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Two Brief Interventions to Mitigate a "Chilly Climate" Transform Women's Experience, Relationships, and Achievement in Engineering

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In a randomized-controlled trial, we tested 2 brief interventions designed to mitigate the effects of a "chilly climate" women may experience in engineering, especially in male-dominated fields. Participants were students entering a selective university engineering program. The *social-belonging intervention* aimed to protect students' sense of belonging in engineering by providing a nonthreatening narrative with which to interpret instances of adversity. The *affirmation-training intervention* aimed to help students manage stress that can arise from social marginalization by incorporating diverse aspects of their self-identity in their daily academic lives. As expected, gender differences and intervention effects were concentrated in male-dominated majors (<20% women). In these majors, compared with control conditions, both interventions raised women's school-reported engineering grade-point-average (GPA) over the full academic year, eliminating gender differences. Both also led women to view daily adversities as more manageable and improved women's academic attitudes. However, the 2 interventions had divergent effects on women's social experiences. The social-belonging intervention helped women integrate into engineering, for instance, increasing friendships with male engineers. Affirmation-training helped women develop external resources, deepening their identification with their gender group. The results highlight how social marginalization contributes to gender inequality in quantitative fields and 2 potential remedies.

Keywords: gender, engineering, STEM, achievement, stereotype threat

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Even as women have entered historically male-dominated fields such as law and medicine in increasing numbers, they remain underrepresented in science, technology, engineering, and mathematics (STEM), sometimes extremely so. For instance, women make up just 18.4% of undergraduate engineering students and 12.9% of professional engineers (National Science Foundation, National Center for Science and Engineering Statistics, 2013). Women also perform worse than men in quantitative fields (The College Board, 2013), especially in settings characterized by gender biases (Hyde & Mertz, 2009; Logel et al., 2009; Steele, Spencer, & Aronson, 2002). Low levels of participation and achievement in STEM restrict women's career opportunities and slow national economic growth (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2007).

Although many factors contribute to gender inequality in STEM (Shapiro & Sax, 2011), the present research focused on social marginalization. When women enter male-dominated STEM fields, they may experience a "chilly climate" in which they feel unwelcome (Flam, 1991). This chilliness arises from explicit and implicit messages that convey to women that their gender could be a liability in STEM settings. Indeed, women may encounter ambient cues that represent STEM fields as masculine (Cheryan, Plaut, & Davies, & Steele, 2009), stereotypes that allege that women lack ability (Appel

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& Kronberger, 2012; Steele et al., 2002; Thoman, Smith, Brown, Chase & Lee, 2013) and men in STEM settings who treat women in subtly sexist ways (Logel et al., 2009). One focus-group participant in the present research relayed that a female professor, "told [classmates] not to present themselves as women first if they wanted to be taken seriously as engineers." In this climate, even highly skilled and motivated women may wonder if they will be fully included, valued, and respected in STEM (Cheryan et al., 2009; Flam, 1991; Good, Rattan, & Dweck, 2012; Murphy, Steele, & Gross, 2007; Shapiro & Sax, 2011; Steele et al., 2002; Yoshida, Peach, Zanna, & Spencer, 2012).

Although gender bias can undermine women's outcomes in STEM directly, for instance, through social exclusion, disrespectful behavior, or biased decision making (e.g., Logel et al., 2009; Moss-Racusin, Dovidio, Brescoll, Graham, & Handelsman, 2012), people's psychological reactions to threatening settings also matter and can change the trajectory of their experience over time. Uncertainty about social belonging can lead students to monitor school for evidence of nonbelonging; this perspective can color interpretations of ambiguous events, leading students to view even commonplace adversities like difficulty making friends or receiving critical feedback as evidence they do not belong in general, further eroding feelings of belonging (Walton & Cohen, 2007). In addition, feeling marginalized can cause high levels of stress and threat with which students may struggle to cope. If left unaddressed, social marginalization may thus feed on itself and worsen students' outcomes over time (Cohen et al., 2009).

If these psychological dynamics partially mediate the effects of a chilly climate on gender inequality, addressing them may improve women's outcomes in STEM over time (Aguilar, Walton, & Wieman, 2014). Building on recent research with ethnic-minority and first-generation students (e.g., Cohen, Garcia, Purdie-Vaughns, Apfel, & Brzustoski, 2009; Harackiewicz et al., 2014; Sherman et al., 2013; Walton & Cohen, 2011), we developed two brief interventions designed to help women cope with the chilly climate of STEM and tested their effectiveness in reducing inequality in STEM achievement. We also explored effects on women's daily experiences in STEM, academic attitudes, developing friendship groups, and self-identity.

Our theoretical analysis suggests two potential intervention strategies (see Garcia & Cohen, 2012). An intervention could forestall inferences of nonbelonging, which undermine students' outcomes over time. Or it could help students cope with stress and threat that arise from social marginalization. We developed and tested both interventions with a group of selective first-year engineering students. The first, a *social-belonging intervention*, gave students a nonthreatening narrative for interpreting negative social events like feelings of exclusion or not being taken seriously in engineering. It conveyed that adversities and worries about belonging are normal at first in engineering and dissipate with time. This message encourages students to ascribe difficulties to the academic transition, not to a permanent lack of belonging on their part or the part of their group. One past variant of this intervention, delivered in an hour-long session toward the end of students' first year of college, halved the gap in GPA between African American and European American students over 3 years (Walton & Cohen, 2011). In the present research, using extensive interviews and focus groups with female engineering students, we identified aspects of belonging of special relevance to women in STEM and adapted the intervention accordingly. We tested its effects on women's achievement. In addition, we examined students' underlying social experiences. By forestalling perceptions of threat in daily social encounters (Walton & Cohen, 2011), we hypothesized that the social-belonging intervention could facilitate better interactions with other people in engineering, especially with men with whom interactions may otherwise be most fraught, and thus facilitate women's social integration in the field.

The second intervention aimed to help students cope with stress and threat by encouraging them to incorporate important self-identities and personal values in their daily lives. One effect of threat is to narrow people psychologically; in the face of threat, it can seem that all that is relevant is the threat, which must be counteracted (Sherman & Hartson, 2011; Walton, Paunesku, & Dweck, 2012). One way to reduce stress and help people function more effectively in threatening settings is to administer specific "value-affirmation" writing exercises that remind people of self-defining values unrelated to the source of threat (e.g., close relationships). Reflecting on alternative sources of self-identity broadens the self, makes specific threats and stressors loom less large, and helps people cope (Cohen & Sherman, 2014; Sherman & Cohen, 2006; Sherman & Hartson, 2011; Walton et al., 2012). In school settings, when given several times over an academic year, value-affirmation exercises can raise achievement among ethnic-minority adolescents (Bowen, Wegmann, & Webber, 2013; Cohen et al., 2009; Sherman et al., 2013; see also Harackiewicz et al., 2014; Miyake et al., 2010). Inspired by this past research, we developed a new intervention called *affirmation training*. Students did not complete an affirmation. Instead, we encouraged students to incorporate personally important self-identities and values in their daily lives as an explicit strategy to manage stress and threat, for instance, to help students avoid "tunnel vision" and find "balance." We anticipated that this might yield more robust benefits than a simple value affirmation because it encourages students to express broader aspects of their self-identity within their daily lives in ways and at times that are optimal for them. It empowers students to maintain their own well-being. Notably, this intervention provides the first test of whether students can be taught to incorporate a sophisticated social–psychological strategy to remedy psychological threat in their own lives. Moreover, whereas past value-affirmation interventions are typically delivered multiple times over an academic term or school year (Cohen et al., 2009; Harackiewcz et al., 2014; Miyake et al., 2010; Sherman et al., 2013), affirmation training allowed us to intervene with students just once.

The aim of both interventions was to mitigate a chilly climate in engineering. To do so, both conveyed at a general level that difficulties are common at first in engineering and that students learn to cope with these difficulties. This encourages students to reappraise difficulties as manageable, a powerful psychological ingredient (Jamieson, Mendes, Blackstock, & Schmader, 2010; Johns, Inzlicht, & Schmader, 2008; Wilson, Damiani, & Shelton, 2002). However, the content of the two interventions differed. The social-belonging intervention focused on the meaning of adversities in the transition to engineering. It invited students to view adversities as due to the challenges all students face. By contrast, affirmation training focused students on themselves—on ways to broaden their self-identity to manage stress and function well.

This distinction draws on Garcia and Cohen's (2012) identity engagement model, which distinguishes *vigilance* and *appraisal* processes people experience in psychologically threatening settings. First, as Garcia and Cohen wrote,

> [People] tend to become vigilant in environments where their identity is engaged . . . They monitor such situations for cues related to whether their identity is relevant to their outcomes, for instance, whether it affects how they are treated by important figures in their social environment . . . As in any hypothesis-testing process, people may be more sensitive to bias-confirming evidence than to bias-disconfirming evidence. (p. 334).

The worry that "people like me" might not belong in a school setting sensitizes students to indicators of nonbelonging (e.g., Cheryan et al., 2009; Murphy et al., 2007; Walton & Cohen, 2007). It leads students to interpret events through the lens of questions like "Maybe I don't belong?" and "Maybe my group doesn't belong?" The social-belonging intervention offers students a more hopeful lens with which to interpret adversity—it invites students to see adversity as normal for all students as they enter a new school and as lessening with time.

Second, Garcia and Cohen argued that, if people perceive threats, a "threat appraisal" process ensues in which people "assess whether they have the ability to deal with the threat . . . Students might see the degree of bias in a classroom as surpassing their ability or desire to overcome it" (p. 334). Value-affirmation interventions, they wrote, "[increase] people's psychological resources" (p. 336) to cope with such threats in part by broadening the self-concept. Rather than focusing on the nature of the social environment, the intervention focuses students on themselves and thereby helps them cope (Cohen & Sherman, 2014).

