

**Changing Social Contexts to Foster Equity in College STEM Courses:
An Ecological Belonging Intervention**

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Abstract

Diverse classrooms often have stereotypes “in the air,” which can interfere with learning and performance among stigmatized students. Two experiments designed to foster equity in college STEM classrooms (N=1822) tested an intervention to establish social norms that make stereotypes irrelevant in the classroom. At the beginning of the term, classrooms assigned to an ecological belonging intervention engaged in discussion with peers around the message that social and academic adversity is normative and that students generally overcome such adversity. Compared to business-as-usual controls, intervention students had higher attendance, course grades, and one-year college persistence. The intervention was especially impactful among historically underperforming students, as it improved course grades for ethnic minorities in Introductory Biology and for women in Introductory Physics. Regardless of demographics, attendance in the intervention classroom predicted higher cumulative GPA 2-4 years later. The results illustrate the viability of an ecological approach to fostering equity and unlocking student potential.

Changing Classroom Contexts to Foster Equity and Unlock Student Potential: An Ecological Belonging Intervention

In collaborative settings, demographic diversity can be a means to harness multiple perspectives to maximize human potential (e.g., Page, 2008). However, in practice this is often not the case. Several large meta-analyses and reviews of the literature indicate that demographic diversity does not generally improve performance in organizational and educational collaborations (e.g., Eagly, 2016; Williams & O'Reilly, 1998; Van Dijk, Van Engen, & Van Knippenberg, 2012). In fact, when group-based stereotypes are “in the air” (Steele, 1997), diverse contexts are sometimes harmful to performance, particularly for people who are subject to negative stereotypes in those contexts. For example, women engineering students who were assigned to a majority-male workgroup participated less, were more anxious, and, if they held masculine stereotypes about engineering, had lower career aspirations following the interaction (Dasgupta, Scircle, & Hunsinger, 2015).

In the present research, we argue that problems with diversity are not simply psychological, but also ecological. Stereotypes gain power from their intersubjectivity: people know about stereotypes, and they know that other people know about stereotypes (Steele, 1997). This has consequences for all involved. For targets of negative stereotypes, the fear of being stereotyped by others taxes working memory and interferes with the learning of new material (Rydell, Shiffrin, Boucher, Van Loo, & Rydell, 2010; Taylor & Walton, 2011). For students who are not subject to negative academic stereotypes (e.g., Whites, men in engineering), knowledge of stereotypes can create anxiety and discomfort when working with stigmatized others (Shelton, 2003), which can harm their own cognitive performance (Blascovich, Mendes, Hunter, Lickel, &

Kowai-Bell, 2001), increase discrimination (Goff, Steele, & Davies, 2008), and reduce their desire for future interactions (West, Koslov, Page-Gould, Major, & Mendes, 2017).

The present research tests an intervention designed to help realize the promise of diversity. Our goal was to change the social norms of contexts where competence stereotypes are salient. When it is widely known or suspected that certain groups underperform, stereotypes help construct the meaning that students make when poor performance does occur (“maybe this unexpectedly poor grade is evidence that people like me/them do not belong here”; Walton & Wilson, 2018). By providing students an alternative narrative – one that holds adversity as both normative and surmountable – we aimed to render stereotypes unnecessary for understanding why underperformance occurs. We do so by taking methods from previous social belonging interventions – interventions that have successfully reduced college attainment gaps (Walton & Cohen, 2007; 2011; Yeager et al., 2016) – and applying them at the ecological (classroom) level.

Whereas previous work has sought to change the experience of individual students with individualized intervention activities (e.g., by delivering the intervention in lab settings or over the internet; e.g., Dasgupta, 2011; Walton & Cohen, 2007; 2011; Yeager et al., 2016; 2019), we targeted the intersubjective space that students and teachers share. We sought to collectively teach students a norm that adversity – both their own adversity and adversity among their peers – is not due to internal and fixed causes (e.g., “Some people just aren’t smart enough”) but rather to universal and temporary causes (“Everyone struggles sometimes, but you can improve by persisting”; Walton & Cohen, 2007). By establishing these beliefs as shared social norms, we sought to create scaffolding to support and reinforce the intervention message over the semester.

Two experiments employed a brief, evidence-based intervention strategy. While incorporating elements of previous social belonging interventions, such as reflective writing and

exposure to testimonials from older students (e.g., Yeager et al., 2016), the intervention also engaged students in a classroom discussion with their peers who they would work with over the ensuing semester. The discussion leveraged maxims of communication (Grice, 1975) in an effort to establish the intervention message as “common ground” (Clark & Brennan, 1991). It sought to use communications with peers as a form of social proof (Cialdini, 2001) of the intervention message that would help normalize adversity and pop a bubble of pluralistic ignorance (Miller & McFarland, 1987), wherein students see their own challenges and adversity as unique when in fact adversity itself is quite common (Walton & Cohen, 2007). As students then collaborated to solve difficult problems over the semester, we wanted them to adopt the intervention message and, to address stereotypes in the air, to know that their peers had done so, too.

