

How a Gender Gap in Belonging Contributes to the Gender Gap in Physics Participation

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Abstract. A great deal of research indicates that feeling a secure sense of belonging in academic settings is critical to students' achievement. In the current work, we present data collected over multiple semesters of a calculus-based introductory physics class indicating that women feel a lower sense of belonging than men in physics. This finding is important because our data also indicate that having a strong sense of belonging in physics positively predicts the degree to which all students see the value of physics in their daily life (an outcome that predicts motivation and persistence in achievement settings) as well as performance on exams in the course. We identify one potential antecedent of women's relatively lower sense of belonging in physics, namely, negative cultural stereotypes about women's inferior ability in physics compared to men. We then discuss pedagogical strategies that might be employed to enhance women's sense of belonging in physics.

Keywords: Belonging, Gender, Achievement, Persistence

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INTRODUCTION

It is now well-established that students need to feel a sense of belonging in academic settings in order to feel motivated and achieve [1]. Importantly, not all students feel a secure sense of belonging in science, technology, engineering and mathematics (STEM) disciplines – particularly, women and racial and ethnic minorities, whose groups are in the minority in STEM in general [2,3] and physics in particular [4].

One reason why women and individuals from other minority groups within STEM feel a low sense of belonging therein may be that they experience social identity threat, where individuals feel unwelcomed and alienated in certain situations due to their social identities [5]. One way in which identity threat can be transmitted is through negative stereotypes about one's group's ability (e.g., the belief that women are less capable than men in math and science). In fact, research indicates that awareness of these stereotypes can lead individuals to feel anxious and, in turn, underperform in testing situations [i.e., stereotype threat, 6-8]. Of import, individuals who personally endorse negative cultural stereotypes about their group's ability tend to be particularly susceptible to the pernicious impact of stereotype threat on performance [9].

It stands to reason, then, that individuals who more strongly believe negative stereotypes about their group's ability may feel a lower sense of belonging than individuals who endorse the stereotype to a lesser extent, though this hypothesis has yet to be empirically tested. Indirect evidence for this claim lies in recent

research conducted by Good and colleagues, indicating that women college students enrolled in a calculus class felt a low sense of belonging when they strongly believed that (a) people in their class endorse the negative stereotype about women's math ability and (b) math ability is a natural aptitude that is difficult to change [2]. We build on this work by assessing the degree to which personally endorsing negative stereotypes about women's ability in math and science reduces women's sense of belonging in an introductory calculus-based college physics course.

In the current work, we hypothesized that whereas stronger gender stereotypic beliefs among women would have a more negative impact on their sense of belonging in physics, stereotypic beliefs among men would not influence their sense of belonging. That is, we anticipated that men's sense of belonging would be less malleable than women's because men are the cultural default in terms of "who belongs in physics" and are therefore not subject to the pernicious effect of identity threat on belonging.

For all students, we expected that a stronger sense of belonging in physics would predict higher achievement in their physics course as well as a stronger tendency for students to see the utility value of physics (i.e., the perception that physics is useful and relevant to everyday life). Perceived utility value is important because it predicts motivation and persistence in achievement settings [10,11]. Utility value has, however, received surprisingly little attention in research on academic belonging; its focus in our work represents an important theoretical contribution to the physics education literature. In

sum, the current work synthesizes education research on belonging with social psychological research on social identity threat to develop and test a comprehensive theoretical model of the predictors and outcomes of women’s sense of belonging in physics. In so doing, our aim is to better understand the determinants of women’s (and individuals of other minority groups’) underrepresentation in STEM in general, and physics in particular.

METHOD

2177 students (573 women; 1604 men) who were enrolled in a calculus-based introductory physics course at The University of Colorado Boulder over the course of five academic semesters participated in our research. Students completed a survey during the second week of class that assessed *stereotype endorsement*, *sense of belonging* and *utility value* [see Table 1 for specific items]. We also obtained ACT and SAT scores and their *course grades* at the end of the semester [12].

RESULTS

We first used independent samples *t* tests [13] to assess whether gender differences existed among gender stereotypic beliefs, sense of belonging, utility value, course grade and quantitative ACT/SAT scores. We found that, relative to women, men held stronger gender *stereotype beliefs*, $t(2175) = 10.37, p < .001$

TABLE 1. Survey constructs and their corresponding individual items rated on a scale ranging from (1) *Strongly disagree* to (5) *Strongly agree*.

Survey Construct	Items
Stereotype Endorsement	1. According to my own personal beliefs, I expect men to generally do better in physics than women.
Belonging	1. I feel like I belong in physics. 2. People in physics accept me. 3. I feel like an outsider in physics (reverse scored).
Utility Value	1. I think about the physics I experience in everyday life. 2. I study physics to learn knowledge that will be useful in my life outside of school. 3. Learning physics changes my ideas about how the world works. 4. Reasoning skills used to understand physics can be helpful to me in my everyday life.