This theorizing implies that the two interventions may cause both convergent and divergent effects. Given the marginalization of women in STEM fields (Cheryan et al., 2009; Logel et al., 2009; Steele et al., 2002), both interventions were predicted to benefit women more than men; moreover, by improving the trajectory of women's experience in engineering over time, both were predicted to cause lasting gains. The primary outcome—on which we expected benefits from both interventions—was students' end-of-year GPA in engineering.

We also predicted that both interventions would lead students to view daily adversities as manageable, not overwhelming. This could occur if adversities are seen either as normal and temporary (social belonging) or as within their capacity to manage (affirmation training; Sherman et al., 2013; Walton & Cohen, 2011). We assessed construals of adversity directly in two daily-diary measures in the 1–2 weeks after the intervention. The first assessed how "important" students saw daily negative and positive events. If students view daily adversities as manageable, we reasoned negative events would loom less large in importance. The second assessed how "confident" students were that they could handle daily stressors in engineering.

Finally, we examined STEM attitudes. These often decline in college and predict exit from STEM fields (Good et al., 2012; Shapiro & Sax, 2011; Stout, Dasgupta, Hunsinger, & McManus, 2011). If women construe daily adversities as manageable, they may report better experiences in engineering and, perhaps with time, greater confidence that they can succeed in the field.

Beyond these convergent benefits, we predicted divergent effects on students' underlying social experiences. If the social-belonging intervention leads women to perceive less threat in daily social encounters in engineering, these interactions may go better and women may form more friendships, especially with male engineers, reinforcing their social integration in the field. We thus examined women's friendships with male engineers, a potentially valuable source of belonging and identity in STEM (Shook & Clay, 2012; Walton & Carr, 2012). We also examined *implicit normative evaluations* about female engineers—the extent to which students associated the constructs "most people like" and "female engineers" on an automatic level (Yoshida et al., 2012). Implicit norms are thought to "arise from repeated exposure to how objects are treated and depicted by groups. For example, if people repeatedly hear negative jokes about female engineers and repeatedly see female engineers treated in a sexist manner, then they will be likely to associate that most people dislike female engineers" (Yoshida et al., 2012, p. 695). Implicit norms thus provide an indicator of women's social experiences in engineering and whether the social-belonging intervention improved these experiences over time. Notably, implicit norms about female engineers tend to become more negative over time in engineering among both men and women and predict women's intentions to leave the field (Yoshida et al., 2012); we tested whether the social-belonging intervention remedied this risk factor.

By contrast, affirmation training encouraged students to incorporate valued aspects of their self-identity in their daily lives to cope with stress and threat; it does not target the meaning of adversities per se but resources students can develop within themselves to cope with and function well despite adversity. Although the intervention does not reference gender, it is women's gender identity that can seem incompatible with pursuing STEM fields (Cheryan et al., 2009; Nosek, Banaji, & Greenwald, 2002; Stout et al., 2011); indeed, women invested in STEM may selectively suppress aspects of their gender identity that seem incompatible with pursuing these fields (Pronin, Steele, & Ross, 2004). We thus predicted that encouraging students to incorporate broader aspects of their self-identity in their daily lives would help women "restore" their gender identity to their self-concept. We examined the subjective importance of women's gender identity to women—their ingroup identification, which can buffer students in threatening settings (Cohen & Garcia, 2005; Oyserman, Brickman, Bybee, & Celious, 2006). We also examined the development of women's friendships with women outside engineering.

This study extends current understanding of brief social–psychological interventions in education in four primary ways. First, it provides the first test of whether such interventions can reduce gender inequality in STEM broadly, a significant problem. Past interventions have examined racial/ethnic disparities (e.g., Bowen et al., 2013; Cohen et al., 2009; Sherman et al., 2013; Walton & Cohen, 2011) or women's or girls' performance on a single test (Good, Aronson, & Inzlict, 2003; Smeding, Dumas, Loose, & Régner, 2013) or in a single class (Miyake et al., 2010; see also Harackiewicz, Rozek, Hulleman, & Hyde, 2012; Hulleman & Harackiewicz, 2009). We examined women's achievement in multiple classes over a full academic year. Second, by assessing diverse indices of students' psychology and social experience, this study provides deeper understanding of how brief social–psychological interventions transform at-risk students' school experience broadly beyond achievement. Third, we developed the novel affirmation-training intervention and tested its effects. Moreover, by directly comparing it with the social-belonging intervention, we tested the hypothesis that the latter helps women integrate into engineering, whereas the former helps women cultivate resources in their lives and identity.

Finally, this study directly tested the hypothesis that social-belonging and value-affirmation interventions allay concerns that arise from a specific social context—from being a member of an at-risk and underrepresented group in a setting—not from some inherent property of ethnic minorities or of women. To do so, we compared students enrolled in gender-diverse and in male-dominated engineering majors. Following past laboratory (Inzlicht & Ben-Zeev, 2000; Murphy et al., 2007; Steele et al., 2002) and field (Hanselman, Bruch, Gamoran, & Borman, 2014; Stout et al., 2011; Yoshida et al., 2012) research, we expected that the underrepresentation of women would create a "chilly climate" that intensifies women's social marginalization. If this is the experience remedied by the interventions, then gender disparities and intervention effects should both be concentrated in male-dominated majors.

Method

Overview

Students in the first year of a demanding university engineering program took part. Early in the academic year, students completed a brief preintervention survey. Intervention or control materials were delivered in sessions in engineering classrooms soon after. To assess construals of daily adversities, students completed surveys every other evening over the next 12 days. To assess change in academic attitudes and social experiences, we asked them to complete one or two second-semester surveys ($\approx$4 months postintervention). Official academic records were obtained for students' first year.

Participants and Recruitment

Participants were first-year engineering students in three successive cohorts at the University of Waterloo (UW), one of the highest ranked engineering schools in Canada (Times Higher Education, 2013). A total of 228 first-year students participated and were randomly assigned to condition (92 women and 136 men). Research staff solicited students with appeals and handouts in engineering classes. The study was called the "Skills for Transitions to Engineering Project" (STEP) and represented as an opportunity for students to learn about other students' experiences entering engineering and to share their experiences with future students to help improve their transition. The study was thus described as of potential benefit to students; it was not, however, referred to as an "intervention" or represented as remedial. As compensation, students received small gift certificates to a local business.

Interested students were invited to complete an online preintervention survey. All women who completed this survey were recruited to take part in the rest of the study; men who matched women based on their major and ethnicity were randomly selected to be recruited for the rest of the study. Male and female participants did not differ in demographic characteristics: engineering major, $\chi^2(10, N = 228) = 13.86$, $p = .18$; ethnicity, $\chi^2(3, N = 220) = 1.10$, $p = .78$. Reflecting the university's student body, most students self-identified as White (38.16%), East Asian (33.77%), or South Asian/Middle Eastern (20.18%; other or unknown: 7.90%). However, insofar as students chose to participate, the sample was not necessarily representative of the student body. Cohort 1 included 64 students (34 women). Cohort 2 included 68 students (30 women). Cohort 3 included 96 students (28 women).

Classification of Engineering Majors

Students enter the Faculty of Engineering enrolled in one of 12 undergraduate programs (i.e., "majors"). These majors organize students' experience, including what classes they take and with whom and represent important sources of self-identity (e.g., students might identify as "electrical engineers," not as engineers). We classified majors as "gender-diverse" if more than 20% of students enrolled in the major in the first year of the study were women (across cohorts, 32.57% of students enrolled in these majors were women; $N = 121$) and as "male-dominated" otherwise (10.01% women, $N = 107$). See Table 1. This classification assigned half of the majors to each category, is consistent with past research, which defines a "critical mass" of women in STEM fields at approximately 20% (Carrigan, Quinn, & Riskin, 2011; Lott, Gardner, & Powers, 2009–2010), and tracked social stereotypes—interviews and focus groups with upper year engineering majors confirmed that "male-dominated" majors were seen as more masculine than "gender-diverse" majors (e.g., one focus-group participant reported that chemical engineering [with 38.62% women in the first year of the study] was known as "fem eng.") See the online supplemental material for more information.

Preintervention Survey (First Semester)

The preintervention survey, completed online in the first few months of school, assessed five key constructs. First, three measures assessed students' evaluation of their current experience in engineering: (a) their sense of belonging in engineering (10 items, e.g., "I belong in engineering at UW"; $\alpha = 0.87$), (b) enjoyment of engineering (three items, e.g., "How much do you enjoy academic work in engineering?" $\alpha = 0.87$), and (c) self-efficacy in engineering (two items, e.g., "I feel confident that I have the ability to do well in engineering"; $r = .53$, $p < .001$; Walton & Cohen, 2011). All items were completed on 7-point scales. These measures formed a reliable scale ($\alpha = 0.64$) and showed a similar

Table 1
Classification of Engineering Majors as Gender-Diverse (>20% Female Students) or Male-Dominated (<20% Female Students)

Gender-diverse majors (>20% women)	Male-dominated majors (<20% women)
Chemical engineering	Computer engineering
Civil engineering	Electrical engineering
Environmental engineering	Mechanical engineering
Geological engineering	Mechatronics engineering
Management engineering	Nanotechnology engineering
Systems design engineering	Software engineering

Note. Overall, women represented 32.57% of students enrolled in gender-diverse majors and 10.01% of students-enrolled in male-dominated majors.

pattern of results (see Table S1 in the online supplemental material). Therefore, we combined them to form a composite measure.

