian-American peer as to where they are "really from" (and not accepting "San Francisco" as an answer) or consistently asking only the women in a lab group to perform clerical or social-organizing tasks. The term "microaggressions" has now entered popular usage and has provoked some criticism as being too broad, subjective, or easily applied. The resources we suggest here are intended to ground these conversations in research and focus on academic or physics contexts. Of course, not all aggressions are microaggressions. We have also included resources on sexual harassment of students and STEM workers, as well as an AIP report highlighting the differential treatment women across the world still experience.

46. "Microaggressions trilogy: Part 1. Why do microaggressions matter?" R. A. Berk, J. Faculty Dev. **31**(1), 63–73 (2017). Short but comprehensive definition of microaggressions, aimed at faculty. (E)

47. "Microaggressions trilogy: Part 2. Microaggressions in the academic workplace," R. A. Berk, J. Faculty Dev. **31**(2), 69–83 (2017). Examples of microaggressions in the academic workplace, with suggestions of how to respond and what professional development workshops might be able to do to help. (E)

48. "Microaggressions trilogy: Part 3. Microaggressions in the classroom," R. A. Berk, J. Faculty Dev. **31**(3), 95–110 (2017). Examples of microaggressions aimed at students, with suggestions of how to respond and what professional development workshops might be able to do to help. (E)

49. "Gender discrimination in physics and astronomy: Graduate student experiences of sexism and gender microaggressions," R. S. Barthelemy, M. McCormick, and C. Henderson, Phys. Rev. Phys. Educ. Res. **12**(2), 020119-1–14 (2016). Interviews with 21 women in graduate physics and astronomy programs, giving themes/subtypes of microaggressions with examples. (E)

50. "Do you see what I see? Perceptions of gender microaggressions in the workplace," T. Basford, L. Offermann, and T. Behrend, Psychol. Women Q. **38**(3), 340–349 (2014). Research participants read case studies of interactions between male supervisors and female subordinates. Male participants were less likely than female participants to perceive these interactions as microaggressions. (A)

51. K. P. Jones, C. I. Peddie, V. L. Gilrane, E. B. King, and A. L. Gray, "Not so subtle: A meta-analytic investigation of the correlates of subtle and overt discrimination," J. Manage. **42**(6), 1588–1613 (2016). This meta-analysis of 90 studies finds that the negative effects of covert discrimination are just as large as those of overt discrimination. (I)

52. L. M. Aycock, Z. Hazari, E. Brewe, K. E. Clancy, T. Hodapp, and R. M. Goertzen, "Sexual harassment reported by undergraduate female physicists," Phys. Rev. Phys. Educ. Res. **15**(1), 020121-1–13 (2019). A survey of students at the 2017 Conferences for Undergraduate Women in Physics found that 74% of respondents had been sexually harassed. Further, those experiences predict more impostor complex and a smaller sense of belonging. (E)

53. Sexual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering,

and Medicine, P. A. Johnson, S. E. Widnall, and F. F. Benya, editors (National Academies Press, New York, 2018). Sexual harassment is rampant in STEM workplaces, with devastating consequences to women's careers. Changes in organizational cultures can have a positive effect. (I)

54. Women Physicists Speak Again, R. Ivie and S. Guo (AIP Pub., College Park, MD, 2006). In a survey of more than 1300 women physicists from more than 70 countries, respondents reported experiencing discrimination and negative attitudes. Many respondents also reported having inadequate funding, space, and equipment to do their work; this problem was worse for those in developing countries. (E)

C. Belongingness and identity

A person's sense of identity is increasingly understood to be a powerful force in shaping their career choices, how they fit into social groups they meet along the way, and how they respond to suggestions that they don't belong. The question "what kind of a person are you?" has many answers—about gender, race, career, family role, political affiliation, and others. Papers in this section explore the issue of belonging in science from several angles. Some key studies in science education frame the issue of how gender interacts with identity development as a scientist.[55,56] Others examine identity in detail as it plays out among communities of practicing[57] or developing[60,61] physicists. Identity is not just an internal sense, but also something that is recognized (or not recognized) and reacted to by others.[58,59] Finally, a related topic is self-efficacy, a person's sense that they can succeed at some task in front of them. Recent work has studied women's sense of self-efficacy in physics to better understand what kind of classroom experiences may shape it.[62]

