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Article

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Belonging to Science, Technology, Engineering, and Mathematics (STEM)

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RUNNING HEAD: Meta-lay theories

Meta-lay Theories of Scientific Potential Drive Underrepresented Students' Sense of

Belonging to Science, Technology, Engineering, and Mathematics (STEM)

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Abstract

The current research investigates people's perceptions of others' lay theories (or mindsets), an understudied construct that we call meta-lay theories. Six studies examine whether underrepresented students' meta-lay theories influence their sense of belonging to science, technology, engineering, and math (STEM). The studies tested whether underrepresented students who perceive their faculty as believing most students have high scientific aptitude (a *universal metatheory*) would report a stronger sense of belonging to STEM than those who think their faculty believe that not everyone has high scientific aptitude (a *nonuniversal metatheory*). Women Ph.D. candidates in STEM fields who held universal rather than nonuniversal metatheories felt greater sense of belonging to their field, both when metatheories were measured (Study 1) and manipulated (Study 2). Undergraduates who held more universal metatheories reported a higher sense of belonging to STEM (Studies 3 and 4) and earned higher final course grades (Study 3). Experimental manipulations depicting a professor communicating the universal lay theory eliminated the difference between African American and European American students' attraction to a STEM course (Study 5) and between women and men's sense of belonging to STEM (Study 6). Mini meta-analyses indicated that the universal metatheory increases underrepresented students' sense of belonging to STEM, reduces the extent of social identity threat they experience, and reduces their perception of faculty as endorsing stereotypes. Across different underrepresented groups, types of institutions, areas of STEM, and points in the STEM pipeline, students' metaperceptions of faculty's lay theories about scientific aptitude influence their sense of belonging to STEM.

Keywords: lay theories; metaperceptions; sense of belonging; social identity threat; STEM; women and minorities

Meta-lay Theories of Scientific Potential Drive Underrepresented Students' Sense of

Belonging to Science, Technology, Engineering, and Mathematics (STEM)

The continued underrepresentation of women and historically underrepresented minorities in science, technology, engineering, and math careers poses a significant challenge to national defense (DARPA, 2010), economic security (Holdren & Lander, 2012; National Research Council, 2011; National Science Board, 2004), and social equality (Hrabowski, 2011). Women's and minorities' sense that they do not belong in science, technology, engineering, and math ("STEM") is a factor that contributes to their dwindling numbers as they move through each level of the career pipeline (National Science Board, 2012). Addressing this challenge will require a multifaceted approach. We identify a critical but as yet understudied psychological factor – meta-lay theories about intellectual potential in STEM – and investigate whether these beliefs contribute to underrepresented students' sense of belonging to STEM fields.

Meta-Lay Theories About Scientific Potential

We bring together research on lay theories and research on metaperceptions to develop the concept of *meta-lay theories*. Lay theories (or mindsets) are people's fundamental beliefs and assumptions about the nature of human attributes (Dweck, 1986, 1999, 2006). This body of research has extensively studied people's naïve beliefs about the nature of their own and others' characteristics (e.g., Carr, Rattan, & Dweck, 2012; Dweck, 2006; Molden & Dweck, 2006; Rattan & Georgeac, 2017; Rattan, Savani, Naidu, & Dweck, 2012). However, just as people have their own lay theories or mindsets, they may be aware that others hold such beliefs as well. Given that people often mentalize about others' psychological states (Frith & Frith, 1999), we argue that people form coherent and meaningful perceptions of important others' lay theories. To our knowledge, little previous research has directly investigated people's perceptions of the lay

theories that important others hold. People's perceptions of other's beliefs relevant to them are known as metaperceptions (Frey & Tropp, 2006; Vorauer, Main, & O'Connell, 1998; Wout, Murphy, & Steele, 2010). Thus, we define *meta-lay theories* as individuals' beliefs about the lay theories that others hold regarding specific, relevant attributes. We suggest that people's meta-lay theories are conceptually and empirically distinct from people's *own* lay theories about specific characteristics, and as such would uniquely predict outcomes above and beyond people's personal lay theories. We also note that meta-lay theories are not a generalized lay theory about the larger institutional or organizational context (Good et al., 2012; Murphy & Dweck, 2010; Murphy & Emerson, 2015), nor do they necessarily represent the actual mindsets of others in the context (Haimovitz & Dweck, 2017; Leslie, Cimpian, Meyer, & Freeland, 2015; Park, Gunderson, Tsukayama, Levine, and Beilock, 2016; Rattan, Good, & Dweck, 2012). Instead, meta-lay theories are perceptions of specific others' lay beliefs in a relevant domain.