Below we report the results of interventions conducted in two college STEM gateway courses. We proceed in three steps. First, using three-years of prior historical data for the courses under study, we sought to determine which groups tended to underperform in each course. Second, using this information, we designed and tested whether an ecological belonging intervention tailored for each course context could attenuate underperformance and thereby foster greater equity in academic outcomes. Finally, we conducted a series of exploratory analyses to understand how the intervention may have affected student outcomes. These analyses revolved around the possibility that establishing a classroom climate where adversity is normal and likely to be overcome may 1) increase student engagement (e.g., higher attendance) and 2) allow students to take greater advantage of learning opportunities that are presented to them (e.g., collaborative learning).

Pre-Study: Understanding Course Contexts

We assume that contextual norms shape the relevance and outcomes of stereotypes in the classroom. That is, stereotypes can be made relevant or irrelevant by the norms of the social context. Negative stereotypes against women, for example, appear to depress women's performance and participation in some learning contexts (e.g., physics and engineering) more so than in others (e.g., biological sciences; Cheryan et al., 2017; Leslie, Cimpian, Meyer, & Freeland, 2015). This suggests that relevance and applicability of academic stereotypes vary across STEM classrooms.

Indeed, historical analyses of the university under study—a large, public research university in the mid-Atlantic region of the United States—found that performance gaps varied across courses. Analyses examined course grades in Foundations of Biology and Basic Physics for Engineers—both of which were first-year level STEM gateway courses. After controlling for prior SAT/ACT scores and high school GPA, analyses of the three most recent years of historical data (reported in Table 1) found that Biology classrooms were associated with an emergent ethnicity grade gap ($B=.13, p<.001, d=.11$), as White students got higher course grades than non-White students controlling for high school preparation. However, there was no gender gap in Biology ($B=.01, p=.821, d<.01$). By contrast, the same analysis in Physics showed both gender and ethnicity gaps, in which men and White students outperformed women and ethnic minority students ($Bs = .12$ and $.13, ps<.006, ds=.12$ and $.13$, for gender and race [White vs. non-White], respectively). Notably, in Biology, students of Asian descent tended to underperform relative to White students ($B= -.13, p=.003, d=.13$). However, this was not the case in Physics, as there was no difference in average Physics course grades between Asians and Whites ($B= -.02, p=.713, d=-.01$).

Table 1. Regression model output for historical analyses of three previous years of data. Panels I and II depict the estimates using ethnicity as a dichotomous variable (0=Non-White; 1=White). Panels III and IV depict the dummy-coded estimates for each of the three main ethnic minority groups with Whites as the reference group. The pattern of results indicates that gender gaps emerged in Physics but not in Biology. Conversely, a race gap between Asian and White students emerged in Biology but not Physics.

	I. Basic Physics for Eng. (N=2389)			II. Introductory Biology (N=4393)		
	B	SE	<i>p</i>	B	SE	<i>p</i>
Semester Code 1	-.09	(.04)	.025	-.32	(.04)	.001
Semester Code 2	-.09	(.04)	.022	.00	(.04)	.931
SAT Verbal	-.04	(.03)	.136	.08	(.02)	<.001
SAT Math	.44	(.03)	<.001	.14	(.02)	<.001
HS GPA	.61	(.04)	<.001	.23	(.04)	<.001
Male	.12	(.04)	<.001	.01	(.04)	.821
White	.13	(.05)	.005	.13	(.04)	<.001
	III. Basic Physics for Eng. (N=2389)			IV. Introductory Biology (N=4393)		
	B	SE	<i>p</i>	B	SE	<i>p</i>
Semester Code 1	-.09	(.04)	.026	-.32	(.04)	<.001
Semester Code 2	-.09	(.04)	.027	.00	(.04)	.924
SAT Verbal	-.04	(.03)	.184	.08	(.02)	<.001
SAT Math	.42	(.03)	<.001	.14	(.02)	<.001
HS GPA	.61	(.04)	<.001	.24	(.04)	<.001
Male	.13	(.04)	<.001	.01	(.04)	.825
Asian	-.02	(.05)	.713	-.13	(.04)	.003
Black	-.22	(.07)	.002	-.09	(.06)	.131
Latino/a	-.17	(.10)	.098	-.04	(.09)	.684

These analyses showed how patterns of underperformance varied across two STEM courses in ways that were consistent with research on inequity and stereotypes in the broader college culture in the US (e.g., Cheryan et al., 2017). As such, we tailored the intervention and analytical approach based on these findings. Namely, whereas the intervention materials and

analyses focused solely on ethnicity in Biology (Study 1), they focused primarily on gender (and secondarily on ethnicity) in Physics (Study 2).

