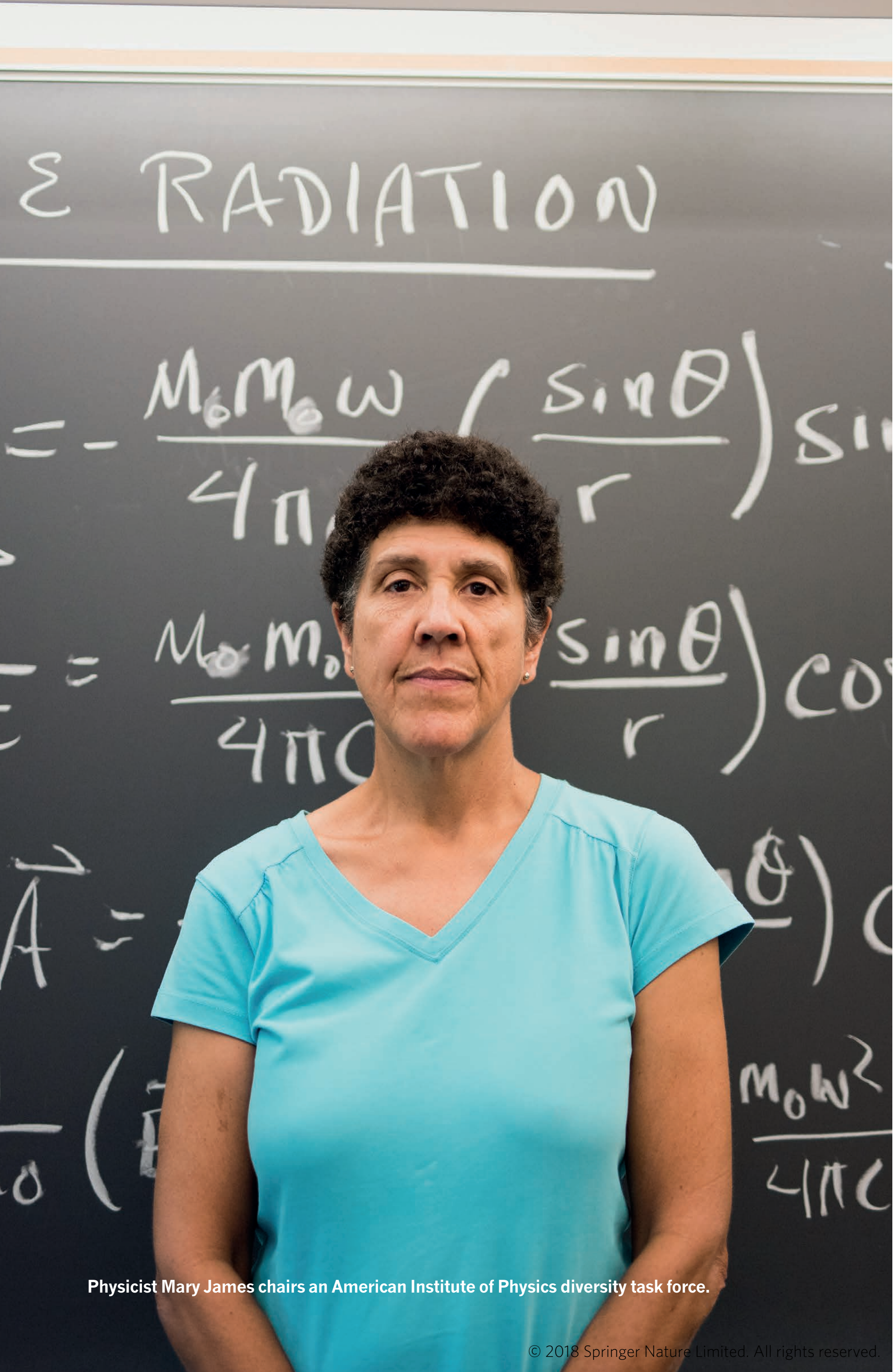
SOCIAL POLICY

Drive for diversity

Physics struggles to attract and retain graduates from underrepresented groups, but changes to the way it is taught may help to close the gap.



Physicist Mary James chairs an American Institute of Physics diversity task force.