In the present work, we focus on students' meta-lay theories about their professors. This is because professors can serve as key gatekeepers who can intentionally or unintentionally encourage or discourage students from particular academic and career pathways. Indeed, the research tradition on "wise feedback" (Cohen, Steele, & Ross, 1999) emphasizes the key role teachers and professors can play in increasing the learning and performance of stigmatized students. By communicating high standards for achievement when sharing negative feedback, teachers can provide useful but critical feedback without activating students' concerns about intergroup bias (Cohen & Steele, 2002; Cohen et al., 1999; Yeager et al., 2014). Building on this body of research, we investigate students' broader perceptions of their professors, and in particular, students' perceptions of their professors' lay theories in the domain of STEM.

One important dimension of lay theories about intelligence is people's beliefs about the

distribution of intellectual potential (Rattan et al., 2012). There are two ends of this continuum, ranging from a belief that not everyone has high intellectual potential (the *nonuniversal belief*), to the idea that almost everyone has high intellectual potential (the *universal belief*). These beliefs tap people's understandings about individuals' inherent potential for achievement, regardless of how, when, or whether they ultimately express that potential. Past work identified cross-cultural variance in these beliefs, documenting that U.S. Americans are more likely to hold the nonuniversal intellectual potential belief compared to South Asian Indians. Endorsing the nonuniversal belief is also associated with less support for policies that redistribute educational resources equally across groups (Rattan et al., 2012) and a lower likelihood of seeing education as a fundamental right that merits continued public support (Savani, Rattan, & Dweck, 2017).

We extend past research on lay theories about the universality of intellectual potential in two ways: (1) by studying domain-specific lay theories about the universality of aptitude in STEM, rather than intellectual potential in general, (2) by investigating people's metaperceptions about others' lay theories. Specifically, we explore students' perceptions of whether their professors believe that most people have high scientific aptitude (a *universal metatheory*) or that only some individuals possess scientific aptitude (a *nonuniversal metatheory*).

Meta-Lay Theories About Scientific Potential and Sense of Belonging to STEM

Consider "weed-out classes" which serve, from students' perspectives, to filter those who lack aptitude in STEM from those who possess it. Or consider the common representation of a science professor opening the class with, "Look to your left, look to your right. One of these people will not make it through this course." Though anecdotal, these examples suggest that students may develop meta-lay theories about their professors' beliefs about scientific aptitude. Although all students are likely develop these metaperceptions, we propose that they would be

particularly influential in shaping underrepresented students' sense of belonging to STEM.

We focus on students' sense of belonging because the need to belong in one's social, academic, and professional contexts is a fundamental human need (Baumeister & Leary, 1995; Fiske, 2004; Lambert, Stillman, Hicks, Kamble, Baumeister, & Fincham, 2013) and because whether students feel that they belong to STEM belonging is a critical factor driving whether they pursue STEM (Hrabowski, 2011; Wilson et al., 2015). One factor reducing many students' sense of belonging to STEM is the widespread negative stereotype in American society that women and historically underrepresented minorities do not have aptitude for math and science (Fiske, Cuddy, Glick, & Xu, 2002; Greenwald, McGhee, & Schwartz, 1998; Nosek, Banaji, & Greenwald, 2002). The theory of social identity threat (Steele & Aronson, 1995; Steele, Spencer, & Aronson, 2002) describes how negative societal stereotypes influence members of stigmatized groups. Social identity threat is defined as the concern that others might view one through the lens of negative stereotypes about one's group memberships, and this concern can derail women's and minorities' belonging, performance, and pursuit in STEM (Good et al., 2012; Schmader & Johns, 2003; Schmader, Johns, & Forbes, 2008; Smith, Brown, Thoman, & Deemer, 2015; Spencer, Steele, & Quinn, 1999; Steele, 1997; Steele & Aronson, 1995; Steele, Spencer, & Aronson, 2002). Because social identity threat is a concern that arises due to salient, prevalent stereotypes in diagnostic contexts (Steele & Aronson, 1995), environmental cues that raise or lower the salience of negative stereotypes can undermine or buffer underrepresented students' sense of belonging to STEM (Cheryan, Plaut, Davies, & Steele, 2009; Master, Cheryan, & Meltzoff, 2016; Murphy, Steele, & Gross, 2007; Thoman, Arizaga, Smith, Story, & Soncuya, 2014; Walton & Cohen, 2007). Drawing together this body of research, the identity engagement model (Cohen & Garcia, 2008) offers further insight into the cues in the

