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If classroom practices designed to increase diversity in physics are to succeed, physics teachers need to understand students' perspectives.

Many physics faculty in the US are looking for ways to increase the diversity of the physics community to enhance the long-term health of our field in an increasingly diverse society. They attempt many things to help their students—particularly from historically underrepresented groups such as women, Latinos, and African Americans—to succeed. Here are three approaches that caring faculty commonly try.

Professor Jones wants all her students in a class for potential majors to succeed, and she hopes to increase the diversity of physicists. So she schedules a weekly help session for students who might be having difficulty, and she personally invites all the women and minorities to attend.

Professor Smith is concerned about the high failure rate in his introductory physics course. To encourage students to work harder, he starts the first class by telling the students how difficult the course is and that usually about 30% of the students fail. They must study hard, particularly if they think that their background preparation is weak.

Professor Doe wants all students to feel encouraged and capable in class, so whenever a student asks a question or offers a comment, he says it is a "great" question or comment. He is particularly enthusiastic if the student is a woman or person of color. Whenever he critiques students' homework, particularly the work of women and minorities, he prefaces it with "Good job, but . . . ."

Recent research in social psychology indicates that those well-intentioned efforts would likely backfire, undercutting the motivation and achievement of many students, especially those from underrepresented groups. For most physicists, that is a profoundly nonintuitive finding.

Many factors contribute to the lack of diversity in physics, including large societal issues over which an individual faculty member has little control. But advances in social psychology have shown that what happens in the classroom also plays a significant part and that every faculty member can take specific actions to make a difference. In this article we summarize that work, give examples of brief classroom interventions that have improved the success of students from groups underrepresented in physics, and explain why the well-intentioned efforts of Jones, Smith, and Doe will likely fail.

How students see the classroom

The problem with the efforts described above is that the professors did not fully understand their students' perspectives. As teachers, we tend to focus on what content to teach and how to present that content. While those issues are important, a focus on them can cause us to overlook how students feel in class and the associated social dynamics. Just as

Lauren Aguilar is a postdoctoral research fellow and **Greg Walton** is an assistant professor in the department of psychology at Stanford University in Stanford, California. **Carl Wieman** is a professor in the department of physics and in the Graduate School of Education at Stanford.

Figure 1. Most readers will see this photo, taken at a lecture during a physics conference, as simply depicting a normal audience. But if you are a woman or member of a minority group, you might wonder, "Is there anyone like me here?" (Photograph by Ken Cole.)

faculty members start each course wondering how they will be perceived and hoping that students will like them, students come to class with their own questions and concerns. Those include the following:

- Do I belong in a physics class?
- Am I smart enough to be successful in physics?
- Will the teacher and the other students respect me?

The coupling between peoples' internal concerns and the social dynamics of their environment determines how they perceive and respond to events. In educational settings, those responses can help or hurt motivation and success. People who are part of a group that is recognizably different (see figure 1) tend to be particularly attentive to negative social dynamics and more likely to suffer detrimental effects.[1] In a physics class, two psychological dynamics are particularly important to the academic success of students from underrepresented groups: beliefs about intelligence and awareness of negative stereotypes.

Can I get smarter?

How quickly students learn is affected to a large degree by whether they believe that ability in physics or some other area of interest is something that can grow and develop like a muscle (a "growth mindset") or something you are born with and can do little to change (a "fixed mindset").[2] Students with a fixed mindset who encounter a difficult problem or concept see that difficulty as evidence that they lack ability. Across many different research studies, such students tend to seek out easy problems (to prove their ability) and avoid challenging ones that would help them learn. They avoid speaking up in class or in group discussions so they don't seem stupid. When they face setbacks, they lose motivation and turn their attention to subjects for which they feel more "natural" ability.

In contrast, students who have a growth mindset see difficulties as opportunities to learn—"I love a good challenge!" So they work harder and ask more questions, which naturally improves their learning. In physics, students inevitably encounter material that they find demanding. Their mindset plays a substantial part in how they respond to that situation and their subsequent level of success.

Students are particularly likely to see physics ability as something that is innate, because our culture consistently sends them that message. Science in general, and particularly math-intensive science like physics, is portrayed as something only special and different people can do. It is the conventional, if erroneous, wisdom that the population can be divided into math-brained and non-math-brained people. In a new line of research, Carol Dweck and coworkers have begun to study the impact on students of teachers with a fixed mindset. The preliminary results are disturbing, although not entirely surprising: Professors with a fixed view of math ability see struggling math students as having lower potential. They comfort them and assign them less homework, which actually undermines students' motivation and expectations for success.[3]

Do I belong?

