

# Female peers in small work groups enhance women's motivation, verbal participation, and career aspirations in engineering

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For years, public discourse in science education, technology, and policy-making has focused on the “leaky pipeline” problem: the observation that fewer women than men enter science, technology, engineering, and mathematics fields and more women than men leave. Less attention has focused on experimentally testing solutions to this problem. We report an experiment investigating one solution: we created “microenvironments” (small groups) in engineering with varying proportions of women to identify which environment increases motivation and participation, and whether outcomes depend on students’ academic stage. Female engineering students were randomly assigned to one of three engineering groups of varying sex composition: 75% women, 50% women, or 25% women. For first-years, group composition had a large effect: women in female-majority and sex-parity groups felt less anxious than women in female-minority groups. However, among advanced students, sex composition had no effect on anxiety. Importantly, group composition significantly affected verbal participation, regardless of women’s academic seniority: women participated more in female-majority groups than sex-parity or female-minority groups. Additionally, when assigned to female-minority groups, women who harbored implicit masculine stereotypes about engineering reported less confidence and engineering career aspirations. However, in sex-parity and female-majority groups, confidence and career aspirations remained high regardless of implicit stereotypes. These data suggest that creating small groups with high proportions of women in otherwise male-dominated fields is one way to keep women engaged and aspiring toward engineering careers. Although sex parity works sometimes, it is insufficient to boost women’s verbal participation in group work, which often affects learning and mastery.

stereotypes | STEM diversity | science education | gender | social psychology

In today’s globalized world, innovation in science and technology is vital for American economic competitiveness, quality of life, and national security. For the United States to maintain global leadership and competitiveness, the nation must invest in research and innovation and grow a talented, large workforce in science, technology, engineering, and mathematics (STEM). Indeed, much of the future job growth in the United States is expected to be in STEM fields, and American businesses search globally for talent (1). This raises concerns about Americans’ preparedness for these jobs because too few domestic students enter STEM fields and among those who do, attrition is high. For example, only 28% of the STEM workforce is female (2), even though women represent 50% of the American population and 58% of its college-bound population (3). Clearly, women are untapped human capital that, if leveraged, could increase the STEM workforce substantially. Accomplishing this goal involves identifying academic stages in the STEM pipeline where women are less likely to enter STEM fields and more likely to exit these fields than men, and developing interventions to address this “leaky pipeline.” A lot of research has drawn attention to this problem, but far less research has tested solutions to this

problem. The present study focuses on one solution targeting undergraduate students.

In the first year of college, fewer women than men report intentions to major in STEM. Between 2009 and 2013, approximately, 22% of women compared with 29% of men intended to major in STEM (4, 5). These numbers dwindle quickly in the first few semesters of college as many students switch out of STEM (6, 7). In engineering, for example, 40% of students who initially intend to major in engineering switch majors (7). Even though women who initially intend to major in STEM tend to be well-qualified in terms of prior preparation in math and science (3, 8), they often report less confidence and motivation to pursue STEM careers compared with male peers (9, 10). These sex differences are often assumed to be driven by individual differences and a matter of free choice in selecting one’s own life path (11–13).

We propose that what seems like a free choice is constrained by subtle cues in achievement contexts, such as its sex composition, that signal who naturally belongs in STEM and is likely to succeed and who else is a dubious fit. In STEM fields that have very small proportions of women (e.g., engineering), women’s lower motivation, participation, and career aspirations compared with men is likely to be driven by isolation and stereotype threat—the concern that one will be judged in terms of a stereotype—more than free choice (14, 15). If this is true, then systematically increasing the presence of female peers in learning contexts ought to have significant positive effects on young women’s engagement in STEM. The present study tests this and other related hypotheses about how sex composition of peers in academic contexts influence

## Significance

Advances in science, technology, engineering, and mathematics are critical to the American economy and require a robust workforce. The scarcity of women in this workforce is a well-recognized problem, but data-driven solutions to this problem are less common. We provide experimental evidence showing that gender composition of small groups in engineering has a substantial impact on undergraduate women’s persistence. Women participate more actively in engineering groups when members are mostly female vs. mostly male or in equal gender proportions. Women feel less anxious in female-majority groups vs. minority groups, especially as first-year students. Gender-parity groups are less effective than female-majority groups in promoting verbal participation. Female peers protect women’s confidence and engineering career aspirations despite masculine stereotypes about engineering.

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women's engagement in STEM using the stereotype inoculation model as the guiding theoretical framework (10, 14).

The stereotype inoculation model proposes that, analogous to biomedical vaccines that protect and inoculate one's physical body against the threat of bacteria and viruses, exposure to in-group experts and peers act as "social vaccines" that inoculate an individual's mind against noxious stereotypes. Past research using the model found that contact with female experts in STEM (e.g., professors) enhanced female students' liking for STEM fields, identification with these fields, confidence, and career aspirations in STEM (10). These findings are consistent with other data showing that individuals' aspirations are positively influenced after seeing successful professional role models, especially if they relate to these role models (16–21). Collectively, past work demonstrates that exposure to same-sex experts who are at an advanced career stage enhances young women's global attitudes toward the field and career aspirations.

What remains unknown is whether same-sex peers in STEM contexts serve as social vaccines too, and if so, under what conditions. Two characteristics make same-sex peers different from experts. First, unlike experts who are successful and advanced relative to young students, peers are at the same stage of development, making their social influence psychologically different. Female peers may be less effective because they have not reached high levels of success as experts. Alternatively, peers may be more effective because of their greater similarity to young students. Second, although exposure to only one female expert is a sufficient social vaccine for young women in STEM (10), it is unclear whether one female peer will produce the same effect.