Second, two measures assessed students' evaluation of their prospects of succeeding in engineering: (a) possible selves in engineering (four items, e.g., "I could see myself being a professional engineer"; 7-point scale; $\alpha = 0.66$; Markus & Nurius, 1987) and (b) perceived potential "to succeed in engineering" relative to classmates (a one-item 100-point percentile scale; Walton & Cohen, 2007). The two measures correlated ($r = .26$, $p < .001$) and showed a similar pattern of results (Table S1), so we combined them. To place them on the same scale, the former measure was transformed into a 100-point scale and then averaged with the latter.

Third, we assessed students' identification with their gender group (four items, e.g., "My gender is an important reflection of who I am"; 7-point scale; Cohen & Garcia, 2005). One item that did not load was dropped ($\alpha = 0.60$).

Fourth, we examined students' friendship groups. Students provided the initials of up to five friends they had made in university at that point and, subsequently, indicated the gender and major of each friend. We calculated the percentage of friends students listed who were male engineers, female engineers, male nonengineers, and female nonengineers.

Finally, we assessed implicit normative evaluations of female engineers (Yoshida et al., 2012), an automatic measure of the degree to which participants saw women as valued in engineering. The measure was a modified version of the Implicit Association Test (IAT), a well-validated computerized measure for assessing implicit attitudes (Peach, Yoshida, Spencer, Zanna, & Steele, 2011; Yoshida et al., 2012). The task assessed the ease with which participants associated the construct "most people like" (vs. "most people don't like," with the term *most people* defined as "most undergraduates at your university") with the construct female engineers (vs. objects) on a reaction-time basis. Higher values represent more positive implicit norms (i.e., "most people like" = "female engineers"). For details, see the online supplemental material.

This measure allowed us to go beyond self-reports,and thus to assess whether intervention effects would extend to a psychological measure less sensitive to demand processes. It also complements past research, which has primarily emphasized implicit gender stereotypes and attitudes in STEM (e.g., Nosek & Smyth, 2011; Smeding, 2012; Stout et al., 2011). Finally, the implicit-norm measure circumvents two debates about traditional IATs: whether they measure personal attitudes or awareness of cultural stereotypes (Arkes & Tetlock, 2004; Yoshida et al., 2012) and whether they predict behavior (Greenwald, Poehlman, Uhlmann, & Banaji, 2009). By using the category labels "most people like" and "most people don't like" (rather than "pleasant"/"unpleasant"), the implicit-norm measure is designed specifically to assess perceived cultural associations, not personal attitudes (Yoshida et al., 2012). Further, although implicit norms have been less researched than traditional IATs, they have been found to predict women's intentions to leave engineering (Yoshida et al., 2012).

Intervention Session (First Semester)

After completing the preintervention survey, students were invited to take part in sessions in an engineering classroom in which intervention or control materials were delivered. Each session was randomly assigned to condition.[1]

Students were told that the study had two purposes: (a) "to better understand your personal experiences and attitudes here in engineering at Waterloo" and (b) "to help us provide incoming UW engineering students next year and in the years to come with more accurate expectations about what university is like." Students in each condition were told that the researchers had previously conducted a survey of upper year students' experiences entering the engineering program and that they would be asked for their help in interpreting the results of this survey. The results, students were told, "were consistent across students' program [i.e., major], gender, and ethnicity." In each condition, students were then given a one-page "summary of results" to review. Students then listened to nine audio recordings of senior engineering students said to have taken part in the survey (four women and five men in seven engineering majors), which were described as "illustrative" of students' experiences in the 'transition to engineering at UW.'" As they listened to these recordings, students viewed a presentation that displayed each student's quotation, name (which, participants were told, had been changed to protect students' confidentiality), year, and major along with photographs of campus engineering buildings.

Social-belonging intervention. In the social-belonging intervention, the materials emphasized that both men and women worried about their social belonging at first in engineering but that these concerns dissipated with time and eventually most students came to feel at home. These materials were drawn from past research (Walton & Cohen, 2011) but revised to incorporate two key themes that emerged in pilot interviews and focus groups with female engineering students: worries about (a) being taken seriously or treated with respect and (b) fitting into a male peer culture. The materials emphasized that both men and women worry about being treated with respect at first in engineering, but this improves with time; and that even when women do not share some interests with men, they share common interests in engineering.

For instance, the "summary of results" indicated that "almost all" upper year students had worried during their first year about "whether other students would accept them" and had felt "intimidated by professors" but that, over time, most students came to feel "comfortable in the academic environment," made "good friends within the Faculty of Engineering," and felt "confident that other engineering students and professors viewed their abilities positively."

The nine quotations, drawn from pilot research, reinforced this theme. One upper year student said, "When I first got to Waterloo, I worried that I was different from the other students . . . Now it seems ironic—everybody feels different first year, when really

[1] Most sessions included just one participant, but when convenient, several students took part in a session. For instance, of the 41 sessions in Cohort 1, 22 had one participant, 16 had two participants, two had three participants, and one had four participants. Multilevel modeling was not required. Students did not interact with one another in sessions, either listening to the experimenter or completing individual activities, and session accounted for no variance in the primary outcome, first-year GPA (at least in Cohort 1).

we're all going through the same things." Another, a male student, said,

> Honestly, when I got here, I thought professors were scary . . . I worried about whether other students would respect me . . . After some time, I began to feel more comfortable . . . I saw that even when professors are critical . . . it didn't mean they looked down on me. It was just their way of pushing us . . . I'm glad I have been challenged. It's made me a better engineer.

A woman said

> [M]y first term . . . some other civil engineers . . . spent 90% of the time talking about hockey, about which I know next to nothing . . . It was discouraging. But over time I got to know my classmates better . . . Once I remember talking about the TV show *Monster Machines*, which I have to admit I love. We had a great time sharing stories about the different episodes. Even though I don't share their love of hockey, I realized that we do have a lot in common.

For more information, see Appendix S1 in the online supplemental materials.

Affirmation-training intervention. In the affirmation-training condition, the materials were similar, but instead of concerns about belonging, they emphasized that upper year students, both men and women, learned to incorporate broader aspects of their self-identity in their daily lives to manage stress and find "balance" in engineering. The materials highlighted six values identified in pilot testing as most relevant in this population: relationships with friends and family, leading a healthy lifestyle, learning for the sake of learning, religious or spiritual values, achieving financial security, and making a difference in the world. For instance, the "summary of results" indicated that during their first year, "almost all" upper year students had "felt overwhelmed by the workload" but that, over time, most students "found ways to manage stress and find balance" by "spending time with friends," "putting their workload in perspective," "going to the gym," and "taking mental 'time-outs.'"

The nine quotations, again drawn from pilot research, reinforced this theme. One upper year student said, "[F]irst year, I sometimes felt like I had tunnel vision . . . I was just so completely caught up with life at Waterloo . . . It was hard at first, and it was stressful. But then I realized that, well there are things outside of engineering that I do care about . . . I decided to get involved with an environmental group here on campus. And even though, objectively, I had less time . . . I found I felt really refreshed, and I could concentrate a lot better . . . the longer I spend in Waterloo, the more I find things to do that are just broadening my life . . . I guess the one thing I had to learn was that it isn't the best thing for me to just study nonstop."
For more information, see Appendix S1 in the online supplemental materials.

"Saying-is-believing" exercises. In the intervention conditions and in the study-skills control condition (described later), after reading the survey, students completed two writing activities designed to facilitate internalization of the intervention message (Walton & Cohen, 2011). These "saying-is-believing" exercises encouraged students to describe the process they had read about in their own words, to view their own personal experiences in light of it, and to advocate for this process to a receptive audience. This is a powerful and noncontrolling persuasive technique. Further, it encourages students to see themselves as helping others, not as beneficiaries or as recipients of a persuasive appeal, which could undermine effects.

First, students were asked, "to write about why you think people's experience in university develops in the way the senior students described"—for instance, why students worry at first about whether they belong in engineering but come to feel at home with time (social-belonging) or how students learn to incorporate broader aspects of their self-identity in their daily lives to manage stress in engineering (affirmation-training). Students were encouraged to illustrate their essay "with examples from your own experience" and invited to look back on the survey results as they worked. In addition, students were told

> [W]e hope to share selections of what students write in this study with first-year students next year. We hope it will help them in the transition to university . . . I am sure that the students who read about your experiences next year will appreciate the effort you put in.

Students were given 15–20 min to write.

Next, students were asked to rewrite their essay into a personal letter to a future student. Students were told

> [W]e have learned . . . that students really appreciate hearing directly from older students who already have some experience making the transition to engineering at UW. To give next year's . . . students a chance to hear directly from an older student, we would like . . . you to write a letter to an incoming engineering student next year . . . about your transition . . . [and] what you've learned [including how students] may feel unsure at first of their belonging in engineering but ultimately come to feel they belong [in the social-belonging condition]/ learn ways to manage stress by thinking about things they value outside school [in the affirmation-training condition].

Students were then told

> We will give these letters to a student of the same program and gender as yourself, so you can imagine it is a student like you. We know that it can be difficult . . . to write a personal letter to a stranger, but . . . [we] believe it will be particularly meaningful for incoming students if they feel as though an older student is speaking directly to them about their experiences.

All students agreed to write the letter. The next year we delivered some of these letters to new first-year students not participating in the study.

Two raters, blind to participants' condition, gender, and major, coded the essays and letters students in the first cohort wrote. Results confirmed that students were sensitive to the divergent content of the two interventions and the study-skills control condition (described later). Their writings did not differ by gender or major. For details, see the online supplemental material.

Control conditions. Two randomized control conditions were used. In Cohort 1, the procedure was the same but the materials addressed an unrelated topic, study skills. Students read information indicating that many students lack adequate study skills at first in engineering but learn better study skills with time. For instance, the "summary of results" indicated that during their first year, "almost all" upper year students had felt "overwhelmed by the workload" and "had difficulty keeping track of due dates and deadlines" but that, over time, most students learned "proper study techniques," including "attending class regularly" and "recording exams and assignment due dates in a day planner." The nine quotations reinforced this theme. Although this controls for the representation that difficulties are common at first in engineering and improve with time, the content is tangential to the key psychological issues targeted by the interventions (and, past research suggests, is generally ineffective; Conway & Ross, 1984).