Another drag on motivation and learning is the worry students have that people like them don't belong in physics and that the teacher or other students will view them negatively because of their group. In demanding intellectual settings, people are often aware of negative stereotypes about their group. In the physical sciences, those stereotypes are most threatening for women and non-Asian ethnic minorities.

That awareness casts daily events in a new light.[1] It is sensible for a student who is one of only a few women in a physics class to wonder whether women belong in physics. If a classmate excludes her from a study group, she might infer that women, in fact, don't belong in physics. When a teacher criticizes minority students' work, the students might wonder whether the criticism reflects a negative judgment on their ability and potential. Students who are aware of negative stereotypes tend to ask fewer questions in class and interact with fellow students in less educationally and socially beneficial ways.[4] They feel more stress and distraction, which results in reduced learning and poorer exam performance.

Social psychologists have studied beliefs about intelligence and negative stereotypes across a wide range of contexts. The results have been consistent across many different educational levels and academic subjects, including undergraduate physics, chemistry, math, and engineering. Student beliefs take on extra importance during transitions from high school to college and from college to graduate school, as each transition introduces new standards and new social situations with new unknowns.

Fortunately, the research has also shown that the detrimental impacts of the psychological factors discussed above can be changed with surprisingly brief interventions. The effects of such interventions seem almost magical[5]—for example, a one-hour reading and writing exercise enabled African American college students to improve their grades and even reduce their visits to the doctor, three years after they completed the exercise.[6] The apparent magic is simply the result of the underlying science behind the interventions.

As illustrated in figure 2, the theory behind the interventions involves a combination of how people

interpret ambiguous events and the feedback loops that come into play. Any social interaction can be interpreted in multiple ways. How a person construes a particular event then plays out over time in self-fulfilling ways. For example, if individuals interpret not receiving an invitation to a social event as indicating that their coworkers do not like them, they will be likely to withdraw and become less friendly. That makes it more likely their coworkers will, in fact, come to dislike them. Alternatively, those who interpret the event as innocuous will be more likely to behave in ways that sustain a positive working relationship. When people tend to interpret events in global, negative ways, a small, well-timed intervention that suggests an alternative perspective can have lasting effects.

We can illustrate the idea with an example familiar to many academics—the assistant professor worried about receiving tenure. Those of you who have been in that situation know how a passing comment by the department chair about not bothering with the informal six-month review or that casual faculty lunch that took place without you can take on quite sinister implications. They reinforce your worry that the faculty are planning to get rid of you. The result is that you feel even more threatened and are more inclined to interpret each new event as reinforcing your fears. Rather than focusing on doing good research and teaching, you spend more time and energy stressing about tenure. In fact, your colleagues' intentions might have been the opposite of what you surmised. It could well have been that the chair and other faculty thought you were a successful and busy assistant professor, and they hoped to shield you from unwelcome distractions.

In such cases, your negative interpretation can be reversed by a rather brief intervention such as a 10-minute talk with the department chair in which you are reminded that most assistant professors worry they may not get tenure, but they usually do, and you learn that the department thinks you are doing well and will have no problem. Now, rather than wasting time and energy worrying, you are less stressed and more focused. You perform better in your work and are friendlier with your colleagues, which further solidifies your chance of getting tenure.

Keys to effective interventions

Effective psychological interventions are precise tools that encourage students to think about their place in school in more hopeful, optimistic ways. Such interventions, typically short reading and writing exercises, target worries like "Maybe I don't belong" in ways that lead students to entertain benign interpretations of difficulties. Examples of such interventions and the anxieties they address are shown in the table on page 46.

Successful interventions include several key elements. First, they deal with the specific concerns students have that prevent them from taking advantage of academic resources, including beneficial interactions with their teachers and fellow students.

Second, they deliver their message without singling out any specific groups, as such special attention may do more harm than good. For example, if an African American woman in an introductory physics course gets an email inviting her to participate in a program to help nontraditional students in physics, but her classmates do not get the email, she is likely to wonder why she is being singled out. She may feel stigmatized or devalued, thinking that others expect her to need help or do poorly because of her race or gender. So all students in the class should participate equally, and the intervention should not seem remedial or be presented as something that some students need more than others.