What is the ideal proportion of female peers in sex stereotypic achievement contexts that is beneficial to women? Past studies have shown that when women are in situations where they are the only woman, the experience of being a solo reduces their sense of belonging and lowers confidence, performance, and satisfaction. For example, women performed significantly worse on a math test when they were in academic contexts where they were the only woman surrounded by male peers compared with contexts where all of their peers were women (22–25). Similarly, women's learning and memory were disrupted when they were a female solo in an otherwise all-male group versus in an all-female group (26). Solo status decreased individuals' task confidence and interest (24, 27), made them feel isolated and dissatisfied with the work environment (28–30), increased concern that others viewed them as representatives of their sex (25, 31, 32), and made them reluctant to enter situations where they would be a minority (33). The negative effects of solo or token status are particularly potent for historically disadvantaged groups (women and ethnic minorities) compared with advantaged groups (White men) and in domains where the solo or token's social group is negatively stereotyped: for example, in STEM where women's abilities are called into question and the ideal expert is assumed to be male (14, 22, 25).

Surprisingly, all past experiments on group composition have been limited to extreme comparisons: peer groups where women were solos or tokens (25% or less) versus all women (100% of the group). None of these studies tested whether sex-parity contexts (50% women) would erase the impact of negative stereotypes. Moreover, past studies did not allow group members to interact. Typically, participants only saw photographs of alleged group members; thus, sex composition was a passive backdrop (22–26). In contrast, our goal was to assess how active interactions among individuals within groups that vary in sex composition influence women's behavior in a stereotypic field. The closest approximation is a recent field study that compared women's and men's performances in student engineering groups. Students in an engineering class were assigned to groups based on instructors' preferences (group assignment was nonrandom). Groups varied in sex composition, ranging from all male, all

female, male-dominated, female-dominated, and sex-parity groups (34). Results showed that group sex composition had no effect on women's behavior. However, because group assignment was nonrandom, it is possible that instructor preferences or unmeasured individual differences confounded the effect of group composition on women's behavior. A few sociological studies have also compared women in large organizations who were solos or tokens. However, none of these studies examined organizations with sex parity and all involved large organizations rather than small groups.

The absence of research examining how sex parity affects women's behavior in masculine achievement contexts is surprising, given that educators and policy-makers commonly assume that achieving numeric sex parity at the recruitment stage will solve the subsequent retention problem of women in STEM. However, this assumption has not been tested and may or may not be borne out by actual data. The first goal of the present study was to test whether or not creating interactive STEM environments with numeric sex parity protects women from the impact of masculine stereotypes and enhances their participation, positive performance appraisals, and future career aspirations in stereotypic domains. A second important goal was to investigate whether women's academic life stage affects their vulnerability to the sex composition of peer groups. Exposure to female peers may be more important to young women who are beginners in college compared with women who are advanced in their college career (14).

## Current Study

Our study was conducted in engineering, a stereotypically masculine field. Women comprise roughly 18% of undergraduate engineering majors (2). Female undergraduates were recruited from engineering courses at a public university to participate in a "study on group work in engineering." They were randomly assigned to work in one of three groups (four-person groups) that varied in sex composition: groups had 75% women, 50% women, or 25% women. Each group had one real naïve participant (always a female student); the remaining three group members were engineering research assistants (RAs) who were trained to behave in a consistent scripted way. Real participants were unaware that their teammates were RAs. Group members had a few minutes to get acquainted with each other before being separated into private cubicles for initial tasks. When alone, participants read the engineering problems they would be solving with their group, worked on these problems alone for a few minutes, and indicated how worried (threatened) or eager (challenged) they felt about the upcoming group task. Participants then worked on the group task with their teammates. Participants' behavior was evaluated by RAs in their group. Afterward, participants returned to individual cubicles where we assessed their confidence, career aspirations, perceived sex distinctiveness, and a few other measures (see *SI Materials and Methods* for details).

We investigated how systematic variations in the proportion of female-to-male students in engineering groups influenced women's feelings of threat and challenge in anticipation of teamwork, their behavior in groups, how distinctive they felt in terms of sex, their confidence, and career aspirations in engineering. We had competing predictions about which sex composition would be most beneficial for women. On the one hand, sex parity in engineering groups might be sufficient to reduce feelings of threat and sex distinctiveness, and increase positive challenge and participation compared with female minority groups. Alternatively, sex parity may not be sufficient to override masculine stereotypes; female-majority groups may be needed for that to happen. Second, based on the stereotype inoculation model we predicted that the presence of female peers would be more beneficial for first-year women whose academic self-concept is in transition compared with advanced college students whose academic self-concept is more developed (14). Third, we

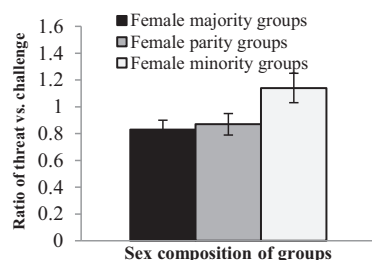
tested if the presence of female teammates would inoculate women's self-concept against masculine stereotypes about engineering. We expected that if women are immersed in engineering groups where they are a numeric minority, the activation of masculine engineering stereotypes would predict less confidence and less interest in engineering careers. However, when immersed in engineering groups with a substantial proportion of female peers, women would be better able to deflect stereotypes, continue to feel confident and aspire toward engineering careers despite stereotype activation.