55. "What kind of a girl does science? The construction of school science identities," N. W. Brickhouse, P. Lowery, and K. Schultz, J. Res. Sci. Teach. **37**(5), 441–458 (2000). Early paper on science identity that describes four Black girls and how the ways they do science in school—and how it is recognized by teachers—are affected by their identities as girls. (I)

56. "Understanding the science experiences of successful women of color: Science identity as an analytic lens," H. B. Carlone and A. Johnson, J. Res. Sci. Teach. **44**(8), 1187–1218 (2007). Uses the experience of successful women of color to develop a model of science identity. (I)

57. Beamtimes and Lifetimes, S. Traweek (Harvard U. P., Cambridge, 1989). An anthropologist studied high-energy physicists and found that, although they claim to have no culture, they do. This book is a fascinating read and the origin of the phrase "culture of no culture" to describe physics. (I)

58. "But you don't look like a scientist!: Women scientists with feminine appearance are deemed less likely to be scientists," S. Banchefsky, J. Westfall, B. Park, and C. M. Judd, Sex Roles **75**(3–4), 95–109 (2016). Participants looked at photos of STEM faculty and rated them on their attractiveness and the likelihood that they were a scientist. For the pictures of women, ratings of attractiveness were inversely correlated with the perceived likelihood that they were a scientist; there was no correlation at all for pictures of men. (E)

59. "'Physics and the girly girl—there is a contradiction somewhere': Doctoral students' positioning around discourses of gender and competence in physics," A. J. Gonsalves, Cultural Stud. Sci. Educ. **9**(2), 503–521 (2014). A case study of three female physics Ph.D. students that studies their physics identity as it relates both to their competence and to their appearance of gender neutrality. (I)

60. "Exploring woman university physics students 'doing gender' and 'doing physics'," A. T. Danielsson, Gender Educ. **24**(1), 25–39 (2012). Case study of five Swedish physics students that describes how they perform as women and as physicists. (I)

61. "Masculinities and experimental practices in physics: The view from three case studies," A. J. Gonsalves, A. Danielsson, and H. Pettersson, Phys. Rev. Phys. Educ. Res. **12**(2), 020120-1–15 (2016). Pools data from three prior studies to analyze multiple models of masculinity that are taken up by physicists of different genders and career stages. (A)

62. "Exploring the relationship between self-efficacy and retention in introductory physics," V. Sawtelle, E. Brewe, and L. Kramer, J. Res. Sci. Teach. **49**(9), 1096–1121 (2012). Looks at gender differences in the importance of different sources of self-efficacy (mastery experiences, vicarious learning, social persuasion). (A)

D. Socialization, cultural impacts, and social capital

Education, psychology, and sociology have a large literature based on the effects of socialization on interests and career choices. The effect of various cultural backgrounds on STEM interests and participation is only partially explored. Finally, social capital is a construct that seeks to model the complex set of tacit knowledge, expectations, and connections which often works to propagate inequality. (For example, the process of choosing, applying to, and successfully matriculating to a university has many unwritten rules and strategic moves that are inaccessible to first-generation college students.) Summarizing all the relevant work is outside the scope of this Resource Letter. To give a sense of the insights offered by these neighboring fields, we include some big-picture reviews and more specific studies with a STEM focus.

63. "Gender roles and women's achievement-related decisions," J. S. Eccles, Psychol. Women Q. **11**(2), 135–172 (1987). Heavily cited paper linking sex differences in occupational choices to sex differences in their socialization, which lead to sex differences in expectations and values. (A)

64. "Perceived gender and racial/ethnic barriers to STEM success," J. M. Grossman and M. V. Porche, Urban Educ. **49**(6) 698–727 (2014). Mixed-methods study of high school students' perceived barriers and coping strategies. (I)

65. "Women's representation in science predicts national gender-science stereotypes: Evidence from 66 nations," D. I. Miller, A. H. Eagly, and M. C. Linn, J. Educ. Psychol. **107**(3) 631–644 (2015). Enormous study of hundreds of thousands of people across 66 countries found that the higher the representation of women in science at universities and beyond, the weaker the negative stereotypes of women in science there are. (I)