For Cohorts 2 and 3, we used a different control condition. Students again took part in sessions in engineering classrooms, equating for their effort and attention received, but they simply completed outcome measures. The use of multiple control conditions follows procedures used in past research (e.g., Cohen et al., 2009; Walton & Cohen, 2011). It ensures that observed condition differences reflect the influence of the intervention conditions, not an unanticipated ironic effect of any given control condition.

Key chain. After completing the writing exercises, students completed initial measures assessing attitudes toward engineering (described later). Finally, students received a key chain designed to remind them of the intervention message. Past research has shown that physical cues can facilitate intervention effects (Dal Cin, MacDonald, Fong, Zanna, & Elton-Marshall, 2006). In the social-belonging condition, the key chain depicted the Waterloo Engineering insignia. In the affirmation-training condition, it was an opaque piece of plastic containing a slip of paper. Students were given a list of the six aforementioned values (e.g., "relationships with friends and family") and asked to select the value that "is most important to you" and to "write a word or phrase that will remind you of this value" on the slip and return it to the key chain. Control-condition students were offered both types of key chains and given their choice (students who chose the opaque key chain were not asked to write on the slip). In each condition, students were then asked "Shall we put it on your keys now?" and then helped in attaching the keychain to their keys.

The various aspects of the procedure were all designed to convey the specific psychological message in each condition (see Table S2 in the online supplemental materials). In total, the intervention session lasted 45–60 min.

Dependent Measures

First-year engineering GPA. The primary outcome was students' GPA in engineering classes over the first year calculated from official school records. GPA is on a scale from 0 to 100. Sixty is needed to remain in engineering; scores above 80 qualify for the Dean's honor list. We did not examine retention in engineering as an outcome because drop-out rates were low (8.38%) in all conditions during the time period examined in this study (the first year of engineering).

Intervention session: Attitudes toward engineering. Immediately after completing intervention or control materials, students reported their attitudes toward engineering. We assessed the same two constructs assessed in the preintervention survey: students' (a) evaluation of their current experience in engineering (sense of belonging in, self-efficacy in, and enjoyment of engineering) and (b) perception of their prospects of succeeding in engineering (possible selves and self-perceived potential in engineering).

Daily diaries: Construal of daily adversities and daily functioning. Beginning a few days after the intervention session, students completed a brief (5-min) online survey every other evening for 12 days (up to six assessments). Each survey assessed students' construals of daily adversities and stressors as well as daily functioning (i.e., daily self-esteem).

First, we assessed the degree to which daily negative events loomed large in importance to students. Students reported each evening on events they had experienced that day that made them "feel positively or negatively about engineering at UW or your experience here" (Walton & Cohen, 2011). Students briefly described each event, categorized it as positive or negative, rated "how positive" or "how negative" (1 = *neutral*, 5 = *very positive/negative*), and then rated "how important" it was (1 = *not at all*, 5 = *very*). Our chief interest was the perceived importance of negative events: the average daily sum total of the perceived importance of negative events.

Second, we assessed students' confidence they could handle stress in school. Each evening, students considered 10 potential sources of stress (Stinson et al., 2008): "family members," "close friends," "other students," "romantic partners," "professors, TAs, or work supervisors," "person you are interested in dating but are not dating," "living independently," "workload for classes," "workload for job," and "any other sources of stress or negative feelings." We assessed how much stress students reported experiencing from each source each day (0 = *not a source of stress*, 1 = *mild*, 2 = *moderate*, 3 = *severe*) and how well students believed they could handle stress from that source ("I can handle this source of stress"; 1 = *strongly disagree*, 7 = *strongly agree*). We were most interested in students' confidence in their ability to handle school-related stress: "other students," "professors, TAs, or work supervisors," "workload for classes," and "workload for jobs" (many students held engineering-related jobs as students through a co-op program). The primary outcome was the average daily confidence students expressed in their ability to handle school stressors.

Third, we examined the level and stability of students' self-esteem across days, as both index daily functioning (Kernis, 2005; Stinson et al., 2008). Each evening, we asked students to choose between 20 pairs of adjectives to describe "your true feelings about yourself right now" (e.g., "bad/good," "ashamed/proud," "adequate/inadequate") on a 7-point scale (from −3 to 3) (Hoshino-Browne et al., 2005; McFarland & Ross, 1982). We scored each item such that higher values represented more positive self-views and, each day, averaged across the 20 items. To provide an overall measure, we calculated the mean and standard deviation of daily self-esteem scores across days, reverse-scored the latter, and standardized and averaged the two measures. Secondary analyses examine the two separately (see the online supplemental material).

Second-semester survey(s): Attitudes toward engineering, friendship groups, implicit norms, and gender identification. In their second semester on campus, students completed one or two surveys. These assessed the same measures assessed in the preintervention survey: (a) attitudes toward engineering, (b) gender identification, (c) friendship groups, and (d) implicit norms about female engineers.

The timing and delivery of the second-semester surveys differed slightly by cohort. For Cohort 1, there was one second-semester survey completed about 4 months postintervention (primarily in April). For Cohorts 2 and 3, there were two second-semester surveys. Their content was identical, and among students who completed both, responses were averaged across assessments.

These surveys were completed about 3½ and 6 months postintervention (primarily in January and February and in May and June, respectively).

Results

Preliminary Data Analytic Issues

Retention rates. Retention rates were adequate, similar to those in past research, and did not vary by gender, major, or condition (see the online supplemental material). Degrees of freedom vary because of missing data on some postintervention measures.

Combination of cohorts. Few analyses were moderated by student cohort (fewer than would be expected by chance alone), so the three cohorts were combined.

Outliers. The results were not driven by outliers. We examined the critical three experimental conditions among women in male-dominated majors. On all primary outcomes, all scores fell within 2.30 standard deviations of the within-condition mean.

Race/ethnicity. No analysis was moderated by student race/ethnicity (White vs. other), Fs < 2.75, ps $> .10$.

Preintervention Measures

Check on random assignment. Confirming the success of random assignment, there was no difference by condition on any preintervention measure, Fs < 1 (see Table S3 in the online supplemental materials).

Baseline differences. First, we examined whether, at baseline, women held more negative explicit attitudes toward engineering than men. They did, both in terms of their evaluation of their current experience in engineering and their perceived prospects of succeeding in the field, main effects of gender, Fs > 5.00, ps $<$ .028. Interestingly, there was no moderation by type of major, Fs < 2.60, ps $> .10$ (see online supplemental material, Tables S4 and S5). Second, we examined gender differences in implicit norms. Past research has shown that women tend to exhibit more positive implicit norms (Yoshida et al., 2012) and gender stereotypes (Nosek & Smyth, 2011; Smeding, 2012) than men in STEM. We replicated this pattern ($M_{\text{women}} = 0.61$; $M_{\text{men}} = 0.48$), $F(1, 206) = 8.75$, $p = .003$, with no moderation by major type, $F < 1$.

Analytic Approach

Overview. Data were analyzed using multiple regression including appropriate dummy codes for student gender, major type (gender-diverse vs. male-dominated), condition, and all two- and three-way interaction terms. Separate analyses tested the combined and separate effects of the two interventions (for specific dummy variables, see the online supplemental material).

Covariates were included as follows: First, where available, the preintervention assessment of each outcome was included in analyses, that is, in analyses of engineering attitudes, friendship groups, implicit norms, and gender identification. This increases statistical power by reducing error variance and ensures that condition differences are not the product of baseline variability. Second, the analysis of engineering GPA controlled for the mean GPA earned in students' major, as this varied widely, $F(10, 181) = 503.25$, $p < .001$. This reduces error variance and ensures that condition differences were not due to any tendency for students to have enrolled in easier majors in one condition than in other conditions. Third, analysis of the perceived importance of daily negative events controlled for the perceived importance of daily positive events, which ensures that effects reflect change in the perception of negative events relative to positive events not change in the perception of all events. In general, covariates were highly significant (see Table S6 in the online supplemental materials).

This study was not designed primarily to explore questions of statistical mediation; issues of sample size and statistical power limit the value of these tests in this study (Mackinnon, Lockwood, Hoffman, West, & Sheets, 2002). However, several exploratory analyses are reported in the online supplemental material.

Robustness of results in alternative analyses. In general, the results were robust to alternative ways of analyzing the data. First, in some cases, participants with intact postintervention scores had missing data on the baseline assessment of that measure, which as noted, was included as a covariate in analysis. To retain as many participants as possible, in primary analyses we replaced missing preintervention values with the Gender × Major mean (Cohen et al., 2009). In general, dropping participants with missing preintervention scores produces similar results. In only one case did this procedure meaningfully affect the results. The effect of affirmation training on the representation of female nonengineers in students' friendship groups was somewhat stronger without replacing missing preintervention values (see the following section).

Second, dropping the two nonbaseline covariates—namely, the mean GPA earned in students' major in analyses of first-year GPA and the perceived importance of daily positive events in analysis of the perceived importance of daily negative events—produced similar results (see the online supplemental material).

Third, analyses of implicit norms were robust to different ways of handling a few participants with high error rates on either the pre- or the postintervention assessment (see the online supplemental material).

Statistical Summary

Figure 1 shows the means and standard errors for first-year GPA by gender, major, and condition. Figures 2–4 show the means and standard errors for the other primary outcomes among students in male-dominated majors; in the online supplemental material, Figures S1–S3 show parallel results among students in gender-diverse majors.