[14]; felt a stronger sense of *belonging*, $t(2175) = 8.15, p < .001$; perceived higher *utility value* of physics, $t(2175) = 7.59, p < .001$; obtained a higher *course grade*, $t(2175) = 5.79, p < .001$ [15]; and entered college with a higher *quantitative SAT/ACT score*, $t(2175) = 4.60, p < .001$ (see Table 2 for descriptive statistics).

We next tested whether our hypothesized model fit differently for women and men. We expected that although belonging would predict perceived utility value of physics and course grades for women and men alike, stereotypic beliefs would predict women’s, but not men’s sense of belonging in physics. That is, whereas the outcomes of women and men’s sense of belonging should be the same, our proposed antecedent of belonging (stereotype endorsement) should differentially affect women and men.

In order to test our hypotheses, we conducted a model-invariance test using the AMOS 20 structural equation modeling (SEM) program [16, 17]. In so doing, we also included the direct effect of students’ background quantitative ability [18] on stereotype endorsement, belonging, utility value and course grade. Our approach first tested for model invariance across women and men (i.e., the assumption that the model applied to women and men in the same way). We then conducted chi-square difference tests to pinpoint the source of any noninvariance between the two groups (i.e., parameter estimates that differed significantly between women and men).

To determine whether the same model is applicable across women and men, we first fit a model in which we allowed all parameters to vary between women and men (i.e., the assumption that the models fit differently for women and men, Model 1). We then fit a second model that constrained the parameter estimates to be equal between women and men (i.e., the assumption that the models fit the same for women and men, Model 2). Next, we tested whether Model 1 was a better representation of the data than Model 2 by conducting a chi-square difference test, which was significant, $\Delta\chi^2(8, N = 2177) = 22.28, p < .01$. Thus, we rejected Model 2 and concluded that the model fit differently across women and men (Model 1).

We next proceeded to locate the specific parameters within the model that differed between women and men (see Figure 1 for standardized path loadings for women and men). As expected, we found that whereas stereotype endorsement negatively predicted women’s sense of belonging in physics, there was no such relationship for men (unstandardized coefficient and standard error for women: $b = -.12, SE = .04, p < .01$; and for men: $b = -.02, SE = .02, p = .16$). We expected

TABLE 2. Means (standard deviations) of each measured variable

	Stereotype Endorsement [1-5 pt scale]	Belonging [1-5 pt scale]	Utility Value [1-5 pt scale]	Course Score [0-4 pt scale]	SAT/ACT score [normalized]
Women	1.72 (1.02)	3.64 (.92)	3.56 (.86)	2.47 (.96)	-.19 (.98)
Men	2.30 (1.20)	3.97 (.81)	3.93 (.77)	2.73 (.90)	.03 (.97)

that these path loadings would be the source of noninvariance across women and men, so we conducted a chi-square difference test between Model 1 and a third model where we constrained the relationship between stereotype endorsement and belonging but allowed all other parameters to vary (Model 3). The chi-square difference test was significant, $\Delta\chi^2(1, N = 2177) = 5.05, p < .05$, indicating the relationships between stereotype endorsement and belonging were a source of noninvariance between women and men.

Using this same noninvariance strategy, we also found that (a) belonging was a stronger predictor of utility value for men than women, $\Delta\chi^2(1, N = 2177) = 5.32, p < .05$, and (b) background quantitative ability more strongly predicted women's course grade than men's course grade. $\Delta\chi^2(1, N = 2177) = 4.18, p < .05$. However, because path loadings for these two predictive relationships were significant for both women and men, we do not draw any strong conclusions about these sources of noninvariance. No other path loadings differed between women and men ($ps > .14$).

DISCUSSION

We found that although a strong sense of belonging predicts higher utility value and course grades for women and men alike, stereotype endorsement is related to women's (but not men's) sense of belonging in physics. That is, the more women endorsed the stereotype that women are less apt at physics than men, the less they felt as though they belonged in physics. Figure 1 depicts this differential relationship [19].

The current work puts forth an integrated model of the predictive nature of cultural stereotypes on women and men's sense of belonging in physics (and, by extension, STEM), which, in turn, predicts subsequent achievement and the personal value students place on physics. This work is of theoretical as well as practical import, as it offers an empirically validated model of the way that students' sense of belonging in physics contributes to gender disparities in physics achievement and participation.