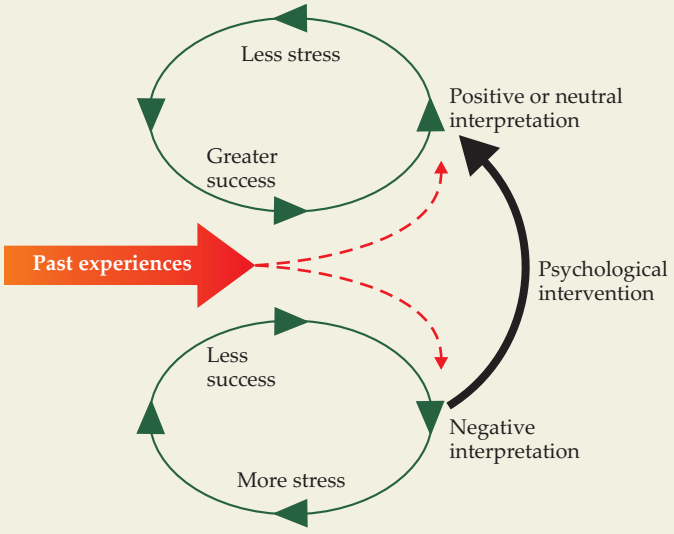

Figure 2. Past experiences shape how a student views classroom experiences. A positive or neutral interpretation leads to greater success and a sense of belonging in the classroom, which in turn causes future experiences to be interpreted in beneficial ways. A negative construal results in a feedback loop of negative interpretation and results. The experiences of students from groups historically underrepresented in physics often tend to nudge them toward the negative interpretation of ambiguous experiences.

Third, the interventions employ methods that psychologists have found to be particularly persuasive and long lasting. Rather than subjecting students to a direct appeal such as "All students can be good in physics if they work at it," the interventions get students to generate the desired message themselves. For example, a student might be told, "Here's some information about how the brain develops and gets 'smarter' as a result of mental exercise. Think about your own experience—how you have learned material that first seemed impossible. Write a letter for younger students summarizing what you now know about the brain and how that information can be helpful when school is hard."

Psychologists call that letter-writing instruction the saying-is-believing technique. It allows students to pull from their own experiences and integrate them with the message. Thus the intervention is more personal and more persuasive. Rather than being treated as needing help, the student acts as a benefactor and an expert who possesses important information to share with other students.

Fourth, interventions should not be presented as interventions and, in general, should be delivered briefly and without repetition. That way, students do not think they are "receiving treatment," which could undermine or reverse the desired effect. Changing students' psychology is fundamentally different from teaching physics content.[5] The more students think about and are taught physics, and the more explicit their learning goals, the more students learn. But with psychological interventions, often less is more.

Practice in an educational setting

We now turn to more detailed descriptions of the interventions summarized in the table. Although we will describe how each could be implemented in an introductory physics course, they also have been used in engineering and mathematics courses in middle school, college, and graduate school.

The social-belonging intervention addresses the tendency of women and underrepresented minorities who perceive the negative stereotypes and underrepresentation of their group as questioning whether they fit in. If you have that worry, then when something negative happens, like being left out of a study group or doing poorly on an exam, it's easy to think you don't belong in general. The social-belonging intervention gives students a more hopeful, optimistic way to understand such negative experiences.

Early in the term, students in an introductory physics class are given the results of a survey of successful graduates of the same course. The survey indicates that most students worry at first about whether they belong in physics, but over time they come to feel at home. The students read quotes attributed to a diverse group of previous students—rich stories that make worries about belonging in physics seem normal and temporary. Here's an example from a study currently being carried out by two of us (Aguilar and Walton) and colleagues: "When I started physics, I worried that I was different from the other students and whether I had the right preparation. But eventually I realized that almost everyone worries at first about whether they fit in, and feels isolated and insecure at times—it's a big class and it's challenging. It's just something everyone goes through. Eventually you find study partners and make friends. Now it seems ironic—everybody feels like they are unprepared or different from everyone else when they start taking physics, when really we're all going through the same things."

Students are then told that as new physics students, they are the experts in what first entering physics is like. They are asked to reflect on their own experience so far, and why students at their current stage are likely to worry at first about their belonging in physics and why that worry typically lessens with time. They are asked to share their insights by writing a letter to a future physics student describing what entering physics is like, ostensibly to help that future student adjust.