Tables 2–5 summarize the primary statistical results: Intervention effects among women in male-dominated majors (Tables 2, 4, and 5) and gender differences by condition among students in male-dominated majors (Table 3). In the online supplemental material, Tables S7–S11 summarize parallel comparisons among men in male-dominated majors and among men and women in gender-diverse majors. Effect sizes (Cohen's ds, calculated using the raw pooled standard deviation) are included for all contrasts at $p \leq .15$.

First-Year Engineering GPA

The primary outcome was students' cumulative GPA in engineering over the full academic year as reported by the university. We used multiple regressions to test the effects of student gender,

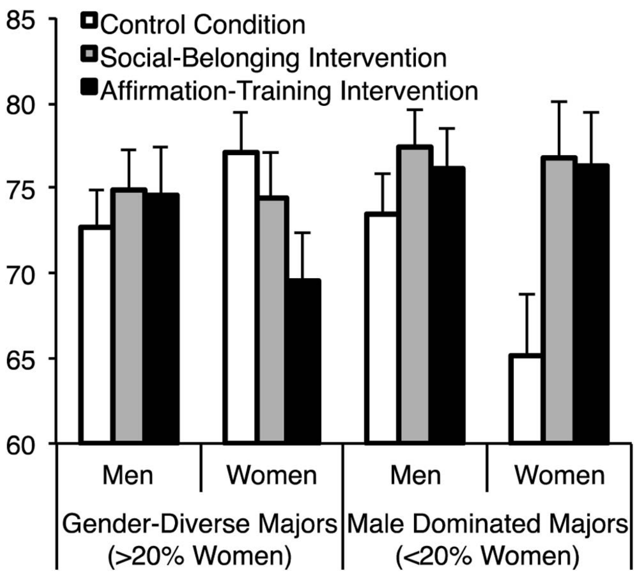

Figure 1. First-year engineering grade point average (GPA), which is calculated on a scale from 0 to 100. Sixty is the average needed to remain in engineering; scores above 80 qualify students for the dean's honor list. Means are adjusted for average within-major GPA. Error bars represent +1 standard error. The *y* axis represents approximately 2.30 standard deviations. Sample sizes: $N_{\text{men}} = 118$; $N_{\text{women}} = 73$.

major, and condition, with the mean GPA earned in different majors controlled.

We first combined the two interventions and compared this group with the control condition. The analysis yielded a three-way interaction, $B = 15.13$, $t(182) = 2.30$, $p = .022$. Examining male-dominated majors, in the control condition, there was a gender gap; women received lower GPAs than men, $B = -8.39$, $t(182) = -1.96$, $p = .051$, $d = -0.77$. But the interventions significantly raised women's GPAs, $B = 11.40$, $t(182) = 2.69$, $p = .008$, $d = 1.04$, eliminating the gender gap, $t < 1$. There was no effect for men, $t < 1.20$. In contrast, in gender-diverse majors, there was no gender difference in either condition, $t\text{s} < 1.40$, $p\text{s} > .15$, and no intervention effect for either men or women, $t\text{s} < 1.65$, $p\text{s} > .10$.

Next, we tested the separate effect of each intervention by creating a dummy variable for each. Both interventions raised GPAs among women in male-dominated majors relative to the control condition—social-belonging intervention: $B = 11.66$, $t(178) = 2.41$, $p = .017$, $d = 1.07$; affirmation-training intervention: $B = 11.13$, $t(178) = 2.30$, $p = .023$, $d = 1.02$. The two interventions did not differ, $t < 1$. See Figure 1 and Tables 2, 3, and S7–S9.

There was only one other condition effect. In gender-diverse majors, women earned lower GPAs in the affirmation-training condition than in the control condition, $B = -7.56$, $t(178) = -2.03$, $p = .043$, $d = -0.69$. Although notable, this pattern was not predicted and was not evident on any other outcome, $t\text{s} < 1.10$, $p\text{s} > .25$, and Table S8. Thus, we interpret it cautiously. Future research should investigate its reliability and, if reliable, its nature.

Construal of Daily Adversities and Daily Functioning

The three daily-diary measures—(a) how "important" students saw daily negative relative to positive events, (b) how confident students were they could handle daily school stress, and (c) the level and day-to-day stability of students' self-esteem—yielded parallel results, so we report them together.

Combining the interventions, multiple-regression analysis of each daily-diary measure yielded a Gender × Major × Condition interaction, $t\text{s} > 2.30$, $p\text{s} < .025$. In male-dominated majors, in the control condition, women exhibited worse outcomes than men on each measure, $t\text{s} > 2.30$, $p\text{s} < .025$, $-1.30 \leq d\text{s} \leq -0.86$. But on all three measures, the interventions improved women's outcomes relative to the control condition. The interventions led women to view daily adversities as less "important," $B = -3.55$, $t(182) = -2.77$, $p = .006$, $d = -0.99$; to express greater confidence they could handle school stress, $B = 0.93$, $t(197) = 2.21$, $p = .028$, $d = 0.94$; and to report higher and more stable self-esteem, $B = 0.71$, $t(196) = 2.16$, $p = .032$, $d = 0.90$. The intervention effects eliminated all three gender differences, $t\text{s} < 1.45$, $p\text{s} > .15$. There were no effects for men, $t\text{s} < 1$. In contrast, in gender-diverse majors, there was no consistent gender difference in either condition and no consistent intervention effect for either men or women. When tested separately, both interventions generated all three benefits for women in male-dominated majors, $t\text{s} > 1.80$, $p\text{s} < .070$. The two interventions did not differ on these outcomes, $t\text{s} < 1$. See Figures 2 and S1 and Tables 2, 3, and S7–S9.

Secondary analyses examined the levels of adversity—the degree of negative relative to positive events and how much school stress—students reported encountering each day. These analyses did not yield consistent effects (see the online supplemental material). The interventions did not consistently reduce the daily challenges women encountered. Instead, they helped women construe challenges as manageable.

Attitudes Toward Engineering

Did the interventions improve women's experience in engineering and, with time, their confidence in their prospects of succeeding in the field? They did. Each analysis controlled for the same measure assessed at baseline.

With the interventions combined, students' felt experience in engineering both immediately after the intervention and in the second semester yielded the predicted Gender × Major × Condition interaction, $t(218) = 2.54$, $p = .012$, and $t(144) = 1.65$, $p = .10$, respectively. Students' confidence in their prospects of succeeding in engineering showed no interaction effect in the intervention session, $t < 1$, but did by the second semester, $t(144) = 2.43$, $p = .016$. In each case, in the control condition in male-dominated majors, women expressed more negative attitudes than men, $t\text{s} > 1.65$, $p\text{s} < .10$, $-1.02 \leq d\text{s} \leq -0.62$. However, the interventions improved women's felt experience in engineering relative to the control condition in the intervention session, $B = 0.58$ $t(218) = 2.76$, $p = .006$, $d = 0.67$, and in the second semester, $B = 0.61$, $t(144) = 1.90$, $p = .060$, $d = 0.67$, and improved women's confidence in their prospects of succeeding in engineering in the second semester, $B = 13.35$, $t(144) = 2.61$, $p = .010$, $d = 0.87$. These effects eliminated all three gender differences, $t\text{s} < 1$. There was no effect for men, $t\text{s} < 1$. By contrast, in

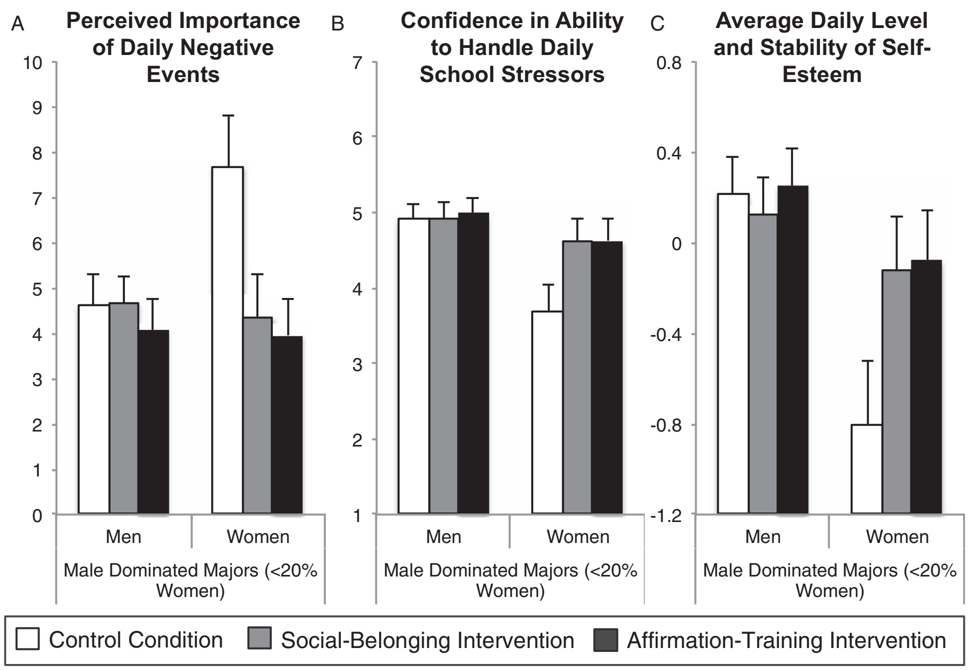

Figure 2. Daily functioning over 12 days after the intervention among students in male-dominated majors (<20% women). Error bars represent +1 standard error. (A) Perceived importance of negative events each day (adjusted for the perceived importance of positive events). (B) Confidence in ability to handle daily school stressors. (**C**) Level and stability (reverse-scored standard deviation) of self-esteem. The two measures were standardized and then averaged. The *y* axes in Panels **A** and **C** represent approximately 3.50 and 2.50 standard deviations, respectively. The *y* axis in Panel B represents the full range of the scale. Sample sizes (including students in gender-diverse majors, Figure S1): N_{men} = 110–121; N_{women} = 81-–84.

gender-diverse majors, there was no gender difference in either condition, $ts \leq 1.40$, $ps > .15$, and no intervention effect for men or women, $ts < 1.55$, $ps > .10$. When tested separately, both interventions generated all three benefits for women in male-dominated majors, $ts > 1.45$, $ps \leq 0.14$, $0.59 \leq ds \leq 1.05$. On no measure did the two interventions differ, $ts < 1$. See Figures 3 and S2 and Tables 2, 3, and S7–S9.