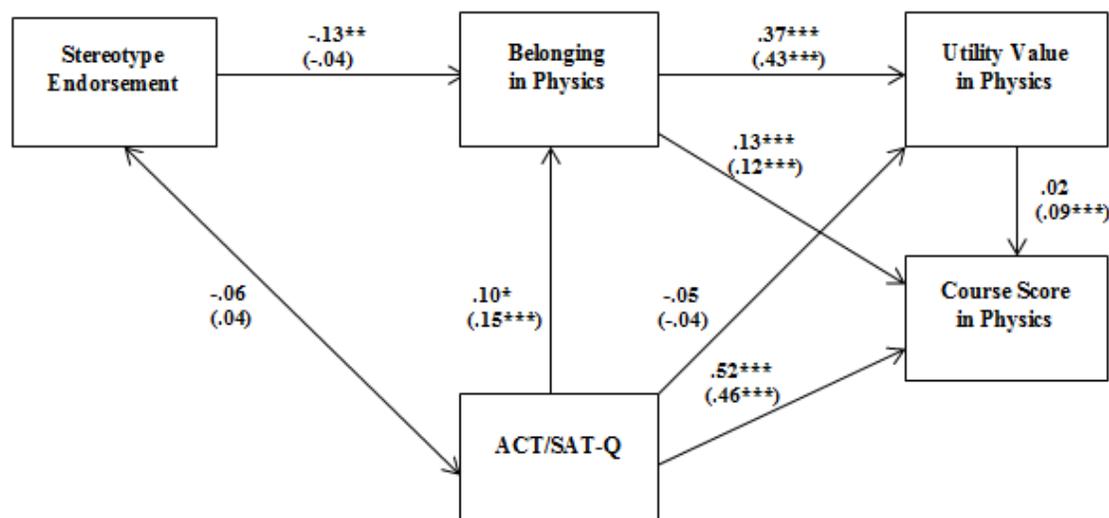


FIGURE 1. Women and men's standardized regression weights where stereotype endorsement predicts belonging and belonging predicts utility value and course score (men's weights in parentheses). ACT/SAT-Q = ACT and SAT quantitative score (normalized). * $p < .05$. ** $p < .01$. *** $p < .001$.

To the degree that a sense of belonging is critical to persistence and achievement, uncovering antecedents personally endorsing negative cultural stereotypes about one's group's ability was associated with a lower sense of belonging in physics among women. This suggests that one way to enhance women's and women and minorities presented in the classroom and curricula (images in text books; guest speakers; of belonging should be of high priority among behavioral scientific research. We found that other minority individuals' sense of belonging in physics (and STEM in general) is to dispel negative stereotypes that may occur in classroom contexts. One way to do this may be to augment the number of examples in homework and exams) in an authentic manner, suggesting to students that a diverse array of people can succeed in physics, including people who belong to their own social group. Alternatively classroom models are emerging that emphasize the nature of community and belonging within the scientific practices of the classroom. [20]

Future research should also pinpoint other antecedents of women and other minority individuals' low sense of belonging in STEM, as there are likely many. For example, students might naively believe that the ideal STEM professionals sacrifice family and social life in order to succeed in their careers. To the extent that women and other minority groups (e.g., students of low socioeconomic status) strongly value family and social connections [21, 22], these groups might feel as though their values do not "fit" with STEM, leading to low belonging and STEM avoidance. A comprehensive understanding of the determinants of all students' sense of belonging in STEM will better allow us to engage a broader pool of students so that they might have the opportunity to feel engaged and succeed, when they might have otherwise avoided STEM.

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14. It is possible that our stereotype endorsement measure induced stereotype threat among students in the current sample. We assessed this by comparing exam scores among students in a prior semester (who had not been exposed to the stereotype endorsement item) to students in the current sample. A 2 Gender (women vs. men) x 2 Sample (prior vs. current) Analysis of Variance indicated that men outperformed women, $F(1,2780) = 41.20$, $p < .001$, but that neither the effect of Semester nor the interaction of Gender x Semester was significant, $ps > .15$. This suggests that the gender difference in physics performance is robust and not simply due to the presence of our stereotype endorsement measure.
15. SEM is a statistical technique that allows researchers to test a theoretical model of the relationship between many variables simultaneously. SEM differs from regression analysis in that the latter assesses the impact of one or more predictor variables on a single outcome variable. SEM, however, is capable of assessing the relationship between many predictor variables on many outcome variables, as is the case in our study.
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17. The background quantitative ability is an average of normalized SAT- and ACT-Math scores.
18. Because our stereotype endorsement, belonging and utility value measures were obtained at the same time point, we cannot conclusively determine the causal relations among them. Rather, our data support a theoretically-driven relationship between factors relating to physics achievement and motivation, and that this relationship differs between women and men. Future studies should be designed to explicitly test the causal nature of the variables in our model.
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