Study 1

Method

Participants. Study 1 was facilitated by one instructor in the same course, Foundations of Biology, over four consecutive semesters with approximately 300 students each semester. The instructor taught the lecture and associated weekly discussion sections (also called “recitation sections”), in which the lecture course was divided into four sections of approximately 75 students each. Each semester, the research team randomly picked two sections to receive the intervention and two to receive business-as-usual control activities. We closed the study when, after four semesters, analyses found the intervention was consistently effective and that a control condition was no longer ethically justifiable. Overall, 608 students from eight discussion sections were assigned to the ecological belonging intervention (177 non-White; 431 White) and 607 students from eight contemporaneous discussion sections received business-as-usual control activities (171 non-White; 436 White). The full sample was 69% White, 21% Asian/Asian American, 7% Black/African American, and 4% Latinx American. The sample was 66% women.

Data Sources and Missing Data. Data for both studies were obtained from instructor grade books that gave a comprehensive list of students enrolled at the beginning of the course, their attendance in discussion section, exam performance, and their course grade. Students completed an end-of-year survey in exchange for course credit (Study 1 only). Finally, individual cases were anonymized and linked to the registrar’s student data warehouse by a campus representative who was not associated with the study. This allowed us to obtain students’ high school preparation records (high school GPA and standardized test scores) as well as their

college enrollment records and cumulative GPA while safeguarding the confidentiality of students' records. The analyses used an intention-to-treat approach (Hollis & Campbell, 1999), meaning that if a student dropped the class either formally or informally after the intervention, whatever data that had been recorded up to that point were included in the analyses. All inferential tests were based on maximum likelihood estimation, which is a full information approach that utilizes all available data.

Timing and Random Assignment. The intervention was delivered during the first week of classes for the semester. Checks on random assignment revealed no main or interactive effects of condition assignment on average levels of high school academic preparation across classrooms (i.e., standardized test scores and high school GPA; see SOM).

Control Condition

During the week of the intervention, the business-as-usual condition used “ice-breaker” activities to help students form social bonds with their peers. Notably, evidence suggests that even superficial similarities with others can exert reliable effects on people’s emotional and cognitive connection with those others (Brannon & Walton, 2013; Cwir, Carr, Walton, & Spencer, 2011). However, the business-as-usual activities lacked the intervention content that sought to foster an intersubjective understanding of the nature of belonging and adversity. Students formed groups of four based on a superficial similarity (e.g., liking the same quote on the wall), created a Biology-related team name together (e.g., “The Heterozy-goats”), drew a picture of their team’s mascot, and presented their mascot to the class.

Intervention Condition

The intervention condition differed from the business-as-usual control in that it sought to change students’ collective understanding of the nature of belonging, competence, and adversity

in college. It did so through a carefully constructed series of activities involving a reflective writing exercise, exposure to student testimonials, and a semi-structured group discussion. After forming groups of four as they did in control classrooms, the instructor introduced and expressed the core intervention message that adversity early in college is quite common and can be overcome with persistence. Students then completed a reflective writing exercise on the challenges they had encountered so far in the transition college (essays were anonymous to avoid making them evaluative; cf. Walton & Cohen, 2007). Next, students were exposed to three written stories attributed to older students. Adapted from prior research (Yeager et al., 2016), the stories were told in the first person and consistently involved a narrative in which students experienced initial adversity (e.g., getting a poor grade or having a hard time making friends), eventually began to turn things around (e.g., by finding a core group of friends to study with), and are now happy and successful. Since this study was focused on the ethnicity performance gap, the stories were attributed to students from different ethnic groups to help convey the universality of struggling across the spectrum of competence stereotypes. Thus, one quote was arbitrarily attributed to an African American student (i.e., “African American, [University name] Senior”), one to an Asian American student, and one to a White American student.

Having now reflected on their own experiences and having learned about the normalcy of adversity from the stories, students engaged in a structured group discussion to help solidify the new norms in the same group setting students they would work throughout the term. Because students knew their peers had received the instructions and testimonials together, we assumed they would proceed in their discussion with the intervention message being “given” in the background (Clark & Brennan, 1991), and that students’ conversations would use this shared information as a jumping-off point for sharing their own narratives (cf. Binning & Sherman,

2011; Schwarz, 2014). Groups were asked to discuss a) why people often do not realize that so many students struggle with the transition college and b) how their lives may be different when they are juniors and seniors. Whereas the first prompt tacitly assumed that adversity is both common and often hidden beneath the surface, the second prompt assumed that students will progress through college and change along the way. By assuming this knowledge in the premise of the discussion questions, we expected participants' answers to adopt the premises in order to cooperatively answer the question (Grice, 1975), and observations of the research team supported this assumption. After several minutes of discussion, the instructor reinforced the activity by asking volunteers to share with the full class what their group had discussed.

Group Diversity

Across the four semesters, students formed 302 (149 treatment; 153 control) 3-5 person groups (*Average group size*=4.03, *SD*=0.52). To measure group diversity, groups were assigned a score reflecting the proportion of their group who were non-White ($M=.28$, $SD=.23$). As such, groups at -1 SD on composition were effectively all White (28% of groups were homogeneously White) while groups at +1 SD were effectively half minority (33% had at least two minorities).