## Results

**Effect of Group Sex Composition on Appraisals of Threat and Challenge.** Two planned contrasts tested if group sex composition affected women's appraisals of threat and challenge before the group task. We predicted that women in female-majority groups would experience less threat and more challenge relative to female-minority groups. We had two competing predictions regarding sex-parity groups. If sex parity is sufficient to reduce sex distinctiveness, women in these groups might anticipate a positive experience similar to female-majority groups. However, if sex remained salient, women in sex-parity groups might have an experience similar to female-minority groups. Contrast 1 compared appraisals of threat and challenge in female-minority groups (contrast weight  $-2$ ) against female-majority and parity groups weighted equally (contrast weight  $+1$ ). Contrast 2 compared female-majority groups (contrast weight  $+2$ ) against female-minority and female-parity groups weighted equally (contrast weight  $-1$ ).

The dependent variable was the ratio of self-reported threat vs. challenge, which captured the relative degree of threat compared with challenge participants experienced (35–37). A ratio greater than 1 would indicate participants felt more threatened than challenged by the group activity. A ratio less than 1 would indicate more challenge than threat. Planned contrasts using Group Composition as the independent variable and the ratio of threat-by-challenge as the dependent variable revealed that contrast 1 was significant,  $t(117) = 2.54$ ,  $P = 0.01$ , Cohen's  $d = 0.47$ , such that women in female-minority groups experienced significantly more threat relative to challenge (mean = 1.14, SE = 0.11) than in female-majority groups (mean = 0.83, SE = 0.07) and female-parity groups (mean = 0.87, SE = 0.08) (Fig. 1). Contrast 2 was statistically nonsignificant,  $t(117) = 1.62$ ,  $P = 0.11$ , Cohen's  $d = 0.30$ .

When threat and challenge were disaggregated as separate dependent variables, contrast 1 was statistically significant for perceived threat,  $t(117) = 2.54$ ,  $P = 0.01$ , Cohen's  $d = 0.47$ , indicating that women in female-minority groups felt significantly more threatened in anticipating the group task (mean = 4.25, SE = 0.23) than women in female-majority groups (mean = 3.60, SE = 0.21) and female-parity groups (mean = 3.51, SE = 0.21). Contrast 2 was nonsignificant,  $t(117) = 1.08$ ,  $P = 0.28$ , Cohen's



**Fig. 1.** Effect of group sex composition on appraisals of threat and challenge experienced by female engineering students in anticipation of group work. The dependent variable is the ratio of threat compared with challenge; if this ratio is greater than one, women experienced more threat (anxiety) than challenge (eagerness). Error bars are  $\pm 1$  SE.

$d = 0.20$ . Similar planned contrasts using challenge as the dependent variable yielded small effects that were statistically nonsignificant, contrast 1:  $t(117) = 1.65$ ,  $P = 0.10$ , Cohen's  $d = 0.31$ ; contrast 2:  $t(117) = 1.62$ ,  $P = 0.11$ , Cohen's  $d = 0.30$ . Women felt somewhat less challenged if they anticipated working in female-minority groups (mean = 4.35, SE = 0.20) compared with female-majority groups (mean = 4.85, SE = 0.18) or female-parity groups (mean = 4.62, SE = 0.18), but these differences were not statistically significant.

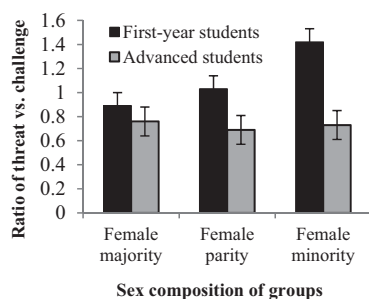
### Effect of Group Sex Composition and Academic Life Stage on Appraisals of Threat and Challenge.

Next, we tested whether women's academic stage in college influenced their experiences of threat vs. challenge in different types of groups. A linear regression was conducted using as predictor variables participants' Year in College (first-year vs. older) and Group Composition (female-majority and parity groups were dummy-coded as 1 and female-minority groups dummy coded as 0). The ratio of threat-by-challenge was the dependent variable. Results showed a significant effect of Year in College,  $B = -0.37$ , SE = 0.10,  $P < 0.0009$ , such that overall, first-year women who were newcomers to engineering experienced more threat compared with challenge than advanced women. A significant effect of Group Composition,  $B = 0.28$ , SE = 0.11,  $P = 0.01$ , showed that women in female-minority groups experienced more threat relative to challenge than women in the other two groups. More interesting was the significant two-way interaction between Group Composition  $\times$  Year in College,  $B = -0.46$ , SE = 0.21,  $P = 0.03$  (Fig. 2). When separate regressions were conducted for first-years and advanced students, results showed first-years experienced significantly more threat vs. challenge in female-minority groups compared with female-majority and sex-parity groups ( $B = 0.47$ , SE = 0.16,  $P = 0.005$ , Cohen's  $d = 0.74$ ). However, advanced female students' experience of threat vs. challenge was not affected by group sex composition ( $B = 0.01$ , SE = 0.13,  $P = 0.93$ , Cohen's  $d = 0.03$ ).