66. "Gender and dialogue in secondary school physics," A. Tolmie and C. Howe, Gender Educ. **5**(2), 191–210 (1993). Contrasts interaction patterns in male, female, and mixed-gender groups of 12- to 15-year-olds on a science task. Argues that different scientific traits (empiricism vs. generalization) are present in the single-gender groups, and all students might benefit from explicitly supporting a blend of communication styles. (I)

67. "Asian and Pacific Islander women scientists and engineers: A narrative exploration of model minority, gender, and racial stereotypes," P. W. U. Chinn, J. Res. Sci. Teach. **39**(4), 302–323 (2002). Looks at the intersection of the "model minority" stereotype with gender issues. (A)

68. J. P. Martin, D. R. Simmons, and S. L. Yu, "The role of social capital in the experiences of Hispanic women engineering majors," J. Eng. Educ. **102**(2), 227–243 (2013). This article utilizes data from a larger, mixed-methods study to compare findings from a case study of four Hispanic women in engineering in terms of access to and activation of social capital. (E)

69. Y. Yang, N. V. Chawla, and B. Uzzi, "A network's gender composition and communication pattern predict women's leadership success," Proc. Natl. Acad. Sci. **116**(3), 2033–2038 (2019). Graduates from an elite professional program placed into better jobs if they were more central in their graduate school network. For men, the effect was independent of personal network makeup, but high-placing women needed an over-representation of women who had diverse contacts. (I)

VI. CAREERS

Some of the resources in Sec. V touch on gender in career choice or work environment. The general focus above is on the student stage and on many factors that contribute to participation; the following set of resources looks at careers in more detail. The first set of studies includes a large-scale study of women's motivations around STEM careers, followed by several physics-specific pieces. Subsection VI B collects several issues of gender bias that occur in academic careers.

A. Career choice

70. "Malleability in communal goals and beliefs influences attraction to STEM careers: Evidence for a goal congruity perspective," A. B. Diekman, E. K. Clark, A. M. Johnston, E. R. Brown, and M. Steinberg, J. Pers. Social Psychol. **101**(5), 902–918 (2011). Women are more likely than men to have communal goals, and because of that they are less interested in STEM careers; they see STEM careers as not useful for achieving these goals. (I)

71. "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," Z. Hazari, G. Sonnert, P. M. Sadler, and M. Shanahan, J. Res. Sci. Teach. **47**(8), 978–1003 (2010). A large study found that physics identity correlated positively with recognition by family and teachers, performance in middle school and high school science and math, confidence, interest, and participation in science and science fiction. It was also positively correlated with a desire for an intrinsically rewarding career and class focus on conceptual understanding. Discussion of the under-representation of women in science was positively correlated with the physics identity of girls, but not boys, in the study. (I)

72. "Factors that affect the physical science career interest of female students: Testing five common hypotheses," Z. Hazari, G. Potvin, R. M. Lock, F. Lung, G. Sonnert, and P. M. Sadler, Phys. Rev. Phys. Educ. Res. **9**(2), 20115-1–8 (2013). Found that discussions about the underrepresentation of women in STEM had a positive effect on female students' desire to go into STEM. Single-sex classes, female teachers, female scientists as guest speakers, and discussing the work of female scientists had no effect. (E)

73. "Women's and men's career choices in astronomy and astrophysics," R. Ivie, S. White, and R. Y. Chu, Phys. Rev. Phys. Educ. Res. **12**(2), 20109-1–11 (2016). A study of people with Ph.D.'s in astronomy looked at reasons for attrition from the field afterwards, and found that relationship with advisors, the two-body problem, and completing a postdoc all affected attrition. These were indirectly related to the sex of the participant, in that women had worse relationships with their advisors and more two-body problems. (I)

74. "Barriers beyond equity: An exploratory study of women graduate students' career pathways in astronomy," R. Barthelemy, M. McCormick, and C. Henderson, Int. J. Gender, Sci. Technol. **7**(1), 57–73 (2015). Interviews with female graduate students in astronomy found that, although they were in a supportive department, they had serious reservations about the career path that their advisors planned for them. They were invested in family and work-life balance, which they saw as incompatible with multiple postdocs and a career at a research-intensive university. (I)

B. Sexism in physics careers

After deciding to pursue a career and earning a college degree, women may encounter a range of sexism issues in their chosen field. For some climate issues specific to transgender or gender non-conforming people, see Resource 9. The resources below discuss bias in hiring and teaching evaluations, recommendation letters, academic hiring of spouses, parenthood, and support on the job. Other important topics, omitted for space, include distribution of teaching, service, and other job responsibilities; nomination for awards and other high-profile events; press coverage that focuses on the appearance or family roles of women in science; and higher expectations of nurturing or "mothering" behavior from women.