Such an intervention can be done in a class period or as part of a homework assignment. In one application, an intervention improved women's performance enough to eliminate the substantial gender difference in first-year grades among students enrolled in engineering majors with less than 20% women. A similar social-belonging intervention with new college students improved minority students' grades for the next three years, halving the achievement gap between majority and minority students.[6]

Another activity, the growth-mindset intervention, teaches students that intelligence is not a fixed quality—people aren't "smart" or "dumb." Instead, intelligence grows with hard work on challenging problems, help from others, and effective strategies. Those ideas can be conveyed in various ways—for example, with information from neuroscience about how the brain grows with learning or with testimonials from older students. In an extensive set of rigorous experiments, even relatively brief messages and activities that support a growth mindset have improved the academic performance of college

Interventions and implementation

Intervention type	Core psychological concern addressed	Helpful intervention message	Typical implementation format
Social belonging	When I feel excluded or disrespected in school or class, does it mean I don't belong there in general?	At first, all students worry about whether they belong, but with time they come to feel at home.	One hour-long reading and writing (R&W) activity in or out of class.
Growth mindset	When I struggle, does it mean I can't do it?	Challenges and struggles are opportunities for the brain to grow and get smarter.	One hour-long R&W activity in or out of class.
Values affirmation	In school, am I more than just a member of a group that is negatively stereotyped?	Class is a place where I can articulate and express my personal values.	One or two 15- to 20-minute R&W activities in or out of class.
Critical feedback with assurance	When I receive critical feedback, does it mean that the teacher judges me or is biased against me?	Instructors give critical feedback because they have high standards and are confident their students can reach those standards.	Brief notes attached to teacher feedback or a one-hour R&W activity.

See reference 5 for a comprehensive review of social-psychological interventions in education.

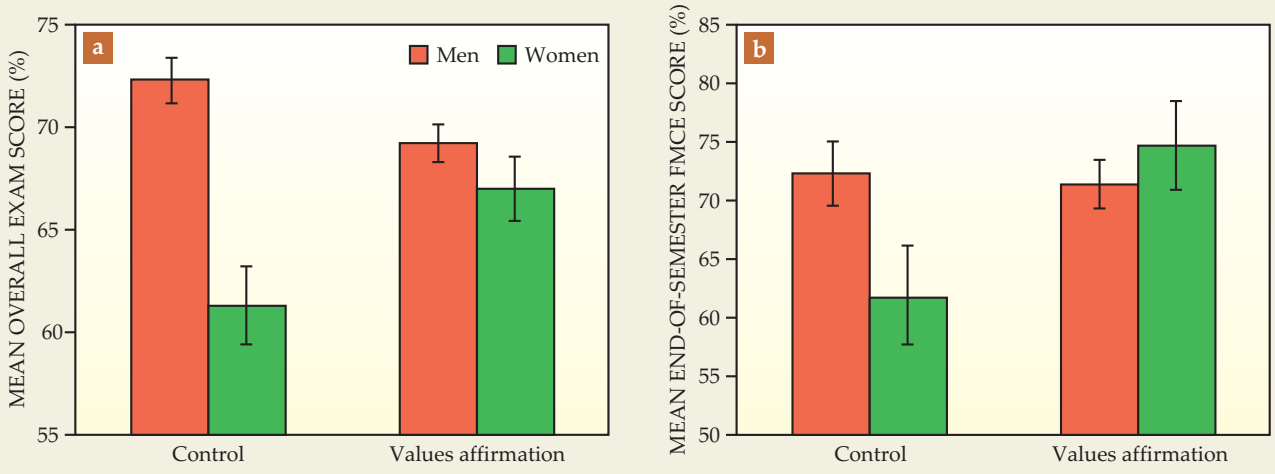

Figure 3. Values-affirmation interventions reduce the academic gender gap. **(a)** Overall mean scores for four exams administered during a semester-long introductory physics course, adjusted for baseline math performance. The values-affirmation group participated in an intervention as described in the text; the control group did not. **(b)** End-of-semester scores for the Force and Motion Conceptual Evaluation standardized exam, adjusted for beginning-of-semester FMCE scores. In both panels, the error bars represent one standard error. (Adapted from ref. 11.)

students,[7] middle school math students,[8] and community-college math students.[9] Similar experiments have not yet been carried out in physics. However, students' beliefs about physics ability are similar to those for math, so such interventions should provide similar benefits.