**Effect of Group Sex Composition on Behavior.** All three RAs within each group evaluated participants' behavior on five items (see *SI Materials and Methods* for measures). Because RAs' ratings on each item were highly correlated ( $r = 0.57$ – $0.70$ ,  $P < 0.0001$ ), item ratings were averaged across RAs. Averaged ratings for all five items cohered nicely (Cronbach's  $\alpha = 0.97$ ) and were collapsed into one composite index capturing participants' behavior in the group (see *SI Results* for details on the validity of behavioral ratings). Using this composite we tested whether participants' behavior varied as a function of group sex composition by conducting two planned contrasts. Contrast 1 compared behavior in female-minority groups (contrast weight  $-2$ ) with female-majority and parity groups weighted equally (contrast weight  $+1$ ). Contrast 2 compared participants' behavior in female-majority groups (contrast weight  $+2$ ) to female-minority and parity groups weighted equally (contrast weight  $-1$ ). Only contrast 2 was statistically significant [ $t(111) = 2.09$ ,  $P = 0.039$ , Cohen's  $d = 0.40$ ], indicating that women participated significantly more when assigned to female-majority groups (mean = 5.36, SE = 0.21) compared with female-minority groups (mean = 4.85, SE = 0.19) and female-parity groups (mean = 4.74, SE = 0.25) (Fig. 3). Contrast 1 was nonsignificant:  $t(111) < 1$ ,  $P > 0.45$ , Cohen's  $d = 0.14$ . Women's behavior in engineering groups was not moderated by their year in college (Group Composition  $\times$  Year in College,  $B = -0.08$ , SE = 0.51,  $P = 0.88$ ). Regardless of academic seniority, women in female-majority groups participated more actively than women in the other two groups.

**Effect of Group Sex Composition on Sex Distinctiveness.** Women perceived their sex to be more distinctive in a negative way in female minority groups (mean = 1.90, SE = 0.20) compared with female-majority and sex parity groups (mean = 1.46, SE = 0.18);





**Fig. 2.** Effect of group sex composition and academic life stage (first-years vs. advanced students) on appraisals of threat and challenge. If the ratio of threat compared with challenge is greater than one, women experienced more threat (anxiety) than challenge (eagerness). Error bars are  $\pm 1$  SE.

mean = 1.51, SE = 0.18, respectively) as indicated by a planned contrast comparing female-minority groups (contrast weight +2) to female-majority and parity groups weighted equally (contrast weight -1),  $t(117) = 1.82$ ,  $P = 0.07$ , Cohen's  $d = 0.37$ . Sex salience was not moderated by year in college ( $F < 1$ ).

**Implicit Stereotypes Moderate the Effect of Group Sex Composition on Women's Confidence and Career Aspirations in Engineering.** Implicit stereotypes associating engineering with men more than women were measured using an Implicit Association Test (IAT), a rapid reaction time task (38) (see *SI Materials and Methods* for details). Female students associated engineering more quickly and easily with men compared with women (IAT  $D = 0.19$ , SE = 0.03) regardless of group composition. Neither group composition, order in which the IAT was administered, nor the interaction effect changed the magnitude of the stereotype IAT (all  $F$ s < 1). Given the stability of implicit stereotypes across treatment conditions we used it as an individual difference measure to test whether stronger implicit stereotypes would be associated with lower confidence and career aspirations for women assigned to female-minority groups compared with the other two groups. Two regressions tested this hypothesis using Group Composition, Implicit Stereotypes (IAT  $D$ ), and the interaction term as predictor variables. For Group Composition, the female-minority group was dummy-coded as 0 and the other two groups as 1.

When the dependent variable was confidence, results revealed a significant effect of Implicit Stereotypes ( $B = -0.74$ , SE = 0.32,  $P = 0.02$ ), showing that women who held stronger implicit stereotypes that engineering is a masculine field felt less confident about their own performance in engineering. We also found an interaction between Group Composition  $\times$  Implicit Stereotypes ( $B = -1.25$ , SE = 0.65,  $P = 0.057$ ) (Fig. 4). When this interaction was decomposed by Group Composition, as expected the relation between implicit stereotypes and lower confidence was significant for women assigned to female-minority groups but not the other two groups. In female-minority groups the more women held implicit stereotypes about engineering the less confident they felt about their own ability ( $B = -1.54$ , SE = 0.55,  $P = 0.009$ ). In female-majority and female-parity groups implicit stereotypes were not associated with self-confidence (respectively,  $B = -0.02$ , SE = 0.53,  $P = 0.97$ , and  $B = -0.47$ , SE = 0.56,  $P = 0.40$ ).

When career aspiration was the dependent variable, a Group Composition  $\times$  Implicit Stereotype regression revealed a significant interaction effect, similar to the one above ( $B = -1.72$ , SE = 0.73,  $P = 0.02$ ) (Fig. 5). When decomposed, this effect showed that women who had strong implicit stereotypes about engineering were less interested in pursuing engineering careers if assigned to female-minority groups ( $B = -1.42$ , SE = 0.62,  $P = 0.03$ ), but no such association was found in female-majority

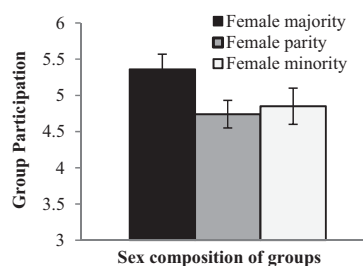
groups ( $B = 0.68$ , SE = 0.50,  $P = 0.18$ ) and female-parity groups ( $B = 0.02$ , SE = 0.68,  $P = 0.98$ ).

Group sex composition did not influence participants' global attitudes toward engineering, identification with engineering, or stereotypes about engineering. See *SI Results* for details.