75. E. Reuben, P. Sapienza, and L. Zingales, "How stereotypes impair women's careers in science," Proc. Natl. Acad. Sci. **111**(12), 4403–4408 (2014). In an experiment, it was found that a people are more likely to hire men than equally qualified women to do an arithmetic task. This bias was slightly less if the subjects were told about the candidates' abilities by someone other than the candidates, but not if the candidates told about their own performance, since men were more likely to brag about themselves than women were. (I)

76. A. L. Graves, E. Hoshino-Browne, and K. P. H. Lui, "Swimming against the tide: Gender bias in the physics classroom," J. Women Minorities Phys. Eng. **23**(1),

15–36 (2017). Students at two universities were shown videos of male and female actors delivering the same physics lecture and evaluated their teaching. Female students gave equivalent evaluations to both sexes, while male student gave significantly higher evaluations to male lecturers. (E)

77. "Exploring the color of glass: Letters of recommendation for female and male medical faculty," F. Trix and C. Psenka, Discourse Soc. **14**(2), 191–220 (2003). Letters of recommendation for women were more likely to refer to them as students or teachers, while those for men referred to them as professionals or researchers. Further, the letters for women tended to be shorter and were more likely to be missing key features of a recommendation. (E)

78. "Gender and letters of recommendation for academia: Agentic and communal differences," J. M. Madera, M. R. Hebl, and R. C. Martin, J. Appl. Psychol. **94**(6), 1591–1599 (2009). A study of letters of recommendation in academia found that letters recommending women were more likely to emphasize communal characteristics than agentic ones. Further, they found that letters emphasizing agentic characteristics were more likely to get people hired. (E)

79. "Reconstructing careers, shifting realities: Understanding the difficulties facing trailing spouses in higher education," E. J. Careless and R. C. Mizzi, Can. J. Educ. Adm. Policy **166** (2015). A review of the literature about academic trailing spouses (examples from Canada). (I)

80. "The changing career trajectories of new parents in STEM," E. A. Cech and M. Blair-Loy, Proc. Natl. Acad. Sci. **116**(10), 4182–4187 (2019). In a longitudinal study, 43% of new mothers and 23% of new fathers left full-time STEM employment, a significantly higher departure rate than non-parents of equal education. (E)

81. "Do babies matter? The effect of family formation on the lifelong careers of academic men and women," M. A. Mason and M. Goulden, Academe **88**(6), 21–28 (2002). Men who have a baby within 5 years of completing a Ph.D. are significantly ("strikingly"!) more successful than women who do so. (E)

82. "Gender disparity in STEM disciplines: A study of faculty attrition and turnover intentions," Y. J. Xu, Res. Higher Educ. **49**(7), 607–624 (2008). Female STEM professors change jobs more often, citing lack of support as a reason to change jobs. (I)

VII. WHAT WORKS

Several studies have been made of success stories. The first set of resources here highlights ways in which departments can be more welcoming to LGBTQIA+ physicists, female undergraduate and graduate students, and Women of Color. Section VIII A ("What physicists can do") has further supporting recommendations. Sections VII B and VIII B here discusses ways in which teaching methods can improve the retention of women and other traditionally excluded populations in our classes, our majors, and our field.

A. Department culture and climate

83. LGBT+ Inclusivity in Physics and Astronomy: A Best Practices Guide (Second Edition), N. Ackerman, T. Atherton, A. R. Avalani, C. A. Berven, T. Laskar, A. Neunzert, D. S. Parno, and M. Ramsey-Musolf (LGBT+ Physicists and The AAS Committee for Sexual and Gender Minorities in Astronomy, 2018), see https://arxiv.org/abs/1804.08406. This comprehensive guide gives concrete suggestions to create a welcoming classroom, department, and institution; how to welcome, advise, hire, and promote LGBT+ people; and how to host more inclusive conferences. (E)