Like the social-belonging intervention, the values-affirmation intervention is designed to address the effects of negative stereotypes. This intervention gives students a structured opportunity to reflect on personal values that are important to them—artistic pursuits or relationships with friends and family, for example—and provides a sense of belonging, worth, and identity. Having personal values in mind reinforces for students that they are more than negative stereotypes. By putting slings and arrows in a broader context, values-affirmation interventions help students to cope more effectively, focus on their work, and achieve.

In such an intervention, students take a few opportunities during the term, either in class or as homework, to write about values important to them. In multiple trials, values-affirmation interventions have raised ethnic-minority adolescents' school achievement, sometimes lasting for as long as two years.[10]

In a different study, students in an introductory physics course spent 10–15 minutes writing about their values on the first day of class and then briefly as part of a homework assignment shortly before the first exam.[11] Remarkably, as shown in figure 3, those brief assignments, apparently unrelated to physics, cut the gender gap in course test scores by 60%. The beneficial effects were most evident among women who endorsed the stereotypical belief that women are less capable of doing physics than men, a finding that suggests the affirmation exercise buffered those women from the stress associated with the fear of confirming negative stereotypes about their gender.

Criticism done right

Critical feedback from a teacher can raise important questions for students, especially those in a new environment: "Why are you giving me this feedback?" "Are you judging me unfairly?" "Are you trying to help me improve?" Students who face negative stereotypes deal with extra ambiguity. They may ask, "Are you biased? Do you think people like me can't succeed?" That kind of mistrust can prevent students from treating critical feedback as valid and learning from it.

Critical-feedback-with-assurance interventions clear up the ambiguity in critical feedback. They go beyond vague bromides like "Good job, but . . ." to communicate that critical feedback reflects high standards and the teacher's confidence that the student can reach those standards.[12]

In one study,[13] the teacher's feedback to students was accompanied by a note that said, "I have high standards but I believe you have the potential to meet them, so I am providing this critical feedback to help you meet those standards." That simple assurance increased, from 17% to 72%, the number of African American students who chose to revise their essay when encouraged to do so (see figure 4). In a related study, students were taught to view critical feedback in general as reflecting high standards and the instructor's confidence in their ability to meet those standards.[13] The study used a saying-is-believing procedure like that of the social-belonging intervention. As a result, the semester grade-point averages of urban black youths increased by one-third of a grade point and the black–white achievement gap decreased by 40%. In a laboratory study, women college students doing projects in the natural sciences were 6.5 times as likely to make substantive improvements to their work in response to critical feedback when the criticism was accompanied by the statement of high standards and assurance.[12]

Unintended messages

Do you want to use psychological interventions in your classes? We hope so; however, you'll need to implement them with care, since well-intentioned efforts can backfire. In this section we'll discuss how to avoid common pitfalls.

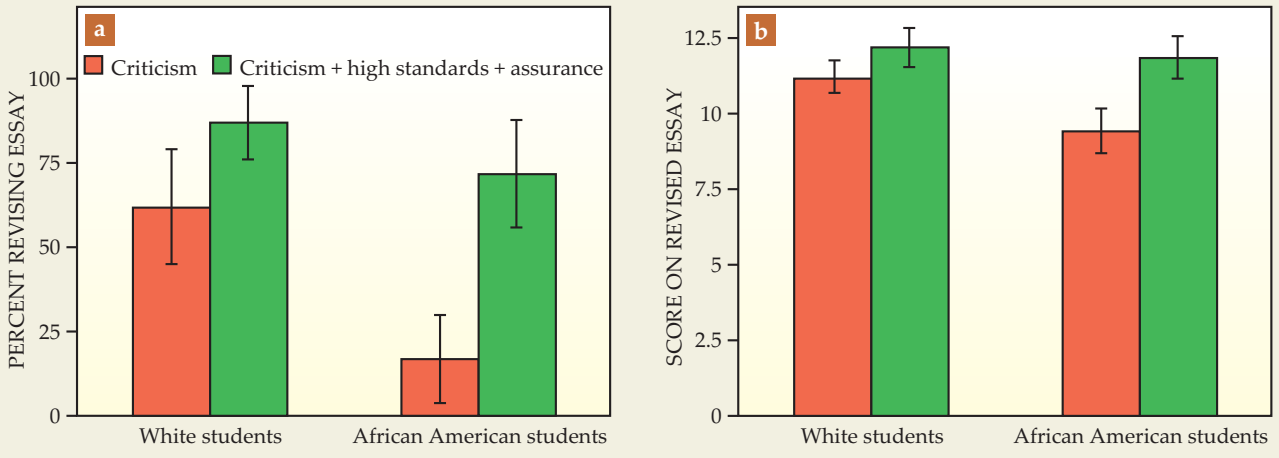

Figure 4. Assurance should accompany critical feedback. (a) For both whites and African Americans, the number of students who elected to revise an essay increased when the teacher made clear that the criticism of the earlier draft was motivated by high standards and the confidence that the student could meet them. The effect was particularly pronounced for the African American students. **(b)** A related study showed that assurances accompanying criticism led to better essays when students were required to turn in a revision. Error bars represent one standard error. (Adapted from ref. 13.)