Social Experiences in Engineering

Next, we examined students' social experience in engineering through the second semester. In contrast to the prior measures, here we found divergent effects of the two interventions. In each analysis, we controlled for the same measure assessed at baseline.

Unique effects of social-belonging intervention: Friendships with male engineers and implicit normative evaluations of female engineers. The social-belonging intervention aimed to facilitate women's social integration in engineering. To explore this integration, we first examined the representation of male engineers among the five closest friends students reported having on campus in the second semester with the baseline assessment controlled. The social-belonging intervention increased these friendships among women in male-dominated majors relative to the affirmation-training and control conditions combined, $B = 0.34$, $t(137) = 3.17$, $p = .002$, $d = 1.10$, and relative to each separately, $ts > 2.60$, $ps \leq .010$, $1.09 \leq ds \leq 1.12$. See Figures 4 and S3 and Tables 4 and S10. Notably, the representation of male engineers in women's friendship groups in the social-belonging condition (75%) more closely resembles the percentage of men among women's classmates (90%).

Second, we examined implicit normative evaluations of female engineers. As noted, negative implicit norms predict women's intentions to leave the field (Yoshida et al., 2012). In male-dominated majors, the social-belonging intervention buffered women against this risk factor. With the baseline assessment controlled, social-belonging-condition women exhibited more positive implicit norms about female engineers in the second semester than affirmation-training and control-condition women combined, $B = 0.34$, $t(143) = 2.39$, $p = .018$, $d = 1.03$, and relative to each group tested separately, $ts \geq 1.99$, $ps < .050$, $1.02 \leq ds \leq 1.04$. On both measures, no other group showed consistent effects of the social-belonging intervention. See Figures 4 and S3 and Tables 4 and S10.

Yoshida and colleagues (2012) found that, absent intervention, implicit norms about female engineers become more negative over time. To examine whether our results replicated this pattern and how it varied by condition, we conducted a repeated-measures analysis of variance involving time (preintervention vs. second semester) as a within-subject factor and gender, major type, and condition (social-belonging intervention vs. affirmation-training intervention and control condition) as between-subjects factors. The analysis yielded a marginal four-way interaction, $F(1, 144) = 3.10$, $p = .080$. Replicating Yoshida and colleagues, in the control

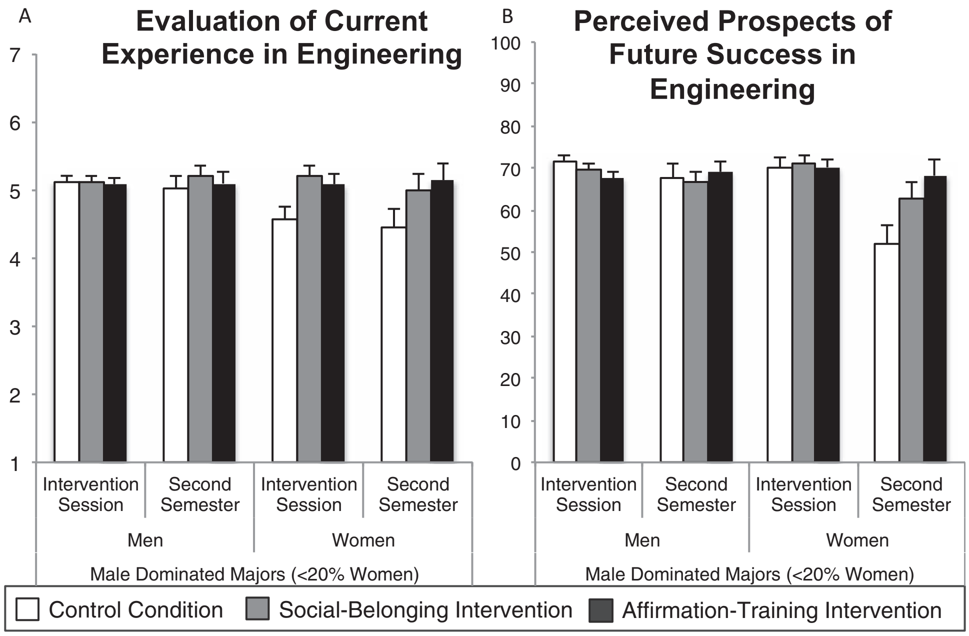

Figure 3. Attitudes toward engineering in the intervention session and in the second semester among students in male-dominated majors (<20% women). Means are adjusted for preintervention reports. The *y* axes represent the full range of each scale. Error bars represent +1 standard error. (A) Students' evaluation of their current experience in engineering. (B) Students' perceived prospects of succeeding in engineering. Sample sizes (including students in gender-diverse majors, see Figure S2): Men: $N_{\text{immediate postintervention}} = 135$, $N_{\text{second semester}} = 88$; Women: $N_{\text{immediate postintervention}} = 92$, $N_{\text{second semester}} = 65$).

and affirmation-training conditions, both men and women exhibited more negative implicit norms about female engineers over time (i.e., irrespective of major; $M_{\text{preintervention}} = 0.57$; $M_{\text{second semester}} = 0.42$), $F(1, 144) = 12.88$, $p < .001$. However, the social-belonging intervention reversed this normative decline among women in male-dominated majors ($M_{\text{preintervention}} = 0.68$; $M_{\text{second-semester}} = 0.78$), $t < 1$ (see online supplemental material).[2]

Unique effects of affirmation-training intervention: Gender identification and friendships with female nonengineers. In contrast, the affirmation-training intervention led women to value their gender identity more, aspects of which they might otherwise suppress in STEM fields (Pronin et al., 2004). In male-dominated majors, affirmation-trained women expressed greater gender identification in the second semester than social-belonging- and control-condition women, $B = 0.98$, $t(141) = 2.48$, $p = .014$, $d = 1.06$; the effect was also significant relative to each comparison group tested separately, ts > 2.00, ps $< .050$, $1.04 \leq d\text{s} \leq 1.08$. In male-dominated majors, affirmation-trained women also reported having marginally more female nonengineering friends in the second semester than social-belonging- and control-condition women, $B = 0.12$, $t(136) = 1.73$, $p = .086$, $d = 0.71$.[3] No other group showed either effect, ts < 1.45, ps $> .15$. See Figures 4 and S3 and Tables 5 and S11.[4]

Discussion

The women who gained admission to the selective engineering programs studied in the present research were among the best prepared in the world. Those who entered programs with a moderate representation of women (on average women accounting for about one third of the students) exhibited relatively positive experiences and performed relatively well. Yet the women who entered male-dominated fields—like computer, electrical, and mechanical

[2] Our theory implies that the social-belonging intervention should facilitate women's friendships with male engineers and improve implicit norms by reducing their experience of identity-based threat in daily social encounters. We did not assess this directly (e.g., daily perceived sexism), however, because we did not want to prime sexism repeatedly for ethical reasons and because we feared that doing so would interfere with intervention effects. However, preintervention and in the second semester, we asked students how often they had heard sexist jokes about female engineers on campus (two items rated on a scale ranging from 1 = *never* to 7 = *frequently*; cf. Yoshida et al., 2012). Analysis of change scores showed that, in male-dominated majors, control- and affirmation-training condition women reported hearing more sexist jokes over time—$M_{\text{diffadj}} = 0.95$); effect of time: $t(142) = 2.88$, $p = .005$—while belonging-condition women showed no increase—$M_{\text{diffadj}} = -0.04$; effect of time: $t < 1$), a marginal condition difference, $t(142) = 1.77$, $p = .079$, $d = 0.71$. See Figure S4 in the online supplemental materials. This pattern could reflect a change in women's social experience (more respectful relationships with men), a change in social perception (perhaps jokes did not seem threatening enough to encode as sexist), or both. This is an important distinction; however, in either case, the results suggest that the belonging intervention uniquely reduced women's experience of identity threat.

[3] This analysis retains 12 participants with missing preintervention scores by replacing these scores with the Gender × Major mean. Not retaining those participants somewhat strengthens the results. See Table 5.

[4] Notably, neither intervention increased the representation of female engineers in women's friendship groups; instead, they led to a marginal reduction in this representation, $B = -0.16$, $t(136) = -1.80$, $p = .074$. For discussion, see the online supplemental material.