84. "Condoning stereotyping? How awareness of stereotyping prevalence impacts expression of stereotypes," M. M. Duguid and M. C. Thomas-Hunt, J. Appl. Psychol. **100**(7), 343–359 (2015). This study from business education suggests that teaching people about implicit bias may, in fact, make it seem acceptable; they suggest teaching about how willing people are to fight against their biases. (I)

85. "What works for women in undergraduate physics?" B. L. Whitten, S. R. Foster, and M. L. Duncombe, Phys. Today **56**(9), 46–51 (2003). Advice for physics departments seeking to support their female students. (E)

86. "What works? Increasing the participation of women in undergraduate physics," B. L. Whitten, S. R. Foster, M. L. Duncombe, P. E. Allen, P. Heron, L. McCullough, K. A. Shaw, B. A. P. Taylor, and H. M. Zorn, J. Women Minorities Sci. Eng. **9**(3–4), 239–258 (2003). Study of department culture, describing the many small things that add up to support for female physics students. (I)

87. "What works for women in undergraduate physics and what we can learn from women's colleges," B. L. Whitten, S. R. Dorato, M. L. Duncombe, P. E. Allen, C. A. Blaha, H. Z. Butler, K. A. Shaw, B. A. P. Taylor, and B. A. Williams, J. Women Minorities Sci. Eng. **13**(1), 37–76 (2007). Study of department culture focuses on what women's colleges can teach us about recruiting students into the physics major. (I)

88. "Pipelines and pathways: Women of color in undergraduate STEM majors and the college experiences that contribute to persistence," L. L. Espinosa, Harvard Educ. Rev. **81**(2), 209–241 (2011). Large U.S. study used hierarchical linear model to predict persistence of Women of Color in STEM and found that attending schools with a real community of STEM students with whom they could talk about their coursework, participate in undergraduate research, and join STEM-related organizations really helped. (I)

89. "Women's persistence into graduate astronomy programs: The roles of support, interest, and capital," M. McCormick, R. S. Barthelemy, and C. Henderson, J. Women Minorities Sci. Eng. **20**(4), 317–340 (2014). Study of female astronomy graduate students found several factors contributing to their success. (I)

90. "A perspective of gender differences in chemistry and physics undergraduate research experiences," J. A. Harsh, A. V. Maltese, and R. H. Tai, J. Chem. Educ. **89**(11), 1364–1370 (2012). Studied the undergraduate research experiences (URE) of practicing scientists, finding that female scientists had participated in more of them than male scientists and were more likely to report that their UREs influenced their decision to go to graduate school. (I)

91. "Common challenges faced by women of color in physics, and actions faculty can take to minimize those challenges," A. Johnson, M. Ong, L. T. Ko, J. Smith,

and A. Hodari, Phys. Teach. **55**(6), 356–360 (2017). Women of Color face isolation and microaggressions when they study physics. It helps if they have "counterspaces," places where they can express frustrations and find validation. Faculty should be explicitly welcoming to these women, exhibit a growth mindset, and shut down microaggressions when they happen. (E)

92. "Educational pathways of Black women physicists: Stories of experiencing and overcoming obstacles in life," K. Rosa and F. M. Mensah, Phys. Rev. Phys. Educ. Res. **12**(2), 020113-1–15 (2016). A study of 6 Black women in physics found that they were helped by being specifically invited into the field and by summer research opportunities. However, they were isolated in graduate school, not invited into study groups. (I)

B. Teaching

93. **Female-Friendly Science: Applying Women's Studies Methods and Theories to Attract Students**, S. Rosser (Pergamon Press, New York, 1990). A classic; Rosser argues that the way science classes have been taught, particularly at the introductory level, has been alienating. She proposes using methods from women's studies to better attract and retain all students in their science classes. (E)

94. "Undergraduate problems with teaching and advising in SME majors—explaining gender differences in attrition rates," E. Seymour, J. College Sci. Teach. **21**(5), 284–292 (1992). More women than men switch out of STEM majors, even though they are equally prepared for them. They cite bad teaching, daily microaggressions, and rejection of the expected lifestyle of a STEM career. (I)