ANNA CAITLIN PHOTOGRAPHY

BY NICOLA JONES

At Reed College in Portland, Oregon, a young woman of colour — a first-year student interested in physics — made an appointment to see Mary James, the college's dean for institutional diversity. "She said: 'I heard there's an African American physicist on campus and I just wanted to meet you'," says James. In their conversation, the student recalled standing at the blackboard the previous week to work on a problem and suddenly realizing that all her group partners were white men. She thought that if she failed they would think that women of colour couldn't hack it. "She said: 'I knew I shouldn't be thinking that. But I couldn't help it.' It was a classic stereotype threat," says James, who handed the student a book from her bookshelf on the phenomenon. "This is a really powerful thing, and it really impedes performance."

James, who now chairs an American Institute of Physics (AIP) diversity task force, is a member of a small club. She was one of only 66 black women who earned physics doctorates at US universities from 1973 to 2012, compared with more than 22,000 white men and over 2,400 white women.

Diversity is an issue across all the sciences, but in the United States, physics (along with maths and engineering) is near the bottom of the pile. The National Science Foundation reported[1] that in 2014, people from underrepresented groups (black people, Hispanic people and American Indians or Alaska Native groups) earned about 20% of science and engineering bachelor's degrees awarded in the United States. The AIP also drilled into the numbers and found[2] that although underrepresented-minority (URM) people make up about one-third of the US population, they are awarded just 11% of physics bachelor's degrees and 7% of PhDs (that's a meagre 60–70 students per year). The percentage of faculty members who are African American actually decreased slightly from 2008 to 2012. Although women obtain just over half of the science bachelor's degrees and PhDs in the United States, they get only 20% of the physics degrees (down from a peak of 23% in 2004).

The reasons for these disparities are many and varied, and leaks happen at every stage of the educational pipeline from elementary school upwards. URM populations are more likely to be economically disadvantaged, for example, leading to poor access to good education and a resulting lack of opportunities.

The lack of role models is also a huge issue, says Jami Valentine, a patent examiner at the US Patent and Trademark Office and an advocate for African American women in physics. "Too many professors have never taught an African American in a graduate course, and they likely never had a colleague who was African American," says Valentine, a former board member of the National Society of Black Physicists. "Students need to see physicists who look like them."

James' task force at the AIP convened in December 2017 and will focus specifically on African Americans in undergraduate physics. The choice of target is strategic, as it highlights an egregious lack of progress: a smaller proportion of physics and astronomy bachelor's degrees are awarded to African Americans today than two decades ago. Over the next two years, the task force will survey students and visit schools to find best practices and develop recommendations to increase the representation of African Americans in these disciplines.

But everyone acknowledges that work is needed across the board to close the gaps for all URM students at all levels of education. "We need to focus on all areas," says Ximena Cid, a physicist at California State University in Dominguez Hills, who publishes on diversity issues in physics. "At each level we're losing people."

HIGH INCLUSIVITY

One wall of the Manor New Tech High School in Texas features a mural painted by the students. In cool blues and greys, it depicts the unformed shapes of a boy and a girl entering a chemical apparatus and bubbling out of the pipeline at the other end. When the school opened in 2007 on the outskirts of Austin, principal Steve Zipkes told researchers at George Washington University that "it was just to get our kids to go to college". Of the district's students — 79% of whom are economically disadvantaged and 24% are African American — only 40% were completing high school and just 15% went to college. By 2010, Manor New Tech was sending more than half of its students to four-year postsecondary institutions compared with a national average of 28%.

Sharon Lynch, a science-education researcher at George Washington University, holds up Manor New Tech as an exemplar of an inclusive science, technology, engineering and mathematics (STEM) school. Lynch and her team are starting to show that such schools are having great success in ensuring that URM students get the education they need to set them up for science at university.

In the United States, says Lynch, URM populations typically face a double-whammy. "Poor kids living in poor neighbourhoods are really underserved by school funding," she says. For example, almost one in five African American high-school students attends a school that does not offer any advanced placement courses. But even in schools that do, says Lynch, URM students are more likely to be placed on courses that are less academically demanding than are white, middle-class children.

"For minority kids, access isn't enough," says Lynch. If a poor black girl with an interest in STEM attends a good school, theoretically she has access to top-stream classes, but in reality, says Lynch, that access is difficult to obtain. "You could go into any high school in my area and tell with exact accuracy the level of a course from the proportion of brown and black students in a classroom," she says. "The only high schools that I have seen completely dismantle this practice are the inclusive STEM high schools."

Unlike science-focused schools that aim to attract high performers, inclusive STEM schools admit students on the basis of interest, rather than test scores. They are public schools, often with no special entrance criteria, and some even use a lottery system. Their mandate is to give all of their students college preparatory work, rather than just some of them. "These schools don't just provide access, they make sure you're having that experience," says Lynch.