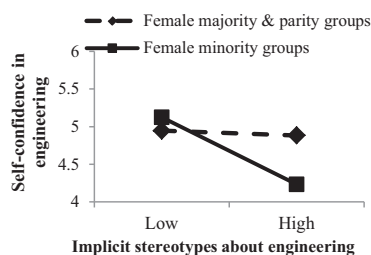
## Discussion

The overarching goal of this research was to investigate whether sex composition of small group learning environments can be leveraged to reduce the attrition of women from STEM. In a field like engineering, where the percentage of women is very small (roughly 18% in college) (2) and even smaller at advanced levels of training, the attrition problem is particularly intractable. Because newcomers who are women will almost always be a solo (one of a kind) or a token (one of a few) upon entry into engineering majors, they are at risk for isolation and eventual attrition from the major, which reinforces the original problem of small numbers. Our solution was to investigate whether creating "microenvironments" (small groups) with more women will allow these women to deflect masculine stereotypes and increase their confidence, participation, and career aspirations in engineering, and if such an intervention is especially important for beginners. To that end, we compared young women's experiences in small engineering groups when their teammates were mostly female peers (75% women) or an equal proportion of female and male peers (50% women) or mostly male peers (25% women) to test which of these groups have the most beneficial outcome. We predicted that groups with female majorities would be significantly more beneficial for women than groups with female minorities; for sex parity groups we posed competing predictions. Second, we predicted that group sex composition would be particularly important to first-year women because they are more likely to be vulnerable to self-doubt in a male-dominated field during their transition to college. Third, we tested if engineering groups with a female majority or sex parity would act as a "social vaccine" and protect women's confidence and career aspirations despite the activation of stereotypes signaling that engineering is a masculine field. Given that prototypical engineering environments are heavily male-dominated, we did not expect the brief experience of working in female-majority or sex-parity groups to reduce engineering stereotypes. Instead we predicted that groups with more women would prevent that stereotype from impinging on women's self-concept.

Our data revealed that group composition has important psychological and behavioral effects on women in engineering. Women's experiences were more positive in groups with a female majority compared with groups with a female minority. Women felt less threatened and more positively challenged in female-majority groups, especially in their first year of college. Advanced students' feelings of threat did not vary as a function



**Fig. 3.** Effect of group sex composition on women's verbal participation during group work. Verbal participation includes generating solutions to the engineering problems, confidence in those solutions, task interest, and so forth, as rated by teammates who were trained research assistants. Error bars are  $\pm 1$  SE.



**Fig. 4.** Implicit sex stereotypes about engineering predict less self-confidence in one's engineering performance for women assigned to female-minority groups but not for those assigned to female-majority or sex-parity groups. On the x axis, low implicit stereotypes are 1 SD below the mean and high implicit stereotypes are 1 SD above the mean.

of group composition. However, both advanced and first-year students' willingness to speak up was significantly influenced by who was in the room. Women were more likely to speak up in group problem-solving if assigned to female-majority groups compared with female-minority groups. Because learning and understanding is enhanced when students engage in verbal discussion with peers (39), verbal participation in group problem-solving is likely to be the precursor of greater mastery of engineering concepts. Moreover, when assigned to female-majority groups, women were able to deflect stereotypes and not internalize them; they expressed high confidence and ambitious career aspirations despite activation of masculine engineering stereotypes. In contrast, women in female-minority groups expressed lower confidence and career aspirations in engineering when masculine engineering stereotypes were mentally activated. Finally, women's experience in sex-parity groups was mixed. On the positive side, they felt less threatened and more positively challenged in sex-parity groups than female-minority groups, especially as first-years. Moreover, sex-parity groups allowed women to deflect engineering stereotypes and protect their confidence and career aspirations. However, on the negative side, women spoke far less during the group activity when assigned to sex-parity groups compared with female-majority groups. This was true regardless of whether they were beginners or advanced students.

Two important take-home points emerge from these findings. First, the results suggest that in fields with very few women and strong masculine stereotypes further attrition of women can be prevented by creating microenvironments (e.g., in-class teams or study groups) with a majority of female students or equal numbers of women and men. These microenvironments provide a way of breaking out of a self-perpetuating cycle of attrition and sex imbalance by allowing women to focus on learning and mastery without the distraction of sex stereotypes. These microenvironments also encourage women's active participation in teamwork and preserve their confidence and career aspirations in engineering despite masculine stereotypes of the field. Second, these findings point to the importance of early interventions during the first year of college when students are most vulnerable to losing confidence and dropping out of STEM fields.

The influence of sex composition may depend on group size. This is an avenue for future research. As groups get larger women may feel especially alienated when same-sex others are 15% or less of the group because opportunities to interact with and form alliances with other women are rare, and sex distinctiveness high (28). These groups may feel as aversive as other groups in which women are solos. However, when group size is smaller, the same-sex composition may feel somewhat less alienating (for indirect evidence, see ref. 29). Moreover, female-minority groups with a "critical mass" (30% women) may

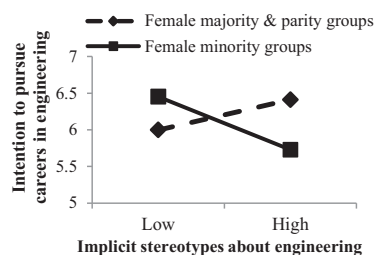
feel less alienating than groups with 15% women or a solo woman (28).