95. "Making sense of retention: an examination of undergraduate women's participation in physics courses," H. Fencl and K. Scheel, in **Removing Barriers: Women in Academic Science, Technology, Engineering, and Mathematics**, edited by J. Bystydzienski and S. Bird (Indiana U. P., Bloomington IN, 2006), pp. 287–302. Including active learning improves retention for all students and reduces the retention gap between male and female students. (I)

96. "Introduction to the SCALE-UP (Student-Centered Activities for Large Enrollment Undergraduate Programs) Project," R. J. Beichner and J. M. Saul (2003), http://www.ncsu.edu/PER/Articles/Varenna_SCALEUP_Paper.pdf. In SCALE-UP classes, failure rates are reduced for women and students from minoritized ethnic and racial groups. (E)

97. "Reducing the gender gap in the physics classroom," M. Lorenzo, C. H. Crouch, and E. Mazur, Am. J. Phys. **74**(2), 118–122 (2006). A Harvard study found that using interactive, collaborative measures to teach physics reduced the gender gap. (E)

98. "Improving learning for underrepresented groups in physics for engineering majors," S. W. Brahmia, 2008 PERC Proceedings [Edmonton, CA, July 23–24, 2008], edited by C. Henderson, M. Sabella, and L. Hsu (AIP Conf. Proc. **1064**, 2008), pp. 7–10. Constructing a class with fewer students, more contact hours, deliberate math skill-building activities and ISLE (Investigative Science Learning Environment) labs significantly increases both the passing rate of women and students from minoritized ethnic and racial groups and their completion of a STEM degree. (E)

99. M. Rodriguez, G. Potvin, and L. H. Kramer, "How gender and reformed introductory physics impacts student success in advanced physics courses and continuation in the physics major," Phys. Rev. Phys. Educ. Res. **12**(2), 020118-1–9 (2016). The authors conduct a longitudinal study on physics majors who have had modeling instruction or ISLE in their introductory courses, and they found that women are even more likely than men to pass their upper-division physics courses and graduate with a physics major. (I)

100. J. M. Nissen and J. T. Shemwell, "Gender, experience, and self-efficacy in introductory physics," Phys. Rev. Phys. Educ. Res. **12**(2), 0201051–16 (2016). This paper sounds a cautionary note: women's self-efficacy lowers more than men's during an introductory physics course, even when the course is designed with interactive engagement. (I)

101. "Increasing persistence in undergraduate science majors: A model for institutional support of underrepresented students," B. Toven-Lindsey, M. Levis-Fitzgerald, P. H. Barber, and T. Hasson, CBE-Life Sci. Educ. **14**(2), 1–12 (2015). This report on the Program for Excellence in Education and Research in the Sciences (PEERS), an academic support program at the University of California, Los Angeles, found that PEERS students had better outcomes than their peers in a comparison group in terms of academic performance and persistence. (E)

VIII. CONCLUSION/WHAT TO DO NEXT

The sections above review the current state and some of the history of gender in physics, with a focus on education and careers. We raised some issues of intersectionality with race (to be developed more in a future resource letter) and discussed various factors that shape the participation and retention of women at all levels of the field. We end with a question, "What next?" and three possible answers to that question.

A. What physicists can do

Resources above for "what works" (Sec. VII) and for inclusive teaching are a possible answer to "what next?" for physicists in the classroom. We start with Resource 102, which includes its own list of recommendations. Graduate admission committee members in the United States do not always know how to increase diversity.[103] In one positive change, those committees have begun re-evaluating the use of the Graduate Record Examination in their admission process. These tests effectively filter out marginalized groups[104] and fail to predict STEM Ph.D. completion,[105,106] but some departments continue to use them with both formal and informal cutoff scores.[107] On the advising side, students should be made aware of the many excellent programs that do not require GRE subject test scores.[108] Additionally, gender stereotypes often shape the language chosen in recommendation letters (Resources 109 and 110, also Resources 77 and 78 above). Letter writers can help by rereading their initial drafts, checking for common bias patterns (e.g., praising women's communication skills over their research acumen), and making sure that they have described all of a candidate's strengths. These habits benefit all students but can be especially important where implicit bias is likely to appear. Note that physicists who are also administrators can, of course, also make real changes. They may particularly have influence over hiring pools and search committees, and the diversity in those pools matters enormously.[111,112]