Survey Measures

At the end of each semester, students completed a 10-minute online survey in exchange for extra credit (N=1039). The analyses below focused on the measures that were included to assess students' perceptions of their collaborative workgroups. See SOM for additional details.

Perceived group competence. Three questions tapped perceptions of group competence (1=*Strongly disagree*; 5=*Strongly agree*; e.g., "My recitation team was effective at accomplishing its goals"; $M=4.23$, $SD=.70$, $\alpha =.79$)

Perceived group warmth. Perceptions of warmth from the group were assessed as the mean of four items (1=*Strongly disagree*; 5=*Strongly agree*; e.g., “Most members of my recitation team like me”); $M=4.20$, $SD=.65$, $\alpha =.85$).

Results

Analyses with Optimal Design 3.0 (Spybrook et al., 2011) revealed that the obtained design, modeled with two-levels (groups of four students nested within 302 student workgroups), yielded .80 power to detect effects (e.g., Control vs. Belonging) as small as $d=.17$. To further increase the sensitivity of the analyses, we included controls for semester at Level 2 and controls for gender, ethnicity, and high school preparation (SAT math, SAT verbal, and high school GPA) at Level 1. All analyses below used these same control variables.

Intervention Outcomes

Course grades. Following the focus on differences between White and non-White students (including Asians), we first examined the effect of the intervention on course grades as a function of ethnicity. A two-level regression analyses (students at Level 1 nested within their four-person workgroup at Level 2) revealed a main effect of the intervention, indicating that students in the ecological belonging condition had higher overall course grades than students in the control condition ($B=.15$, $p=.021$, $d=.12$). Consistent with expectations, this effect was further moderated by participant ethnicity (i.e., an Ethnicity \times Condition interaction; $B= -.40$, $p=.005$, $r=.08$). As depicted in Figure 1, the intervention effect (Control vs. Belonging) was stronger among non-White ($B=.44$, $p=.001$, $d=.36$) than among White students ($B=.08$, $p=.326$, $d=.07$). Further simple slopes analyses also revealed that in the control condition, there was a performance gap favoring White students ($B=.34$, $p=.001$, $d=.28$), which was eliminated in the intervention condition ($B= -.05$, $p=.623$, $d=.04$).

Analyses of the intervention effect as a function of gender revealed that, as in historical analyses, there was no gender gap in the control condition ($B = -.08$, $p = .601$, $d = .04$). The intervention effect was similarly weak for both genders (Gender \times Condition interaction, $B = .08$, $p = .539$, $r = .02$). As such, the intervention in Biology addressed underperformance where it existed, among ethnic minority students, but it had no effect as a function of gender, where historical analyses showed no performance gap was present. We further parsed course grade into its two main components, exam performance and attendance, to see where the effects were strongest.

Exam performance. The primary component of student grades (85-90% of course grade), average exam performance, showed no main effect of condition ($B = 0.79$, $p = .276$, $d = .06$), but as above, there was a Ethnicity \times Condition interaction ($B = -4.19$, $p = .007$, $r = -.08$). Simple slopes analyses revealed the intervention effect (Control vs. Belonging) was stronger among non-White ($B = 3.47$, $p = .014$, $d = .26$) compared to White students ($B = -.71$, $p = .772$, $d = -.05$). Further simple slopes analyses also revealed that in the control condition, there was a performance gap favoring White students ($B = 3.81$, $p = .001$, $d = .29$), which was eliminated in the intervention condition ($B = -.37$, $p = .775$, $d = -.03$).

Attendance. A minor component of course grade (10%-15%), attendance in the discussion section where the intervention took place was a counted variable with 12 to 13 possible days, depending on the semester. We used the same predictors and approach as above, but we analyzed attendance with a two-level Poisson regression model using a log-link function with the variable exposure assumption. The analysis revealed that students in the ecological belonging condition had slightly higher average attendance than students in the control condition

($B=.02$, $p=.078$, $d=.12$). There was no Ethnicity \times Condition interaction ($B= -.03$, $p=.267$, $r= -.03$).

One-Year Persistence. To assess whether students persisted in college over the year following the intervention, we used the same predictors with a two-level binomial (Bernoulli) model (0=*Not persisting*; 1=*Persisting*). This revealed a main effect of condition on one-year persistence, ($B=.70$, $p<.001$, $h=.22$), indicating students in the ecological belonging condition were more likely to complete their courses (i.e., with a GPA greater than 0.00) in the two semesters following the intervention. There was no Ethnicity \times Condition interaction ($B= -.015$, $p=.716$, $r= -.01$), indicating the effect held regardless of participants' ethnic group.

Cumulative GPA. We obtained from the registrar students' most recent cumulative GPA, which ranged from four years (eight semesters) after the intervention for the first cohort to two and a half years (five semesters) after the intervention for the most recent cohort. However, results found no main effect ($B=.07$, $p=.240$, $r=.07$) nor an Ethnicity \times Condition interaction ($B=-.07$, $p=.303$, $r=-.03$).