In conclusion, consistent with the stereotype inoculation model, our findings show that sex composition of working groups has a significant impact on women's situational appraisals and behavior. The presence of female peers act as "social vaccines" to decrease women's feelings of threat, decrease the feeling of being under a spotlight, and increase their comfort speaking up. Responses that are more distal from the immediate situation (confidence and career aspirations) are compromised only for the subset of women who hold masculine stereotypes about engineering and who find themselves in a situation where they are a minority. These women feel less confident and less interested in pursuing engineering careers after working in female-minority groups, but are able to hold on to their confidence and career aspirations after working in sex-parity and female-majority groups.

## Materials and Methods

**Participants.** Female undergraduate students ( $n = 122$ ) majoring in engineering at a large public university participated in this study in exchange for \$20. Participants provided written informed consent approved by the Institutional Review Board at the University of Massachusetts. Only 15% of engineering students at this university are female. Two participants were excluded, one for using a cell phone during the study and another for being more than 2 SDs above the mean on multiple measures. Of the remaining 120 participants, first-year students comprised 55% of the sample ( $n = 66$ ), sophomores were 30% ( $n = 36$ ), juniors were 10% ( $n = 12$ ), seniors were 5% ( $n = 5$ ), and one person did not report her year in college. In terms of race, 75% were White ( $n = 90$ ), 15% were Asian ( $n = 18$ ), 6% were Black ( $n = 7$ ), 3% indicated "other ethnicity" ( $n = 3$ ), 0.8% were Hispanic ( $n = 1$ ), and 0.8% did not answer the question ( $n = 1$ ).

**Procedure.** Female participants arrived expecting to participate in a study on group problem-solving in engineering. They were randomly assigned to one of three types of groups varying in sex composition: (i) female minority group, where the participant was the only woman working with three men ( $n = 36$ ); (ii) sex parity group, where the female participant worked with one woman and two men ( $n = 41$ ); or (iii) female majority group, where the female participant worked with two women and one man ( $n = 43$ ). In each group, one female student was the real participant; three other group members were RAs who had been trained to behave in a consistent manner during the problem-solving task. Participants were unaware that their teammates were RAs. RAs were unaware that group sex composition was the experimental manipulation; they believed variations in group composition were a natural part of scheduling. After participants got acquainted with their teammates, but before they started the group task, they were taken to private cubicles where they worked on the engineering problems alone, after which we assessed how threatened or positively challenged they felt in anticipation of the group task using reliable self-report measures (35, 36, 37, 40). Participants then worked with their teammates on the engineering problems for 15 min. All RAs in the group evaluated participants' behavior in terms of how helpful her input was to solving the problems, how motivated, confident, interested, and comfortable she was during group



**Fig. 5.** Implicit sex stereotypes about engineering predict less interest in pursuing engineering careers for women assigned to female-minority groups but not for those assigned to female-majority or sex-parity groups. On the x axis, low implicit stereotypes are 1 SD below the mean and high implicit stereotypes are 1 SD above the mean.

work. Following the group task, participants returned to private cubicles and completed measures assessing self-confidence in their engineering performance, career aspirations, how salient their sex felt in the group, and demographics. Half the participants also completed measures assessing sex stereotypes about engineering, attitudes toward and identification with engineering using implicit and explicit measures. The remaining half of the participants completed these measures before the group problem-solving

task. Finally, all participants were probed for suspicion (none expressed any), debriefed, and paid for their participation. Details of all measures are provided in [Supporting Information](#).

**ACKNOWLEDGMENTS.** This research was supported by National Science Foundation Grant GSE 1132651 (to N.D.) and National Science Foundation CAREER BCS 0547967 (to N.D.).

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# Supporting Information

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## SI Materials and Methods

**Engineering Problems.** Two engineering problems were written by a doctoral student in engineering who had been a teaching assistant for many undergraduate classes. These questions were different from standard test questions used in undergraduate classes so that participants had to think creatively to solve them. The same problems were used for all participants regardless of their year in college to keep the group task standardized across all treatment conditions. Because the test problems were not closely tied to course content in engineering we ensured that advanced students in college would not necessarily have an advantage over first-years. Participants' individual performance on the problems (before the group task) was graded by the engineering doctoral student as a measure of objective ability. Ten points were allocated to each question. As expected, individual performance was uncorrelated with participants' seniority in college ( $r = -0.13$ ,  $P = 0.15$ ).

**Threat and Challenge.** Before group work (but after briefly working on the problems alone) participants were asked to indicate their feelings about the upcoming group task on four items that measured appraisals of threat and challenge adapted from prior research (1–4). Perceived threat was assessed by the statements “I feel unsure about the upcoming group task” and “I feel stressed about the upcoming group task” ( $r = 0.59$ ,  $P < 0.001$ ). Perceived challenge was assessed by the statements “I have what it takes to handle the upcoming group task” and “I feel confident about the upcoming group task” ( $r = 0.68$ ,  $P < 0.001$ ). Participants indicated the degree to which these statements described how they felt at that moment on seven-point scales anchored by 1 (not at all true) and 7 (very true). Question order was randomized for all participants.

**Behavior in Groups.** The three RAs in each group independently evaluated the participant's behavior in the group using five items: (i) how motivated was the participant during group problem-solving; (ii) how helpful was her input to the group problem-solving; (iii) how confident was she about the solutions she offered; (iv) how interested was she in the group task; and (v) how comfortable was she working with the group. Ratings were done on seven-point scales ranging from 1 (not at all) to 7 (very much so).

**Sex Salience.** Immediately following the group task, participants were asked to indicate the degree to which the group activity made their sex uncomfortably salient using a single item: “I thought I was being seen as a woman rather than as a unique individual by my teammates” (3). Participants responded on a scale from 1 (not at all) to 7 (very much).