102. "Fitting in or opting out: A review of socio-psychological factors influencing a sense of belonging for women in physics," K. L. Lewis, J. G. Stout, S. J. Pollock, N. D. Finkelstein, and T. A. Ito, Phys. Rev. Phys. Educ. Res. **12**(2), 020110-1–10 (2016). Synthesizes socio-psychological literature on the causes of low representation of women in physics and on the strategies designed to improve representation, summarized in a table of recommendations. (E)

103. "Fixed and growth mindsets in physics graduate admissions," R. E. Scherr, M. Plisch, K. E. Gray, G. Potvin, and T. Hodapp, Phys. Rev. Phys. Educ. Res. **13**(2), 020133-1–12 (2017). Faculty seeking diversity in their graduate physics programs had a mixture of beliefs about student intelligence and potential, and often did not have specific goals for the admissions process. (I)

104. "A test that fails," C. Miller and K. Stassun, Nature **510**, 303–304 (2014). Differential impact of a GRE quantitative score cutoff by gender and race or ethnicity. (E)

105. "Multi-institutional study of GRE scores as predictors of STEM PhD degree completion: GRE gets a low mark," S. L. Petersen, E. S. Erenrich, D. L. Levine, J. Vigoreaux, and K. Gile, PLoS One **13**, e0206570 (2018). GRE scores failed to predict completion rates, time to degree, or first-year retention in a four-institution study of 1800 doctoral students. (I)

106. "Typical physics Ph.D. admissions criteria limit access to underrepresented groups but fail to predict doctoral completion," C. W. Miller, B. M. Zwickl, J. R. Posselt, and T. Hodapp, Sci. Adv. **5**(1), eaat7550 (2019). A multiple regression analysis of data for 3900+ physics doctoral students finds that undergraduate GPA is a statistically significant predictor of Ph.D. completion, but GRE physics score is not, and GRE quantitative score is only predictive for some samples. (E)

107. "Investigating approaches to diversity in a national survey of physics doctoral degree programs: The graduate admissions landscape," G. Potvin, D. Chari, and T. Hodapp, Phys. Rev. Phys. Educ. Res. **13**(2), 020142-1–13 (2017). Larger and higher-ranked Ph.D. programs in physics gave comparatively less weight to GRE scores. However, faculty comments indicated that unofficial cut-off scores existed even when not formally present. (I)

108. "Physics GRE requirements for US/Canadian Astronomy & Physics Programs," <https://docs.google.com/spreadsheets/d/19UhYToXOPZkZ3CM469ru3Uwk4584CmzZyAVVwQJJcyc/> (accessed January 7, 2019). Community-maintained list of doctoral programs and whether they require, recommend, or do not accept GRE physics subject test scores. (E)

109. "Avoiding unintended gender bias in letters of recommendation (Case study 1)," L. Barker, <https://www.ncwit.org/resources/how-can-reducing-unconscious-bias-increase-women%E2%80%99s-success-it/avoiding-unintended-gender> (accessed January 7, 2019), National Center for Women & Information Technology (2010). A brief best practices guide for avoiding implicit bias in writing recommendation letters. (E)

110. Gender-bias calculator <https://slowe.github.io/genderbias/>. A website to help estimate gender bias in recommendation letters (or other text) by highlighting the number of male- and female-typed words. (E)

111. "If there's only one woman in your candidate pool, there's statistically no chance she'll be hired," S. K. Johnson, D. R. Hekman, and E. T. Chan, Harvard Business Review, April 26, 2–6 (2016). The authors did multiple studies that showed that the likelihood of a search committee choosing a woman or minority candidate goes to zero if there is only one underrepresented person in the pool of finalists. (E)

112. Searching for Excellence & Diversity: A Guide for Search Committees, National Edition, E. Fine and J. Handelsman (WISELI, Madison, WI, 2012). A start-to-finish guide for search committees to improve the depth and fairness of faculty recruiting and hiring. Includes notes and research pertaining to women, candidates from under-represented racial and ethnic groups, and candidates with disabilities. (E)