Exploring How the Intervention Affected Learning

The weekly discussion sections where the intervention took place were rich with learning opportunities, some of which we were able to measure and explore. Learning opportunities included physically attending the discussion sections where the intervention took place (i.e., greater attendance is associated with improved academic outcomes, e.g., Credé, Roch & Kieszczyńska, 2010), the presence of diversity in collaborative workgroups (e.g., Page, 2008), and working in effective collaborations with peers (e.g., Kyndt et al., 2013). To examine whether intervention students were able to take better advantage of these learning opportunities, we

explored whether each feature was more predictive of students' outcomes in the intervention condition compared to the control condition.

Attendance × Condition. We first explored if attendance in discussion section was differentially predictive of long-term outcomes (retention and cumulative GPA). Analyses found that discussion section attendance was more predictive of students' outcomes in the ecological belonging condition than in the control condition, and these effects were not moderated by participant ethnicity. First, attendance predicted higher one-year retention in the control condition ($B=.45$, $p=.023$, $OR=1.36$), but it was a slightly stronger predictor in ecological belonging condition ($B=.71$, $p<.001$, $OR=1.51$; *Attendance × Condition*: $B=.26$, $p=.100$, $OR=1.26$). Analyses revealed a similar pattern on cumulative GPA (*Attendance × Condition*: $B=.07$, $p=.012$, $r=.07$). This indicated that while attendance predicted cumulative GPA in the control condition ($B=.16$, $p<.001$, $r=.24$), it was a stronger predictor in the ecological belonging condition ($B=.23$, $p<.001$, $r=.27$). Moreover, when we controlled for exam performance, the interaction effect remained ($B=.06$, $p=.025$, $r=.08$; simple slopes: $Bs=.01$ and $.06$; $ps=.603$ and $.004$, for control and belonging, respectively).

Group Diversity × Condition. Despite evidence that group diversity does not generally improve performance (e.g., Eagly, 2016), it has the potential to be beneficial (e.g., Page, 2008). Exploratory analyses on course grades showed that in the intervention condition, the grades of ethnic minority students benefitted from greater group diversity. There was a three-way interaction (*Group Diversity × Condition × Participant Ethnicity*: $B=-1.70$, $p=.021$). For non-White students, there was no effect of diversity on grades in the control condition ($B=-.14$, $p=.735$, $r=-.02$). But in the ecological belonging condition, greater diversity was associated with higher grades ($B=1.00$, $p=.038$, $r=.12$). There was no effect of diversity on grades among White

participants ($B_s = .19$ and $-.38$, $p_s = .501$ and $.155$, $r_s = .04$ and $-.08$, for control and intervention, respectively). There were also no Group Diversity effects (main or interactive) on one-year retention or cumulative GPA.

Analyses of the two survey measures revealed a Group Diversity \times Condition interaction on perceptions of group competence ($B = .50$, $p = .026$, $r = .12$). A breakdown of this interaction showed that in the control condition, the more diverse their four-person group was, the less competent it was seen by its members ($B = -.29$, $p = .073$, $r = .10$). But in the ecological belonging condition, this association was eliminated ($B = .18$, $p = .225$, $r = .07$). Neither factor interacted with participant ethnicity, nor was there a three-way interaction (Group Diversity \times Condition \times Participant Ethnicity: $B = -.68$, $p = .157$, $r = -.04$). A parallel analysis on perceived warmth found no interaction effect (Condition \times Diversity: $B = .26$, $p = .201$, $r = .07$). Thus the diversity benefit to students in the belonging condition held on group competence (but not group warmth), and it held regardless of students' own ethnic group.

Group Effectiveness \times Condition. Finally, a variety of evidence indicates that students benefit from working in effective collaborations (Kyndt et al., 2013). To see if this was more likely to be the case in the belonging condition, we simply used students' survey measure of group competence as a proxy of group effectiveness. There was a Group Competence \times Condition interaction on final course grades ($B = .21$, $p = .019$, $r = .08$). This showed that in the control condition, perceived competence was not associated with class grades ($B = -.05$, $p = .394$). But in the intervention condition, higher competence was associated with higher grades ($B = .16$, $p = .010$). This effect still held ($B = .20$, $p = .024$, $r = .07$), even after controlling for the Ethnicity \times Condition interaction on course grades, and it did not interact with group diversity (Condition \times Group Diversity \times Competence: $B = -.16$, $p = .458$).

Similarly, analyses found a Group Competence \times Condition interaction on cumulative GPA ($B=.07$, $p=.012$, $r=.07$). As seen with course grades, group competence had no effect on long-term GPA in the control condition ($B= -.03$, $p=.317$, $r= -.03$), but it predicted higher cumulative GPA among students who received the ecological belonging intervention ($B=.07$, $p=.022$, $r=.07$). Together, these exploratory analyses were suggestive that the intervention improved students' ability to benefit from learning opportunities in their discussion section.

