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Women in Physics in the United States: Reaching Toward Equity and Inclusion

Robin Bjorkquist[1], Abigail M. Bogdan[2], Nicole L. Campbell[3], Mary Chessey[4], Geraldine L. Cochran[5],[a)], Beth Cunningham[6], Jessica N. Esquivel[7], Laura Gladstone[8], Natalie M. Gosnell[9], Sathya Guruswamy[10], Kelsey M. Hallinen[11], Candace Harris[12], Angela Johnson[13], Jolene L. Johnson[14], Christine Jones[15], Regina A. Jorgenson[16], Laura McCullough[17], Marta D. McNeese[18],Tennille D. Presley[19], Nicole Quist[20], Arlisa Richardson[21], Sally Seidel[22], and Chandralekha Singh[23]

[1]*Cornell University, USA;* [2]*Seton Hill University, USA;* [3]*University of Michigan, USA;* [4]*University of California-Davis, USA;* [5]*Rutgers University, USA;* [6]*American Association of Physics Teachers, USA;* [7]*Syracuse University, USA;* [8]*Massachusetts Institute of Technology, USA;* [9]*Colorado College, USA;* [10]*University of California, Santa Barbara, USA;* [11]*University of Michigan, USA;* [12]*Florida A&M University, USA;* [13]*St. Mary's College of Maryland, USA;* [14]*St. Catherine University, USA;* [15]*Smithsonian Astrophysical Observatory, USA;* [16]*Maria Mitchell Association, USA;* [17]*University of Wisconsin-Stout, USA;* [18]*Spelman College, USA;* [19]*Winston Salem State University, USA;* [20]*Oregon State University, USA;* [21]*Maricopa Community College, USA;* [22]*University of New Mexico, USA;* [23]*University of Pittsburgh, USA*

[a)]moniegeraldine@gmail.com

Abstract. The United States has a major deficit in the proportion of women earning degrees in physics, peaking around 20%. To promote excellence and maximize creativity, additional efforts to diversify the physics community must be implemented. Challenges to improving the proportion of female physicists include microaggressions, active discouragement, poor advising or mentoring, inadequate acknowledgement of achievements, sexual harassment, and many others. The latest research on gender bias suggests two main underlying psychological themes that explain much of the behavioral bias: implicit (unconscious) bias and stereotype threat. To ensure that excellence is not compromised, we need to guarantee that our entire population has access to adequate resources and the necessary support structures for success. To fully understand women in physics, we must also examine the many obstacles that women of various identities face in efforts to navigate their academic and professional careers. These identities may be related not only to gender but also to race, ethnicity, language, religion, social class, or sexuality. Increasing women's participation in physics requires increased access to high school physics courses, funding opportunities to attend college, availability of research opportunities, and access to and support from professional societies. These approaches will enhance the culture in physics, leading to gender equity, social equity, and improved social justice for many people.

STATISTICS ON PHYSICS PARTICIPATION

The proportion of women earning degrees in physics in the United States is approximately 20%. Figure 1 shows the percentages of women earning bachelor's degrees and PhDs in physics for the last 40 years. Figure 2 gives the numbers of women of color earning physics bachelor's degrees in the United States from 2002 to 2012.

CHALLENGES FACED BY WOMEN IN PHYSICS IN THE UNITED STATES

In the United States, women face multiple challenges as they seek to enter and stay in physics and related fields. These challenges often stem from issues with the predominate culture in physics and the external issues of behavorial

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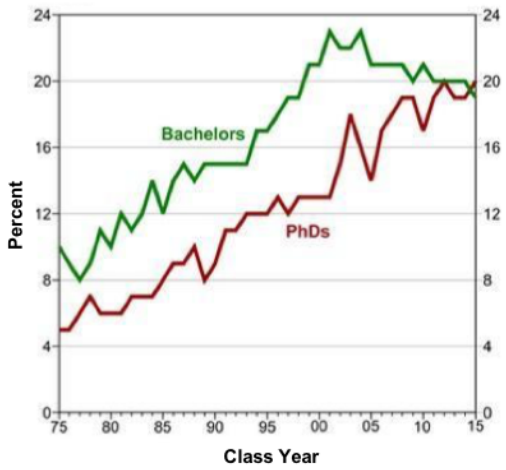

FIGURE 1. Proportion of U.S. women earning physics degrees [1].