B. Emerging work on LGBTQIA+ physicists

When asking "what next?," we also reflect on how much cultural views of gender, gender roles, and sexuality have changed in the last 50 years. One challenge in writing this resource letter is that "gender in physics" is often interpreted, in conversation and in research, to mean "women in physics." There are several problems with this framing. First, it continues to cast women as the piece of the issue that needs to be resolved. Second, only a small fraction of the research explicitly considers masculinity,[57,61] meaning that many of the social practices of physicists are going relatively unexamined. Third, even interpreting "gender in physics" to mean "men AND women in physics" still leaves us with a program that ignores non-binary, gender non-conforming, and transgender scientists. Freeman[113] argues eloquently for the inclusion of gender and sexual minorities in the data collection and mission statements of diversity initiatives in science. LGBTQIA+ identity overlaps with gender identity, and members of the LGBTQIA+ community are frequent targets of the gender norms (and policing of those norms) that we have discussed above. One of the next steps to improving the state of gender in physics must be broadening the scope of the problem from "women" to embrace a less binary, more nuanced view of gender. We have tried to highlight these reports and resources where they exist,[9,83] but it is still a very underdeveloped area.

113. "LGBTQ scientists are still left out," J. Freeman, Nature **559**(7712), 27–28 (2018). Argues for the inclusion—currently lacking—of LGBTQ people in diversity initiatives by the NSF, NIH, and other large-scale STEM organizations. (E)

114. "Factors impacting the academic climate for LGBQ STEM faculty," E. V. Patridge, R. S. Barthelemy, and S. R., Rankin, J. Women Minorities Sci. Eng. **20**(1), 75–98 (2014). Results from one of the rare large-scale surveys of LGBQ faculty in the United States, reporting both demographic data and climate experiences. (E)

115. "A virtual community of practice to promote LGBTQ inclusion in STEM: Member perceptions and community outcomes," S. Farrell, R. C. C. Guerra, A. Longo, and R. Tsanov, Paper #223550 In 2018 ASEE Annual Conference & Exposition (Salt Lake City, 2018). Describes a multi-campus support network and Safe Zone training program for LGBTQ community members and allies in engineering. (I)

C. Call to action

In this Resource Letter, we have tried to balance theoretical work and empirical studies. Resources that physicists can immediately apply to their classrooms, mentoring, or departments were a high priority, but understanding the underlying mechanisms is a fundamental goal of science and of this letter. We end with a few ideas about bridging from the present to a better future.

Faculty goals about diversity in physics are often not clearly articulated.[103] "We want to increase the diversity of our students" is a common sentiment. In practice, does it mean "we want more women physics majors because our program is too small," or "we want to improve our departmental culture to be more supportive for students across the gender spectrum?" Both statements (and many other variations) express overlapping but not identical values, goals, and possible next steps. Number-based "diversity" efforts are likely to fail if they address only a symptom (under-representation of women in physics) and not the underlying problems (the many barriers of sexism and racism discussed above). In seeking to answer "what next?," we must be thoughtful about the interplay and differences between diversity, inclusion, and equity.[120] For those looking to improve the state of "gender in physics," the task begins with deciding what that means to you in your local space.

116. "Curiosity and the end of discrimination," C. Prescod-Weinstein, Nat. Astron. **1**(6), 1–3 (2017). Summary of recent conversations on gender and racial harassment in astronomy with a warning that intersectional perspectives are often suppressed. (E)

117. "Addressing underrepresentation: Physics teaching for all," M. Rifkin, Phys. Teach. **54**(2), 72–74 (2016). Argues for explicitly teaching about stereotypes and bias in physics class, citing research to motivate this path and curricular resources to do it. (E)

118. "Gender matters," J. Blue, A. L. Traxler, and X. C. Cid, Phys. Today **71**(3), 40–46 (2018). Gives several concrete suggestions about what physicists can do to fight inequity and implicit bias. (E)

119. "Unveiling privilege to broaden participation," R. E. Scherr and A. D. Robertson, Phys. Teach. **55**(7), 394–397 (2017). Discusses what white male privilege means for physics education and reframing to build a better future. A follow-up letter to the editor typifies the offense and backlash that these conversations can provoke from physicists. (E)

120. "**Guest Post: The Problem with Diversity, Inclusion, and Equity**," G. Cochran, Scholarly Kitchen (June 22, 2018), online at https://scholarlykitchen.sspnet.org/2018/06/22/problem-diversity-inclusion-equity/ (accessed May 30, 2019). Discusses the danger of using diversity, inclusion, and equity as interchangeable concepts, with many links to related resources. (E)