Study 2

Historical analyses of the last three years of student data revealed that, unlike in Biology, there was a clear gender gap in Basic Physics for Engineers, with men consistently outperforming women. Also unlike Biology, where women comprised a majority of students (66%), women were a minority in Physics (32%), which is consistent with broader societal trends in engineering-focused courses (Cheryan et al., 2017). As such, we sought to customize the intervention to this context. We conducted a focus group with women graduate students in Physics to generate content for the student stories presented in the second phase of the intervention. Please see the SOM for more details and sample scripts of the Physics intervention.

Study 2 was conducted during a single semester, after the conclusion of the Biology study, with the discussion sections for three different instructors (two Asian males and one White male), each of whom had two discussion sections who received the intervention and at least three other discussion sections that did business-as-usual. Rather than the course instructor leading the intervention as in Biology, White women graduate students in Physics visited the intervention sections and delivered the intervention during the second week of classes to sections associated with each instructor (with their remaining sections serving as control conditions). The Physics classrooms featured a smaller classroom environment (20-30 students versus the 70-80 students

in Biology). Unlike in Biology, students' workgroups were not formalized in Physics, and as such we did not obtain data on groups' demographic composition.

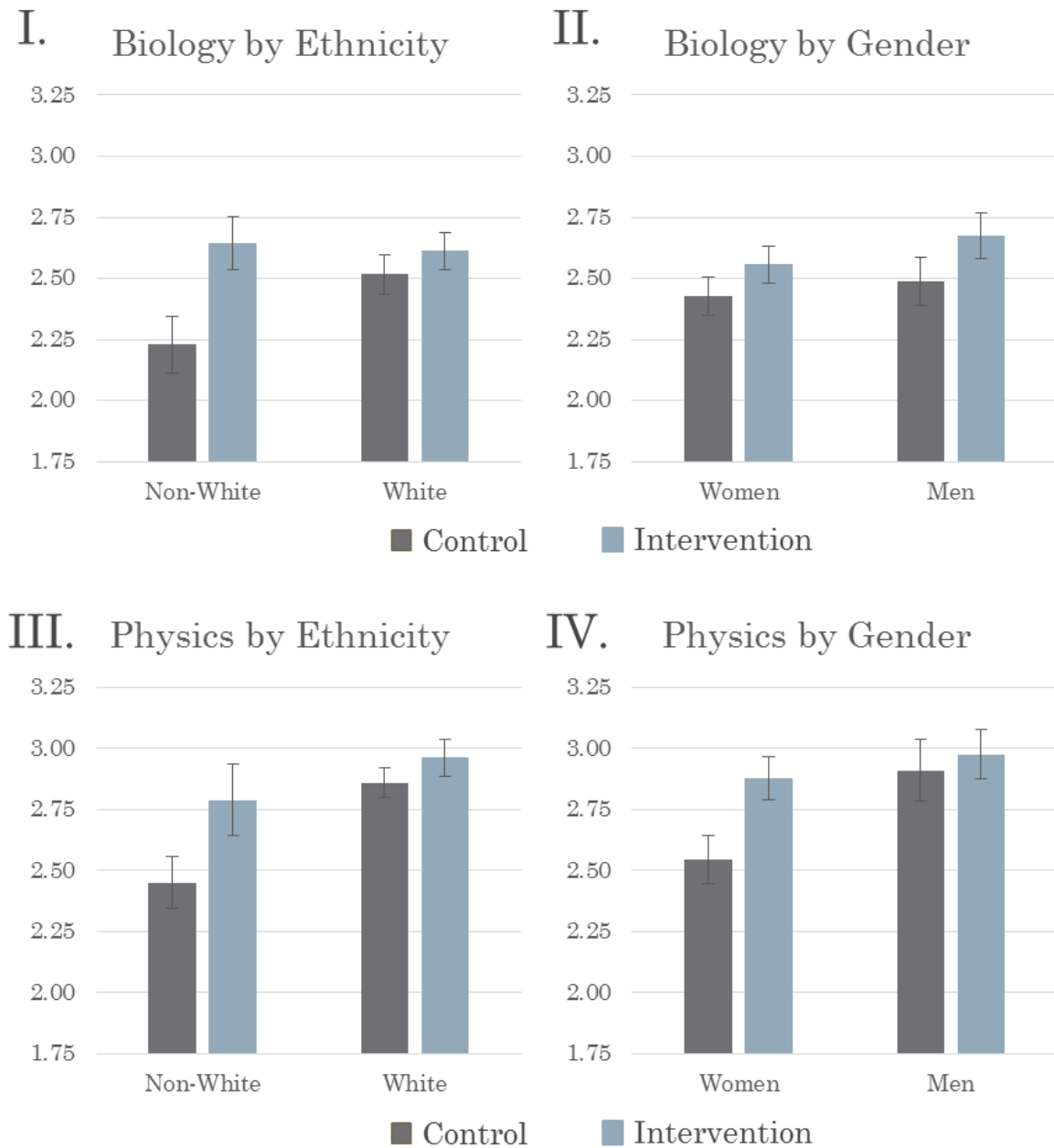
Participants and Design. The Physics sample was 32% women and 82% White, 12% Asian/Asian American, 4% Black/African American and 4% Latinx American. The intervention was delivered to 169 students across six discussion sections (47 women; 122 men), with 438 students from 14 contemporaneous discussion sections serving as controls (149 women; 288 men; 1 unknown).