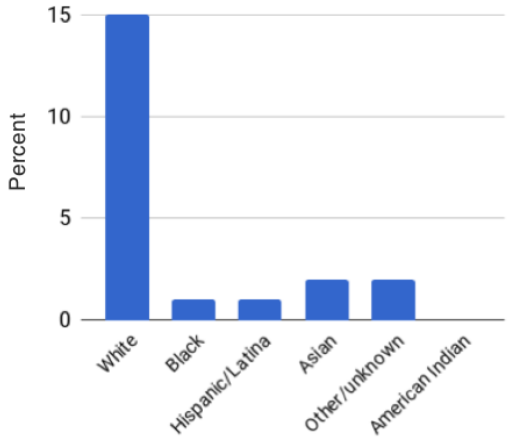

FIGURE 2. Proportion of U.S. women earning physics bachelor's degrees broken down by race/ethnicity, 2002–2012 [2].

bias, called implicit bias, and the internal behavioral bias called stereotype threat. An examination of gender bias in physics must acknowledge the dominant culture in the field as well as the particular effects of that culture on Barthelemy and colleagues note that physics is a field that is challenged in observing its own social influence [3]. Physicists have described themselves as having a "culture of no culture" and claimed that social interactions and influences have no part in their work and professional decisions [4]. However, Traweek observed that the physics culture consists of intense competition and a biased distribution of resources, which can create a negative experience for women in the physics classroom and workplace. Women in science disciplines are systematically treated differently. Subtle and unintentional discriminatory practices can create an inequitable and sometimes hostile environment. Interpersonal and gender bias can manifest in many forms, including stereotype threat, microaggressions, and harassment [3].

Some women in physics experience no overt discrimination, but microaggressions are a frequent issue. Microaggressions are subtle dismissals, insults or slights directed toward people who are viewed as intruders in a setting, particularly because of their gender or race [5, 6]. Although subtle individually, over time microaggressions have a significant negative effect on women's experiences in physics. As examples, Rosa and Mensah use "surprised looks from colleagues and teachers, differential treatment, and being outnumbered in a classroom" [7]. Some research indicates that microaggressions are common for women in physics. In a series of qualitative studies of 17 women physicists and physics students of color (Black, Latina, American Indian, Asian American/Pacific Islander and mixed race), 15 reported experiencing microaggressions [8, 9]. A common form of microaggression that these women experienced was having their competence in physics questioned.

The latest research on gender bias suggests two main underlying psychological themes that explain much of the behavioral bias: implicit (unconscious) bias and stereotype threat. Implicit or unconscious bias (https://implicit.harvard.edu) is the primary source of the behavioral biases that women in the United States face both in entering and reaching the highest echelons in the field. Stereotype threat (ST) is a well-researched phenomenon (http://www.reducingstereotypethreat.org) that people in a stereotyped group tend to perform more poorly when reminded of the stereotype, whether explicitly or implicitly. In a society which promotes the belief that science is an endeavor for men or that "women are weaker in science," both men and women grow up unconsciously internalizing these biases. Studies show that stronger societal beliefs against women in science correlate strongly with women's lower representation in science [10]. Studies also show that women in science are less likely to receive glowing recommendation letters than their male counterparts [11], thereby representing them as weaker candidates for jobs, awards, promotions, and scientific leadership roles. Progress in addressing this issue, including within the scientific community, must begin with the acknowledgment that objectivity is compromised by this unconscious bias. One of the problems that women face because of the belief—the stereotype—that women can't do science is a chance of lowered performance due to the stereotype itself. In physics, ST can cause women to perform worse than when the stereotype is explicitly countered [12]. The existence of a stereotype uses up cognitive resources for the stereotyped person, leaving them with fewer resources for performing difficult tasks. Belonging to more than one stereotyped group (e.g., woman in science *and* Latina in science) can inhibit performance even further [13].