**Confidence in Engineering.** Participants indicated their confidence in engineering using a single item: “In general, how confident do you feel about your engineering performance?” (5). Participants responded on a seven-point scale ranging from 1 (not at all confident) to 7 (very confident).

**Career Aspirations in Engineering.** After the group task we also assessed participants' career aspirations by asking: “How likely are you to pursue a professional job in engineering?” (5). Participants answered on a scale from 1 (not at all likely) to 7 (very likely).

**Implicit Stereotypes About Engineering.** An Implicit Association Test (IAT) was used to measure how strongly participants associate engineering compared with English with masculine vs. feminine concepts by assessing how quickly sex “popped into mind” when people thought of each discipline. The IAT uses

participants' reaction time as an unobtrusive measure of stereotypes in the mind (5). One feature of the IAT is that preference for one discipline (e.g., engineering) is assessed in relation to a second discipline (e.g., English). Participants saw four types of words flash rapidly on a computer screen; words related to: (i) engineering (e.g., equation, computation), (ii) English (e.g., literature, poetry), (iii) masculine pronouns (e.g., he, him), and (iv) feminine pronouns (e.g., she, her). Participants classified each word as quickly as possible using one of two response keys according to instructions presented onscreen. For some blocks they were instructed to use the same key to classify engineering and feminine words and a different key to classify English and masculine words (abbreviated as engineering + feminine, English + masculine). In other blocks response key assignment was reversed: this time they were asked to use the same key to respond to engineering and masculine words and a different key to respond to English and feminine words (i.e., engineering + masculine, English + feminine). The order in which these two blocks were completed was counterbalanced between participants. If participants implicitly stereotype engineering as masculine, they ought to be faster at grouping together engineering + masculine and English + feminine and comparatively slower at grouping engineering + feminine and English + masculine. However, if they have no sex stereotypes about disciplines they should be equally fast at both blocks. The difference in participants' response latency for each type of block converted into effect size was a measure of implicit stereotypes of engineering. Participants completed a total of seven blocks of trials in the IAT of which three were practice blocks and four were data-collection blocks.

**Explicit Stereotypes of Engineering.** Participants also completed two items assessing their explicit sex stereotypes about engineering (5). They were asked to indicate on a seven-point scale whether they thought of “mostly men” (anchored at 1), “equal numbers of men and women” (anchored at 4), or “mostly women” (anchored at 7) when they thought of people who are very good at engineering and people who have careers in engineering. These items were combined into a single index because they correlated well ( $r = 0.47$ ,  $P < 0.001$ ).

**Implicit Attitudes Toward Engineering.** A second IAT assessed participants' implicit attitudes toward engineering compared with English by measuring how quickly they associated engineering compared with English with good vs. bad concepts (5). Participants saw four types of words flash rapidly on a computer screen: (i) engineering (e.g., computation), (ii) English (e.g., literature), (iii) good concepts (e.g., love), and (iv) bad concepts (e.g., hate). The basic procedure of this IAT was identical to the one above. If participants implicitly prefer engineering more than English they ought to be faster at grouping together engineering + good and English + bad, and slower at grouping engineering + bad and English + good. However, if they prefer English more than engineering they ought to be faster at the opposite groupings.

Explicit attitudes toward engineering were measured using seven-point scales anchored by dislike-like, hate-love, boring-fun, and bad-good (5). Ratings on the four items were combined into a single index ( $\alpha = 0.90$ ).

**Implicit Identification with Engineering.** A third IAT assessed participants' implicit identification with engineering vs. English by assessing how quickly they associated engineering compared with English with first person pronouns (e.g., I, me) vs. third person pronouns (e.g., they, them) (5). The four types of stimuli used in

this IAT were: (i) first-person pronouns, (ii) third-person pronouns, (iii) words related to engineering, and (iv) words related to English. The basic procedure of this IAT was identical to the one above. If participants implicitly identify more strongly with engineering than English, they ought to be faster at grouping together engineering + me and English + they than vice versa.

Explicit identification with engineering was measured with three items: How important is engineering to you? How useful is engineering to you? How much do you care about doing well in engineering? Participants responded on seven-point scales anchored by “not at all” to “very much” ( $\alpha = 0.83$ ) (5).

**Procedure.** Participants were randomly assigned to one of three types of groups that varied in sex composition: (i) a female-minority group, where the participant was the only woman with three men ( $n = 36$ ); (ii) a sex-parity group, where the participant was one of two women with two men ( $n = 41$ ); or (iii) a female-majority group, where the participant was one of three women with one man ( $n = 43$ ). Five participants were run in three-person groups because of scheduling difficulty, but in all these cases the ratio of male-to-female teammates was always maintained to be either female-minority groups or female-majority groups. We analyzed the data with and without these five participants and the results did not change. In every group, all members except for one female student were RAs who had been trained to behave in a consistent manner and give scripted answers during the problem-solving task; thus RAs’ behavior was held constant across groups. RAs were trained to minimize their speaking time to allow the real participant plenty of opportunity to speak. Real participants were unaware that their teammates were RAs. RAs were unaware that group sex composition was the primary experimental manipulation; they believed variations in group composition occurred as a natural part of scheduling.