Analytic Approach. Information on who students worked with during discussion sections was not collected by instructors. Thus we opted not to conduct multi-level modeling due to the small number (six) of sections that received the treatment. As each instructor's lecture course had two treatment and at least three control discussion classrooms, we simply controlled for mean differences across students' instructors using dummy codes. Analyses used a non-parametric bootstrapping regression procedure that was robust to violations of normality assumptions.

Results

Course grades. As in Study 1, analyses revealed a main effect of the intervention, indicating that students in the ecological belonging condition had higher overall course grades than students in the control condition ($B=.16$, $p=.023$, $d=.11$). Consistent with expectations, this effect varied across genders (Gender \times Condition interaction: $B= -.30$, $p=.050$, $r= -.08$). As depicted in Figure 1, the intervention effect (Control vs. Belonging) was stronger among women ($B=.37$, $p=.004$, $d=.43$) compared to men ($B=.07$, $p=.326$, $d=.09$). Further simple slopes analyses also revealed that in the control condition, there was a performance gap favoring men ($B=.37$, $p<.001$, $d=.46$), which was reduced in the intervention condition ($B=.07$, $p=.400$, $d=.08$).

Figure 1. Average course grade on a 4 point scale (0.00=F; 4.00=A or A+) among students assigned to business-as-usual control conditions or intervention conditions within Introductory Biology as a function of both ethnicity (I) and gender (II) and within Basic Physics for Engineers as a function of both ethnicity (III) and gender (IV). Error bars reflect +/-1 standard errors.



Analyses of ethnicity effects revealed the intervention effect did not statistically differ between White ($B=.11, p=.100, d=.13$) and non-White students ($B=.31, p=.173, d=.36$; Ethnicity \times Condition interaction: $B= -.23, p=.191, r=.05$). However, the pattern of results for ethnic minorities was similar to that seen in Biology (Figure 1).

Exam performance. Analyses on students' average exam performance revealed the main effect of condition ($B=.14, p=.142, d=.12$) was stronger among women ($B=.43, p=.017, d=.35$) compared to men ($B=.03, p=.823, d=.02$; Gender \times Condition interaction: $B= -.41, p=.060, r= -.08$). Further simple slopes analyses also revealed that in the control condition, there was a performance gap favoring men ($B=.62, p<.001, d=.50$), which was reduced in the intervention condition ($B=.21, p=.261, d=.17$).

Attendance. Analyses on students' average attendance found a main effect of the intervention, such that students in the ecological belonging condition had higher average attendance than students in the control condition ($B=.65, p=.004, d=.22$). There was no Gender \times Condition interaction ($B= -.71, p=.148, r= -.04$).

One-Year Persistence. Results were consistent with Study 1 in that one-year persistence was higher in the ecological belonging condition than in the control condition ($B=.84, p=.074, h=.16$). There was no Gender \times Condition interaction ($B= -.41, p=.736, r=-.01$).

Attendance \times Condition. As above, we examined the effect of attendance on students' long-term outcomes. First, attendance predicted one-year retention in the control condition ($B=.58, p<.001, OR=1.79$), and in the belonging condition ($B=1.28, p=.037, OR=3.50$). Despite being in the hypothesized direction, these slopes did not differ statistically (Attendance \times Condition: $B=.67, p=.265, OR=1.96$). However, replicating Study 1, analyses on cumulative GPA revealed a Condition \times Attendance interaction ($B=.37, p<.001, r=.15$). This indicated that

attendance was a stronger predictor of cumulative GPA in the ecological belonging condition ($B=.49, p<.001, r=.20$) than in the control condition ($B=.12, p<.001, r=.20$). Moreover, when we controlled for exam performance in the model, the interaction effect was unchanged ($B=.37, p<.001, r=.16$), as attendance predicted GPA in the belonging condition ($B=.38, p<.001, r=.16$) but not in the control condition ($B= -.01, p=.781, r=.01$).

GENERAL DISCUSSION

An ecological belonging intervention fostered equity in two STEM gateway courses by lifting the course performance of previously underperforming students. Specifically, Study 1 found the intervention lifted the performance of ethnic minorities in first-year level Biology, whereas Study 2 found it lifted the performance of women in first-year level Physics. These groups had been found to underperform in recent years compared to majority students, but the intervention statistically eliminated performance gaps. To help understand how these effects unfolded, analyses found the intervention had both psychological and ecological impacts.