The schools emphasize many of the things advocated by education researchers for all groups, all ages and all subjects of study. There is a lot of problem-based learning, for example, and a strong sense of community, and they incorporate new technologies into everyday activities. Lynch's team sat in on a chemistry class at Manor New Tech in which students were designing a gas canister for use in a biodome on the Moon. Less than 15% of class time was spent on instruction from the teacher, and some of that was specifically requested by the students.

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In 2012, Lynch and her colleagues started studying eight high-performing inclusive STEM schools to understand why they are so successful. Her co-investigator Barbara Means from SRI International, a non-profit research organization based in Menlo Park, California, has crunched the numbers for about 50 inclusive STEM schools in North Carolina and Texas.

The study found that these schools are clearly living up to their 'inclusive' mandate. For example, half of the high-school graduates in the North Carolina schools were African American, compared with just 9% in the 2013 class of the selective North Carolina School of Science and Mathematics. In both North Carolina and Texas, most of the students came from low-income homes — a proportion that exceeds, or is on a par with, the averages in these states.

Students who went to these inclusive STEM schools graduated with stronger attitudes about, and more career interest in, science than average state students. Lynch cites a longitudinal study that tracked the STEM schools' students two years after graduation: "African Americans, Latinos and girls all do better on many measures than their counterparts in comprehensive schools," she says. "More kids are going to college and more kids are staying in college."

Even at schools that do not focus specifically on STEM, physics teachers have access to a host of approaches to make them more inclusive, many of which boost test scores and attitudes among URM students in particular.

DON'T GIVE UP

Eugenia Etkina grew up in Moscow, where she trained as a physics teacher. She moved to the United States in 1995 and now researches physics education at Rutgers Graduate School of Education in New Brunswick, New Jersey. In the 1990s, she saw that most high-school and undergraduate physics classes were taught using the 'predict, observe, explain' model. This might sound like a sensible way to learn physics, but Etkina argues that it damages women and URM students.

Much of the time, Etkina explains, physics predictions based on intuition are wrong. If a teacher asks what falls fastest, something heavy or something light, for example, most people would say something 'heavy', based on everyday experiences with rocks versus leaves, say. When the teacher whips out two equal-sized, differently weighted balls and proves you wrong, it seems like a trick. The intended effect is to surprise the student, making them curious and keen to solve a mystery. Why do these balls fall at the same speed? Is it really exactly the same speed? And at what point does air friction make a difference? But instead it often makes students feel threatened and defensive. "Then they think: 'I'm stupid — I don't belong here'," Etkina says.

Groups that are already predisposed to thinking that they don't fit in, because of their minority status or various cultural factors, are hit hardest by such blows. URM people have been shown to face stigma and stereotypes that can affect their self-confidence[3] and their performance in science classes, for example, and women tend to judge themselves more harshly than men judge themselves[4]. "As a woman, I realized what I was putting my students through," Etkina says.

Etkina dedicated herself to designing some alternative teaching philosophies to get around this problem specifically for physics, and developed the Investigative Science Learning Environment (ISLE). In this system, she explains, students are given the chance to observe a phenomenon before coming up with testable observations. "We call them 'crazy ideas' so it's fun to rule them out," she adds. Maybe, for example, the speed of an object's fall depends on whether it is made of rock or rubber. This promotes a 'mistake-rich' environment in which the fear of failure is reduced.

Etkina says that more than 1,000 teachers have used the ISLE approach in their high-school and undergraduate physics classes, using a textbook and materials designed to support the approach. Suzanne White Brahmia, a physics-education researcher at the University of Washington, integrated ISLE into her first-year physics course[5] at Rutgers


CSUDH

Ximena Cid (second left) studies diversity issues at California State University in Dominguez Hills.

University in 2001 and credits it in part for a huge change in the demographics of her students. The percentage of URM students who went on to complete a STEM degree in under six years jumped from 8% in the late 1980s to 58% in 2008.

Geraldine Cochran, who studies physics education and teaches at Rutgers, started using ISLE in 2017. It has many good qualities, she says, including "creating a culture where it's okay to make mistakes, highlighting strengths instead of weaknesses."