Upon arrival to the laboratory, participants were greeted by a male experimenter who introduced them to their teammates, who were three RAs pretending to be fellow participants in the study. Two participants were run by a female experimenter because of experimenter illness. In all cases, the experimenter introduced the study describing it as a study on group problem-solving. Participants were told that they would be asked to work on the group task together but would also complete a number of questionnaires and computerized tasks about engineering individually in private cubicles. Participants were allowed some time to get acquainted with their teammates; after this they were separated into individual cubicles for the initial measures. In the individual cubicles, all participants were given a brief opportunity to work on the engineering problems alone, that they would later tackle as a group, so that participants could get a sense of the difficulty of the problems. Next, we assessed participants’ feelings of threat and challenge as they anticipated the upcoming group activity. Half the participants also completed measures assessing sex stereotypes about engineering, their attitudes toward engineering, and identification with the field using implicit and explicit measures. The remaining half of the participants completed these three measures after the group activity. All participants then returned to their teammates and worked on the two problems as a group for 15 min. At the conclusion of the group activity, participants returned to their individual cubicles and completed measures that assessed perceived sex salience, self-confidence in engineering, career aspirations, and demographic questions. Finally, all participants were probed for suspicion (none expressed any), fully debriefed, thanked, and paid for their participation.

## SI Results

**Behavior During Group Task.** Because RAs’ ratings on each item were highly correlated ( $r_s = 0.57$ – $0.70$ ,  $P_s < 0.0001$ ), item ratings were averaged across RAs. Averaged ratings for all five items cohered nicely (Cronbach’s  $\alpha = 0.97$ ) and were collapsed into

one composite index capturing participants’ behavior in the group. We tested the validity of RAs’ behavioral ratings by examining whether RAs’ observations correlated with participants’ objective performance on the same engineering problems when they worked them alone before the group task, and their self-perceptions of threat, challenge, and sex distinctiveness. Correlations showed that participants who performed well when working alone were subsequently more likely to speak up in their groups when discussing solutions to these problems as rated by RAs ( $r = 0.43$ ,  $P = 0.000002$ ). Participants who reported feeling more positively challenged and less threatened before the group task were significantly more likely to speak up in their groups while discussing solutions to these problems ( $r = 0.26$ ,  $P = 0.006$ , and  $r = -0.20$ ,  $P = 0.03$  respectively). Finally, participants who reported feeling sex distinctive in an aversive way were significantly less likely to speak up in their groups when working on the engineering problems ( $r = -0.17$ ,  $P = 0.07$ ). Taken together, these correlations provide converging evidence supporting the validity of behavioral ratings. The findings suggest that behavioral participation as rated by RAs is associated with participants’ knowledge of engineering, their feelings of threat, challenge, and sex distinctiveness.

**Global Appraisals of Engineering.** As reported in the main text, the group composition manipulation had significant effects on women’s situational appraisals in terms of threat and challenge, verbal participation in the group task, perceived sex salience in the group, confidence in their performance, and motivation to pursue engineering careers. However, group composition did not significantly affect global stereotypes of, attitudes toward, and identification with engineering at an implicit or explicit level. The difference between situational appraisals and global appraisals is not surprising; it is logical that short-term experiences in a peer group are more likely to influence participants’ momentary affective and motivational experiences and behaviors than their global assessments of the field. However, if these group composition experiences were repeated over time for an extended period they would probably start to change participants’ global assessments of engineering.

**Implicit and Explicit Stereotypes About Engineering.** Single sample  $t$  tests comparing stereotype scores to zero indicated that women in all three conditions implicitly stereotyped engineering as masculine [ $t(119) = 5.80$ ,  $P < 0.0001$ , mean IAT  $D = 0.19$ ,  $SE = 0.03$ ] and also explicitly stereotyped engineering as masculine [ $t(115) = 35.46$ ,  $P < 0.0001$ ,  $M = 2.95$ ,  $SE = 0.08$ ]. Group Composition did not affect implicit or explicit stereotyping ( $F_s < 1$ ).

**Implicit and Explicit Attitudes Toward Engineering.** Single sample  $t$  tests comparing attitude scores to zero indicated that women across the three conditions implicitly liked engineering more than English [ $t(119) = 2.27$ ,  $P = 0.025$ , mean IAT  $D = 0.10$ ,  $SE = 0.04$ ] and also explicitly liked engineering [ $t(115) = 55.25$ ,  $P < 0.0001$ , mean = 5.59,  $SE = 0.10$ ]. Group Composition did not significantly affect the magnitude of implicit or explicit attitudes ( $F_s < 1$ ).

**Implicit and Explicit Identification with Engineering.** Single sample  $t$  tests indicated that women across three conditions implicitly identified with engineering over English [ $t(119) = 5.74$ ,  $P < 0.0001$ , mean IAT  $D = 0.20$ ,  $SE = 0.03$ ] and also explicitly identified with engineering [ $t(115) = 66.93$ ,  $P < 0.0001$ , mean = 6.13,  $SE = 0.09$ ]. As before, Group Composition did not significantly affect the magnitude of implicit identification ( $F < 1$ ) or explicit identification with engineering,  $F(2, 113) = 1.09$ ,  $P = 0.34$ . Thus, a short-term experience in a peer group of varying sex compositions did not affect women’s global attitudes, stereotypes, or identification with engineering. However, it did affect their affective and motivational experiences in the situation and well as their spoken behavior in an achievement-oriented environment.



1. Jamieson JP, Mendes WB, Blackstock E, Schmader T (2010) Turning the knots in your stomach into bows: Reappraising arousal improves performance on the GRE. *J Exp Soc Psychol* 46(1):208–212.
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## Other Supporting Information Files

[Dataset S1 \(XLSX\)](#)

[Dataset S2 \(XLSX\)](#)