Psychologically, the intervention fostered engagement, as evidenced by greater attendance in the discussion section where the intervention occurred and greater one-year college persistence. These findings replicate studies showing that social belonging interventions can enhance college engagement, such as the number of office hours students attend and how often they participate in class (Walton & Cohen, 2007; Yeager et al., 2016). Notably, in the present research the effects on engagement did not differ across demographic groups, meaning the intervention increased engagement even among students who were not previously underperforming.

By ecological effects, we mean that the intervention actually modified or interacted with elements in students' learning environments. Specifically, we found several pieces of evidence

suggesting that the intervention allowed students to take better advantage of the learning opportunities they encountered over time. Our reasoning built on research that threatening social contexts can interfere with effective learning (Rydell & Boucher, 2017; Rydell et al., 2010), but social psychological intervention can lift this interference (Taylor & Walton, 2011). Evidence came from three sets of analyses.

First, Studies 1 and 2 found similar Attendance \times Condition interactions on students' long-term GPA. Here, attendance in the discussion section was the learning opportunity (Credé et al., 2010), and in the attendance in intervention classrooms was especially predictive of students' long-term college GPA. Notably, this finding held independently of students' exam performance in the course. This suggests that the intervention did not just impact *what* students learned in their course (as assessed by exam performance) but, by changing the classroom ecology, it also may have changed *how* students learned, and this change may have endured long after the course ended.

Second, the intervention appeared to activate benefits of diversity in learning contexts (Page, 2008), as only in intervention classrooms did the diversity of students' four-person workgroups predict higher perceived group competence and, among ethnic minorities, higher course grades. Third, being part of an effective workgroup can itself be thought of as learning opportunity (Kyndt et al., 2013). And indeed, only in the intervention classrooms did group competence predict higher course grades and, more distally, students' cumulative college GPA. Together, these findings suggest that the intervention increased engagement, and students' experiences in these more engaged settings positively impacted their academic outcomes. We argue that the ecological belonging intervention may have changed the classroom context in ways that promoted student learning.

Changing the Context of Learning

Stereotype threat and belonging uncertainty can undermine students' ability to take advantage of learning opportunities. In one study, when students were reminded of negative stereotypes about their group during a memorization task, they had poorer memory for the learned items on a subsequent low-threat recall task (Taylor & Walton, 2011). In the present work, historical analyses were consistent with the possibility that stereotypes in the air may have hindered the performance of negatively stereotyped students. These students underperformed, even after controlling for their high school preparation (e.g., HS GPA), suggesting the gaps emerged during the course itself. We reasoned that if these students were underperforming because of stereotypes in the air, then addressing those stereotypes could help students realize their potential (Walton & Spencer, 2009).

The current work adds to research showing how social psychological interventions may mitigate the impact of threat on learning and performance (for reviews see Cohen & Sherman, 2014; Harackiewicz & Pirinksi, 2018; Walton & Yeager, 2019). We showed for the first time how this may be accomplished, not just by targeting students' subjective experience, but by targeting the social ecology to change norms and mindsets about the nature of adversity. By teaching students norms that encouraged them to see their own and their peers' adversity as normative and temporary, the ecological belonging intervention appeared to enhance student engagement and create a context to support and reinforce the intervention message over time. The long-term intervention benefits on GPA – benefits that were not moderated by ethnicity or gender – suggest students actually took the social ecology with them out of the context where the intervention took place.

Future Directions and Limitations

The mechanisms by which more generalized benefits of interventions materialized (e.g., on long-term GPA) are not yet clear, but ecological-level benefits of interventions have been documented in prior research (Powers et al., 2016). This prior work found that when classrooms had a high number African Americans who had benefited from a self-affirmation intervention the previous year, White students got higher grades, too. This suggests that benefits from interventions may be contagious. Moreover, benefits of interventions may persist over time when they are reinforced by others in the social context (Cohen & Sherman, 2014; Yeager et al., 2019). Understanding how intervention effects catalyze, generalize, and persist are pressing topics for additional research.

Echoing Yeager & Walton (2011), we wish to emphasize that the ecological belonging intervention is not a silver bullet for improving equity. Rather, the results prompt the need for research to understand the many factors that moderate the intervention's effectiveness. Above we stressed that different groups underperform in different classrooms, and interventions should be tailored to these different contexts (see Binning & Browman, 2020). In both present studies the intervention facilitators happened to be White women, but facilitators from other genders or ethnicities may change students' experiences with the intervention (Dennehy & Dasgupta, 2017; Marx & Goff, 2010). The numerical and structural distribution of minorities in the setting may also be crucial moderators (Binning & Unzueta, 2013; Walton, Logel, Peach, Spencer, & Zanna, 2015), as may the pre-existing norms in the context (Yeager et al., 2019).

Finally, we note the scope of the present studies. We did not address intersectional identities, nor did we focus on less visible identities, such as those related to sexual orientation, disability, and social class, that could make students question their belonging. By better

understanding how the many identities in classrooms impact performance, it may be possible to engineer diverse social contexts to unlock students' latent potential.

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