Psychological interventions are not magic bullets. To be effective, they have to speak directly to students' worries and concerns. Delivering them requires one to be thoughtful and to have a good understanding of the students' perspectives. Interventions to instill belonging, a growth mindset, or a sense of affirmation hinge on subtle and not-so-subtle details of implementation. Classroom activities or messages like "everyone belongs here" that promote a rah-rah ethos or that express platitudes can backfire; they make students feel they are the only ones with worries, inevitably at times when they feel they don't belong. Instead, students need to know that worries about belonging are common and, further, that they fade with time. A focus on growth and improvement—a positive change in students' trajectory—is crucial.

The seemingly encouraging remark "What a smart comment" can also backfire. It conveys a fixed mindset about ability, an attitude that makes students crumble when they struggle. Far better is to emphasize that being smart is about learning and that students learn by struggling with challenging material. Values-affirmation exercises might backfire if delivered in a cursory way that suggests the teacher does not take the exercise seriously and does not personally value and respect the student.

A light and stealthy touch can be important for psychological interventions. Excessive repetition of a message that a student can succeed or belongs, particularly if it singles out members of an underrepresented group, can send the opposite message. Students might well ask themselves, "Why am I constantly being told I can succeed, unless my teacher really believes I will fail?" In targeting women and minority students for a weekly help session, Professor Jones, whom we met at the beginning of this article, makes that mistake.

Many teachers are inclined to overpraise students for mediocre work in the belief that it will boost their self-esteem—and they are especially likely to do so for students who face negative stereotypes.[14] For the same reason, some teachers excessively praise students for things like asking routine questions in class. Such overpraising can send a message of low expectations or suggest that ability is more important than effort and good strategy use. Professor Doe makes that mistake, along with that of singling out women and minority students.

Another common mistake is to encourage students to work harder when they need not only to work harder but also to work smarter—for instance, by changing their learning strategy. Effort is necessary but not sufficient, and most undergraduate students are still learning how to learn effectively. When confronted with continued failures despite heightened effort, it is easy for students to have their motivation sapped and conclude, "I guess I'm just not a physics person." By teaching the fuller formula for success—effort plus good learning strategies plus help from others, including collaboration—effective growth-mindset interventions challenge the myth that raw ability or raw effort matters most. Research in physics education provides guidance on learning strategies that are effective for physics (see the article by Carl Wieman and Katherine Perkins, PHYSICS TODAY, November 2005, page 36).

Professor Smith errs in telling his students that 30% of them will fail and directing them to simply "study hard." Moreover, in singling out students who think their background preparation is weak, he exacerbates the concerns and stress of students who worry about their prospects in a field in which their group is negatively stereotyped. One of us (Wieman) did a small unpublished study on how stu-

dents responded to being warned by the professor that the course had a high failure rate. Some students saw the warning as a challenge and were motivated to meet it; all students in the sample who responded that way were white males or Asian males. Other students responded quite differently. They heard the warning as an indication they would likely fail and that the teacher was satisfied for that to happen. To them, the message was discouraging—and it made them less inclined to put time and effort into the course.

Emerging research shows the important role of social psychological factors in physics classrooms and other intellectually demanding settings. To be effective, teachers must think not only about what physics they want their students to learn and how to present it but also about their students' perspectives. For students from groups that are underrepresented or negatively stereotyped in physics, those perspectives may be quite different from the perspective of majority-group students or physics professors. Understanding where students are coming from and the concerns they have will allow teachers to teach more effectively and help all their students take full advantage of the educational resources at their disposal. By investing a small amount of class time in carefully designed and implemented interventions, physics teachers can promote greater success among students from diverse backgrounds. Ultimately, we hope such efforts will indeed improve the diversity and health of the physics profession.

The online version of this article includes an essay by one of us (Walton) titled "The Social-Belonging Intervention: Getting the Message Right."

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