The ISLE approach is just one of many teaching innovations in STEM that seem to have a disproportionately positive impact for women and URM students. Another of these, the Student Centered Active Learning Environment with Upside-down Pedagogies (SCALE-UP), was developed in the physics department at North Carolina State University (NCSU) in Raleigh. This approach involves getting students to watch lectures or read books before coming to the lesson so class time can be spent on discussion and problem solving. The teachers who use SCALE-UP report that their students become more comfortable with the idea of not understanding something at first glance. They tend to feel less isolated and are less likely to think they are alone in not 'getting it'. This in turn reduces failure rates, particularly for URM students. In a study of more than 16,000 students taking introductory calculus-based physics courses at NCSU over a five-year period, students in a more-conventional lecture-style class were about 2.8 times more likely to fail in tests than SCALE-UP students. That proportion shifted to 4.7 for women and 3.5 for African Americans.

But assessing the effectiveness of such programmes is difficult because they are confounded by other variables, including societal evolution. There are established ways of assessing whether changes to undergraduate education improve student understanding, including simple things such as class size or course content, but even these are subject to bias. According to Cid, 63% of college students represented in the US physics-education research literature are white, compared with 45% for all college-bound students. This imbalance stems from the fact that most of the studies are done at selective, top-tier research universities that have fewer URM students. "Effectively, the physics-education research community has inadvertently cherry-picked its data," wrote Cid in a 2017 paper[6]. They have created an accidental focus on "well-prepared calculus-based students with relatively homogenous and privileged backgrounds."

TOP TIER

If students can be attracted to university physics, and stay long enough to earn a degree, the final educational hurdle is to get them into graduate work. The American Physical Society's Bridge programme aims to do just that, working with more than 35 US institutions to improve admission and retention rates for URM students in graduate physics programmes.

One of the main effects of the Bridge programme is to counteract biases introduced by the Graduate Record Examinations (GRE), a standardized test required for admission into most graduate schools in the United States. A survey of about 150 US physics graduate programmes (out of about 200 in the United States) showed that more than one-third use GRE scores to make admissions decisions. But research has shown that GRE scores do not relate to success in completing a PhD. They do, however, correlate strongly with race and gender[7].

The result of using GRE scores as cutoffs, argues Casey Miller, associate dean for research and faculty affairs at the Rochester Institute of Technology, is "a glass ceiling erected by the lopsided treatment of minorities and women before they even set foot in grad school."

Bridge programmes encourage universities to consider other qualities, such as a candidate's devotion to the subject, motivation to work hard, creativity, tenacity and drive. They also provide mentoring for students once they are in graduate school, along with some financial support. Since its launch in 2012, the APS Bridge programme has helped 129 students enrol for PhDs. If all these students complete their studies, this will double the percentage of PhDs awarded to URM students in the United States. Individual universities have seen similar gains. Ohio State University, for example, made a conscious effort to increase diversity in its physics PhD programme, in part through a Bridge programme. It saw URM students rise from less than 5% of its domestic students in 2012 to almost 20% in 2017.

The effects of such programmes might also be self-reinforcing. Just as a lack of role models tends to undermine the retention of URM students in physics, their presence can have disproportionately large effects. Making role models more available and more visible is a major part of the work of the National Society of Black Physicists, says Valentine. The organization hosts an annual conference, partly to help reinforce the sense that it is normal for African Americans to do physics, and also to forge connections for mentorships. Its upcoming conference, taking place this November in Columbus, Ohio, is expected to bring together more than 500 African American students and professionals.

Many programmes are aimed at targeting funding and efforts specifically towards URM populations, but others are simply about changing the way physics is taught to make it more inclusive from the outset — not only to include all races and genders, but also all learning styles and a more diverse array of talents. Students shouldn't be thinking 'I don't belong here', says James, "even if they're likely to overhear that in the cafeteria". Programmes that lessen the fear of speaking up, promote teamwork and self-satisfaction, and chip away at stereotypes, are bound to help the whole of science. ■

Nicola Jones *is a freelance journalist based in Pemberton, British Columbia, Canada.*

1. *Women, Minorities, and Persons with Disabilities in Science and Engineering* (National Science Foundation, 2017).
2. Ivie, R. *Beyond Representation: Data to Improve the Situation of Women and Minorities in Physics and Astronomy* (American Institute of Physics, 2018).
3. Correll, S. J. *Am. Sociol. Rev.* **69**, 93–113 (2004).
4. Hurtado, S., Cabrera, N. L., Lin, M. H., Arellano, L. & Espinosa, L. L. *Res. High. Educat.* **50**, 189–214 (2009).
5. Brahmia, S. W. *AIP Conf. Proc.* **1064**, 7 (2008).
6. Kanim, S. & Cid, X. C. Preprint at https://arxiv.org/pdf/1710.02598.pdf (2017).
7. Miller, C. W. *APS News* **22** (2), The Back Page (2013).