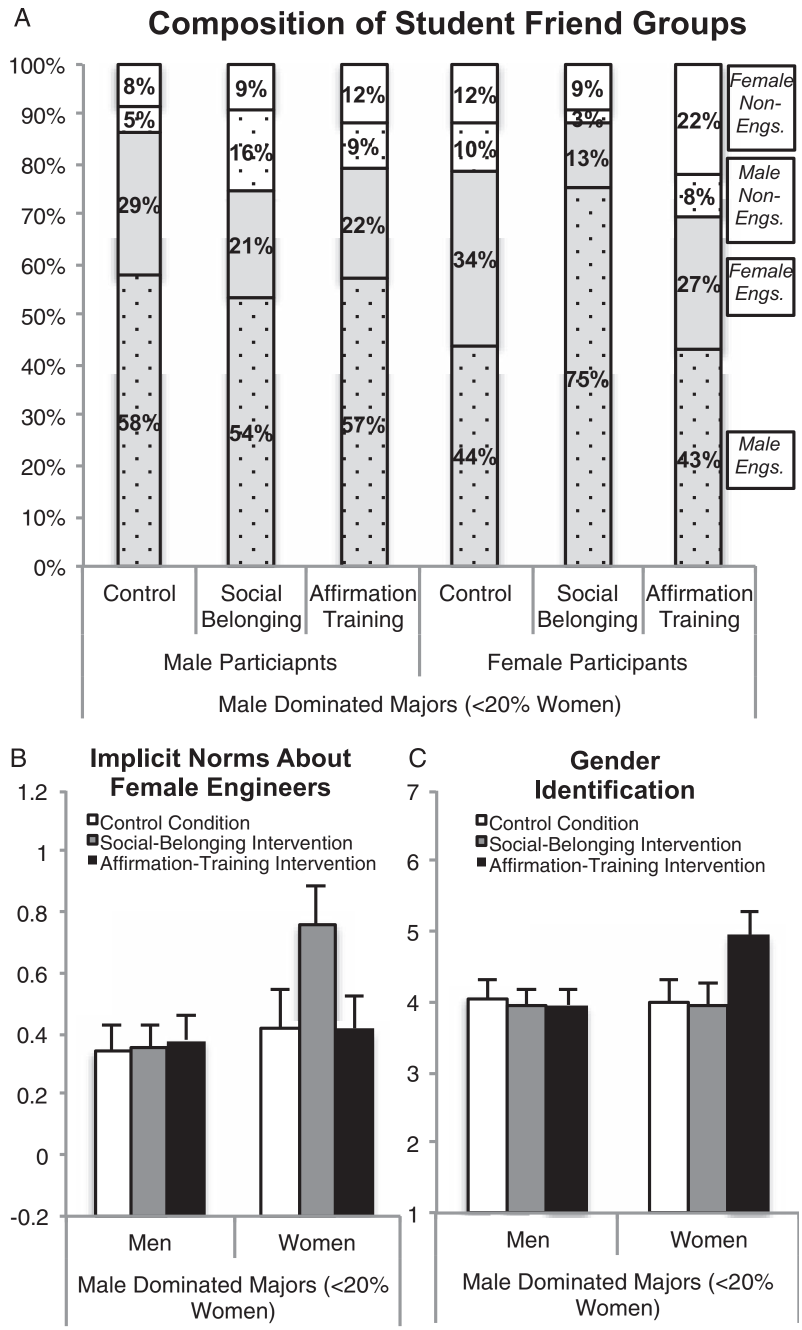

Figure 4. Friendship groups, implicit norms, and gender identification in the second semester among students in male-dominated majors (<20% women). Means are adjusted for preintervention reports. Error bars represent +1 standard error. (A) Representation in students' friendship groups of male and female engineers (Engs.) and nonengineers. (B) Implicit normative evaluations of female engineers. Higher values represent more positive implicit norms about female engineers (i.e., "most people like" = "female engineers"). The *y* axis represents approximately 3.50 standard deviations. (C) Self-reported gender identification. The *y* axis represents the full range of the scale. Sample sizes (including students in gender-diverse majors; see Figure S3): N_{men} = 81–87; N_{women} = 64–65.

engineering, which had on average 10% women in their programs—struggled. Compared with men, they reported feeling more overwhelmed by daily adversities, anticipated less success, and performed worse in class.

However, these struggles were not fixed. Instead, each of two 45- to 60-min interventions designed to help women navigate "chilly" STEM settings catalyzed broad improvement in women's lives and achievement. Both interventions raised women's grades

Table 2
Intervention Effects on Primary Outcomes Among Women in Male-Dominated Majors

	Contrasts among women in male-dominated majors				Interactions (interventions combined)	
Variable	Combined intervention (1) vs. control (0)	Social belonging (1) vs. control (0)	Affirmation training (1) vs. control (0)	Social belonging (1) vs. affirmation training (0)	Gender × Condition in male-dominated majors	Gender × Major × Condition
First-year engineering GPA	$B = 11.40$, $t(182) = 2.69$, $p = .008$, $d = 1.04$	$B = 11.66$, $t(178) = 2.41$, $p = .017$, $d = 1.07$	$B = 11.13$, $t(178) = 2.30$, $p = .023$, $d = 1.02$	$t < 1$	$B = -8.09$, $t(182) = -1.59$, $p = .11$	$B = 15.13$, $t(182) = 2.30$, $p = .022$
Daily diaries						
Perceived importance of daily negative events	$B = -3.55$, $t(182) = -2.77$, $p = .006$, $d = -0.99$	$B = -3.32$, $t(178) = -2.25$, $p = .026$, $d = -0.93$	$B = -3.73$, $t(178) = -2.67$, $p = .008$, $d = -0.94$	$t < 1$	$B = 3.34$, $t(182) = 2.21$, $p = .028$	$B = -4.33$, $t(182) = -2.32$, $p = .022$
Confidence handling daily school stress	$B = 0.93$, $t(197) = 2.21$, $p = .028$, $d = 0.94$	$B = 0.93$, $t(193) = 1.91$, $p = .057$, $d = 0.93$	$B = 0.94$, $t(193) = 2.01$, $p = .046$, $d = 0.94$	$t < 1$	$B = -0.89$, $t(197) = -1.80$, $p = .073$	$B = 1.63$, $t(197) = 2.63$, $p = .009$
Day-to-day level and stability of self-esteem	$B = 0.71$, $t(196) = 2.16$, $p = .032$, $d = 0.90$	$B = 0.68$, $t(192) = 1.83$, $p = .069$, $d = 0.87$	$B = 0.73$, $t(192) = 2.02$, $p = .045$, $d = 0.92$	$t < 1$	$B = -0.74$, $t(196) = -1.94$, $p = .054$	$B = 1.55$, $t(196) = 3.21$, $p = .002$
Intervention session:						
Evaluation of current experience in engineering	$B = 0.58$, $t(218) = 2.76$, $p = .006$, $d = 0.67$	$B = 0.65$, $t(214) = 2.76$, $p = .006$, $d = 0.75$	$B = 0.51$, $t(214) = 2.18$, $p = .031$, $d = 0.59$	$t < 1$	$B = -0.60$, $t(218) = -2.48$, $p = .014$	$B = 0.79$, $t(218) = 2.54$, $p = .012$
Perceived prospects of succeeding in engineering	$t < 1$	$t < 1$	$t < 1$	$t < 1$	$B = -3.92$, $t(218) = -1.14$, $p = .26$	$t < 1$
Second semester						
Evaluation of current experience in engineering	$B = 0.61$, $t(144) = 1.90$, $p = .060$, $d = 0.67$	$B = 0.54$, $t(140) = 1.47$, $p = .14$, $d = 0.60$	$B = 0.69$, $t(140) = 1.90$, $p = .060$, $d = 0.77$	$t < 1$	$B = -0.49$, $t(144) = -1.24$, $p = .22$	$B = 0.83$, $t(144) = 1.65$, $p = .10$
Perceived prospects of succeeding in engineering	$B = 13.35$, $t(144) = 2.61$, $p = .010$, $d = 0.87$	$B = 10.64$, $t(140) = 1.81$, $p = .072$, $d = 0.69$	$B = 16.13$, $t(140) = 2.73$, $p = .007$, $d = 1.05$	$t < 1$	$B = -13.36$, $t(144) = -2.13$, $p = .035$	$B = 19.62$, $t(144) = 2.43$, $p = .016$

Note. Contrasts were derived from multiple regression analyses. For intervention effects among men in male-dominated majors, see Table S7. For intervention effects among students in gender-diverse majors, see Table S8. GPA = grade point average.

Table 3
Gender Differences on Primary Outcomes by Condition Within Male-Dominated Majors

Variable	Male-dominated majors: Control conditions	Male-dominated majors: Intervention conditions
First-year engineering grade point average	$B = -8.39$, $t(182) = -1.96$, $p = .051$, $d = -0.77$	$t < 1$
Daily diaries:		
Perceived importance of daily negative events	$B = 3.06$, $t(182) = 2.34$, $p = .020$, $d = 0.86$	$t < 1$
Confidence handling daily school stress	$B = -1.22$, $t(197) = -2.89$, $p = .004$, $d = -1.22$	$B = -0.33$, $t(197) = -1.29$, $p = .20$
Day-to-day level and stability of self-esteem	$B = -1.03$, $t(196) = -3.12$, $p = .002$, $d = -1.30$	$B = -0.28$, $t(196) = -1.42$, $p = .16$
Intervention session:		
Evaluation of current experience in engineering	$B = -0.55$, $t(218) = -2.66$, $p = .008$, $d = -0.64$	$t < 1$
Perceived prospects of succeeding in engineering	$t < 1$	$B = 1.94$, $t(218) = 1.07$, $p = .29$
Second session:		
Evaluation of current experience in engineering	$B = -0.56$, $t(143) = -1.69$, $p = .093$, $d = -0.62$	$t < 1$
Perceived prospects of succeeding in engineering	$B = -15.67$, $t(144) = -2.96$, $p = .004$, $d = -1.02$	$t < 1$

Note. Men coded as 0; women coded as 1. For analyses, intervention conditions were combined. Contrasts derived from multiple regression analyses. For gender differences within gender-diverse majors, see Table S9.

in male-dominated majors over the full academic year, eliminating gender differences. Moreover, both helped women view daily adversities and stressors as challenges they could manage, strengthening their resilience. They also led women to report more positive experiences in engineering immediately and, by the second semester, greater confidence they could succeed in the field.