BROADENING PARTICIPATION TO ALL WOMEN IN PHYSICS

In addition to gender, we must take into account the challenges created by race, ethnicity, language, religion, social class, age, sexuality, and other socio-demographic identities. How a person's intersecting identities structure their experience is called intersectionality, a concept that grew out of the work of feminist activists of color [14–20]. Intersectional analyses direct our attention to how women's experiences differ depending on other socio-demographic identities.

A 2015 survey that gathered responses from 324 lesbian, gay, bisexual, and transgender (LGBT) physicists indicated that LGBT women were more likely to report having experienced exclusionary behavior in the past year than LGBT men (~30% of women vs ~10% of men) [21]. Gender-nonconforming physicists reported even higher levels (~40%) and almost half of trans physicists reported experiencing exclusionary behavior within the past year. Clearly, gender interacts in complicated ways with sexuality; it is not enough to consider either dimension of identity on its own. Further, "LGBT people of color often report feeling fully at home neither within majority-white LGBT support groups nor within majority-cis/straight organizations that serve the needs of people of color" [21].

Rosa and Mensah [7] report on the experiences of six Black women studying physics. These women reported difficulties joining informal student study groups, groups in which White and Asian women seemed to have "automatic membership." These women felt that their race presented more obstacles to persistence in physics than their gender: "The ethnic and racial composition of the study groups seem to be more salient than gender positionality. The Black women say being a woman is more of an issue than being Black in their physics departments. When it comes to integrating study groups, the women talk about the other students being White Americans, Asian, or White Europeans more than the fact they are predominantly men."

Intersectional analyses help us understand how race, gender, sexuality, and other attributes work in combination to confer unearned advantages to some groups and disadvantage others. Intersectionality also points to how to rectify social injustice and thus increase access to resources and support. Rosa and Mensah documented that certain kinds of students found it easier to access informal study groups; math professors at the University of California–Berkeley noticed the same phenomenon [22]. In response, they started "Emerging Scholars" programs: Formal study groups, open to all students in a class, to which women and students from minoritized/marginalized racial and ethnic groups are deliberately recruited. Participants in a calculus Emerging Scholars program have been shown to achieve significantly higher grades and graduation rates [23]. Participants in a computer science version were more likely to succeed in their introductory computer science course and continue towards a computer science major [24]; participation in a physics version was a significant predictor of physics grades for under-represented students [25]. Efforts to increase inclusion and equity in physics that are grounded in intersectional analyses are more likely to be effective. Studies have shown that cultural influences on the perception of abilities affect the performance of girls, especially those from minoritized ethnic/racial groups, as early as elementary school and into middle school [26, 27]. The number and scale of outreach programs targeting these groups has grown as more funding has been allocated. Although many of these programs are too new to determine retention for ethnic/racial minorities in scientific fields, primary findings have indicated success in increasing interest and resulted in tools for creating more effective future programs [28].

Aiming to retain and inform undergraduate women, the American Physical Society hosts annual Conferences for Undergraduate Women in Physics (CUWiP) at 11 universities in the United States. The 3-day conferences reach more than 1,500 students each year and are attended by nearly every female physics student at some time during her undergraduate studies. The conference has recently spawned sister conferences in Canada and the United Kingdom. CUWiP's goals include providing information about graduate school and professions in physics, an opportunity to experience a professional conference, and a chance to practice and improve networking skills with other women in physics. External evaluators Eric Brewe and Zahra Hazari found that the conferences resulted in consistent and strongly positive understandings of physics careers and how to pursue them, as well as a growth in community and mentoring relationships among participants. However, from evaluation surveys from 2014 conferences, students came away with the perception that career successes were due to luck and perceptions of others. Susan Blessing suggested speakers at such conferences should de-emphasize being lucky.

CONCLUSION

To reach gender equity in physics, we need to account for the many identities that women possess. In doing so, we will develop stronger community in physics and counteract not only gender bias but many other biases as well. Biased behaviors typically are rooted in implicit societal bias, and by working against these biases we will help change society's views towards women in physics. These actions will also promote a more socially aware and equitable culture in physics.

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