The results highlight two high-level implications. First, they suggest the power of social marginalization to cause gender inequality in STEM settings. This inequality arises in settings in which women are grossly underrepresented (see also Inzlicht & Ben-Zeev, 2000; Murphy et al., 2007; Stout et al., 2011; Yoshida et al., 2012); it is mitigated by interventions that help women cope with marginalization. At least among selective samples, this marginalization may be a primary cause of gender inequality in STEM fields (Walton & Spencer, 2009; Walton, Spencer, & Erman, 2013). Second, the results suggest the importance of students' reactions to social marginalization in determining its impact on their achievement over time. In the present context, women's underperformance was not due simply to a lack of opportunities or to high levels of sexism; the interventions addressed neither factor. Rather, when students enter settings in which their group is underrepresented and negatively stereotyped, they contend with psychological challenges that other students do not face. They must make sense of daily adversities, which could seem to signal a global lack of belonging, and they contend with high levels of stress and threat. By helping students meet these challenges, the two interventions helped women succeed in male-dominated STEM environments over time.

In addition, the results carry implications for brief psychological interventions. First, in replicating and extending the basic effects of past social-belonging and value-affirmation interventions on achievement among women in STEM (Cohen et al., 2009; Harackiewicz et al., 2014; Miyake et al., 2010; Walton & Cohen, 2011), the results increase confidence in this general approach and invite us to consider the broader array of students who may benefit from it in specific school contexts, for instance, where their group is underrepresented or socially marginalized (e.g., men in some settings).

Second, even as the two interventions caused similar improvements in women's outcomes, they encouraged different responses to social marginalization and set students on divergent paths. By providing a more positive narrative for interpreting daily adversities, the social-belonging intervention helped women integrate in engineering. It led women to feel, on an automatic level, that women were more valued in engineering, and it facilitated friendships with male engineers. The latter finding is especially striking: It suggests that a brief intervention aimed narrowly at the meaning of adversities can change students' social circumstance over time. By the second semester, social-belonging-condition women were embedded in social networks with male engineers—one potential route to success for women in STEM (cf. Shook & Clay, 2012; Walton & Carr, 2012). By contrast, even as affirmation training produced the same improvement in women's grades, it did not promote this social integration. It had no effect on women's implicit norms or friendships with male engineers. Instead, in encouraging women to express broader aspects of their self-identity in engineering, affirmation training led women to place greater value on their gender identity, which they might otherwise selectively suppress in STEM, and to form marginally more friendships with women outside engineering. An important question for future research concerns how these divergent strategies affect women's well-being and retention in STEM over a longer period of time, for instance, as they enter the profession. In addition, this analysis raises questions about how these interventions would interact. Although it is natural to assume that two interventions, both of which improve women's experience in STEM, would be more effective together, it is possible that, insofar as they set in motion divergent strategies for navigating a chilly environment, a combination may produce less optimal results.

Third, a significant ongoing question in the field involves how and when brief psychological interventions can cause lasting gains in achievement (Cohen et al., 2009; Garcia & Cohen, 2012; Sherman et al., 2013; Walton & Cohen, 2011; Yeager & Walton, 2011). In demonstrating change in students' friendship groups, the present results suggest that, at least in some cases, an interplay between psychological processes and the development of positive social relationships may contribute to lasting benefits. Perhaps less threatening construals of daily social interactions inspired by the social-belonging intervention "locked in" to improve women's downstream outcomes by facilitating positive cross-sex friend-

Table 4
Effects of the Social-Belonging Intervention on Outcomes Predicted to Yield Effects Only for This Intervention Among Women in Male-Dominated Majors

	Contrasts among women in male-dominated majors				Interactions (affirmation-training intervention and control condition combined)	
	Social-belonging intervention (1) vs.					
Second semester	Affirmation training and control (0)	Affirmation training (0)	Control (0)	Affirmation-training intervention (1) vs. control (0)	Gender × Condition in male-dominated majors	Gender × Major × Condition
Percentage of male engineers in students' friendship groups	$B = 0.34$, $t(137) = 3.17$, $p = .002$, $d = 1.10$	$B = 0.35$, $t(133) = 2.80$, $p = .006$, $d = 1.12$	$B = 0.34$, $t(133) = 2.62$, $p = .010$, $d = 1.09$	$t < 1$	$B = -0.37$, $t(137) = -2.77$, $p = .006$	$B = 0.26$, $t(137) = 1.46$, $p = .15$
Implicit normative evaluations of female engineers	$B = 0.34$, $t(143) = 2.39$, $p = .018$, $d = 1.03$	$B = 0.35$, $t(139) = 2.16$, $p = .033$, $d = 1.04$	$B = 0.34$, $t(139) = 1.99$, $p = .049$, $d = 1.02$	$t < 1$	$B = -0.35$, $t(143) = -2.04$, $p = .043$	$B = 0.52$, $t(143) = 2.25$, $p = .026$

Note. Contrasts derived from multiple regression analyses. For contrasts for the other three Gender × Major groups, see Table S10.

Table 5
Effects of Affirmation-Training Intervention on Outcomes Predicted to Yield Effects Only for This Intervention Among Women in Male-Dominated Majors

	Contrasts among women in male-dominated majors				Interactions (social-belonging intervention and control condition combined)	
	Affirmation-training intervention (1) vs.					
Second semester	Social belonging and control (0)	Social belonging (0)	Control (0)	Social-belonging intervention (1) vs. control (0)	Gender × Condition in male-dominated majors	Gender × Major × Condition
Percentage of female nonengineers in students' friendship group						
Retaining participants with missing preintervention data	$B = 0.12$, $t(136) = 1.73$, $p = .086$, $d = 0.71$	$B = 0.13$, $t(132) = 1.66$, $p = .099$, $d = 0.79$	$B = 0.10$, $t(132) = 1.28$, $p = .20$, $d = 0.63$	$t < 1$	$B = -0.09$, $t(136) = -1.14$, $p = .26$	$B = 0.05$, $t < 1$
Dropping participants with missing preintervention data	$B = 0.20$, $t(124) = 2.62$, $p = .010$, $d = 1.19$	$B = 0.20$, $t(120) = 2.38$, $p = .019$, $d = 1.21$	$B = 0.19$, $t(120) = 2.16$, $p = .033$, $d = 1.17$	$t < 1$	$B = 0.20$, $t(124) = -2.22$, $p = .028$	$B = 0.18$, $t(124) = 1.48$, $p = .14$
Gender identification	$B = 0.98$, $t(141) = 2.48$, $p = .014$, $d = 1.06$	$B = 1.00$, $t(137) = 2.20$, $p = .029$, $d = 1.08$	$B = 0.96$, $t(137) = 2.05$, $p = .042$, $d = 1.04$	$t < 1$	$B = -1.03$, $t(141) = -2.12$, $p = .035$	$B = 1.70$, $t(141) = 2.59$, $p = .011$

Note. Contrasts derived from multiple regression analyses. For contrasts for the other three Gender × Major groups, see Table S11.

ships. The present study is limited in its ability to test specific meditational processes. However, it points to the kinds of psychological and social-relational measures that future studies could track with larger samples, including perceptions of threat in daily events and peer and mentor relationships, for instance using sociometric measures. In so doing, it will be exciting to assess both how changes in the construal of daily events affect developing relationships and potential recursive processes, such as how a change in friendship groups or the acquisition of a mentor feeds back to promote resilience in the face of adversity.

Fourth, an important contribution of the present research was to demonstrate the moderating role of the school context. Only women in male-dominated majors had worse outcomes than men, and only they benefited from the interventions (see also Inzlicht & Ben-Zeev, 2000; Murphy et al., 2007; Stout et al., 2011; Yoshida et al., 2012). Although psychological interventions can be brief, their effects depend on the context (Walton, 2014). If the process that an intervention targets does not serve as a barrier to achievement for a given group or in a given setting, the intervention will not affect behavior (Hanselman et al., 2014). In addition, in contexts in which other conditions for learning are not met—such as when instruction or students' academic preparation is poor—interventions that open students up to learning opportunities may be insufficient. Contexts may also differ in the extent to which they propagate the benefits of psychological interventions or undermine their effects. For instance, if the effectiveness of the social-belonging intervention depends on the potential for students to become more integrated in a school setting, long-term effects may depend on the willingness of peers and instructors to develop positive working relationships with target students. Further exploring these questions will shed light on pressing theoretical questions and applied issues, including where psychological interventions will be most effective, where they may be unnecessary, and where they may need to be paired with other reforms.

The present study also has its limitations; addressing these points to exciting directions for future research. One is that participating students chose to take part in the study; they were thus not representative, either of the university they attended or of STEM students in general. What benefits would we see in broader and more representative samples? A second limitation involves the small sample. Can we develop effective ways to deliver social-psychological interventions to larger samples, for instance, in collaboration with STEM educators (Aguilar et al., 2014; Yeager & Walton, 2011) or online (Paunesku et al., 2014; Yeager et al., 2014)? Larger samples would further test intervention effects and address important questions of moderation and mediation. It would also test whether these interventions can be a practical solution for education reform—that is, when delivered in ways that would be practical en masse.

At a time when it is essential to promote women's achievement in STEM, the results highlight the importance of addressing feelings of social marginalization. Yet in a very real sense, the interventions tested here are "second-choice" interventions. They help women navigate a difficult environment—one in which their group is grossly underrepresented and subject to stigma and negative stereotypes. Although these interventions were successful, it would be far better, if possible, to improve STEM settings themselves—to reduce sexism (Logel et al., 2009), to remove cues that convey a strongly masculine representation of STEM fields (Cheryan et al., 2009; Murphy et al., 2007; Ramsey, Betz, & Sekaquaptewa, 2013; see also Purdie-Vaughns, Steele, Davies, Ditlmann, & Crosby, 2008), and to increase the representation of women. Consistent with the concept of critical mass (Etzkowitz, Kemelgor, Neuschatz, Uzzi, & Alonzo, 1994), a community of women may reduce social marginalization and the need for specific intervention. Efforts to increase the representation of women in STEM thus go hand-in-hand with efforts to help women function well in male-dominated STEM settings as means to promote gender equality.

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