environment that activate social identity threat. This model suggests that negative stereotypes and underrepresentation psychologically engage the social identities of those from relevant groups. In contexts where their identity is thus engaged, this model proposes that individuals come to be vigilant to cues that might either confirm or disconfirm whether or not others view them through the lens of stereotypes (Cohen & Garcia, 2008; Murphy et al., 2007). According to this model, when cues disconfirm social identity threat, students' outcomes are based on their individual abilities, experiences, and idiosyncrasies of the performance context. When cues activate identity threat, the concern that one's group may be devalued, and students are uncertain about their ability to cope with the threat, then negative consequences for their performance, belonging, and pursuit in the domain are theorized to follow. We suggest that universal-nonuniversal meta-lay theories may represent one such cue.

Although meta-lay theories may at first seem unrelated to the dynamics of identity threat, we argue that beliefs about the distribution of scientific aptitude share a fundamental conceptual overlap with negative stereotypes about women and historically underrepresented minorities' lack of ability in science, namely assumptions about who has high aptitude for the sciences. The nonuniversal scientific aptitude belief is consistent with existing stereotypes: If not everyone has high scientific aptitude, then it is possible to believe that certain groups lack aptitude. In contrast, the universal scientific aptitude belief is fundamentally inconsistent with existing stereotypes: If everyone has high scientific aptitude, then negative stereotypes about women's and minorities' lack of ability cannot be viewed as legitimate. Extending this logic into the domain of metaperceptions, if underrepresented students hold nonuniversal metatheories, the question as to whether or not their professors will judge them through the lens of a belief that their group lacks aptitude remains an open one. In contexts characterized by underrepresentation and prevalent

negative stereotypes, we propose this question allows for vigilance to social identity threat cues (Cohen & Garcia, 2008) and this is enough to interfere with underrepresented students' sense of belonging to STEM. In contrast, if underrepresented students hold universal metatheories, the question of whether or not their professors also judge them through the lens of a belief that their group lacks aptitude is moot – the metatheory is inconsistent with stereotypes and therefore the worry that one will be viewed through the lens of negative stereotypes cannot follow. We thus propose that relative to nonuniversal metatheories, universal metatheories may boost underrepresented students' sense of belonging because they reduce students' experience of social identity threat. For those whose groups are not associated with negative stereotypes, we propose that meta-lay theories may not be systematically related to their sense of belonging as these students do not suffer from social identity threat to begin with.

Theories of social identity threat emphasize that it is possible to undercut students' sense of threat without altering their perceptions of the extent to which others endorse negative stereotypes – stigmatized students may be relieved of their worries about their social identity while knowing that the people around them still endorse negative stereotypes to the same degree (Steele & Aronson, 1995; Cohen & Garcia, 2008). However, we have proposed that a universal meta-lay theory is fundamentally inconsistent with the content of negative stereotypes. Thus, in addition to the predictions derived from traditional stereotype threat perspectives, we suggest a perhaps more radical alternative may also be possible: Universal-nonuniversal meta-lay theories may also influence perceptions of the stereotype itself. In addition to undercutting students' worry about whether professors would judge them through the lens of negative stereotypes, universal metatheories may also undercut the degree to which students believe that professors endorse negative stereotypes. Interacting with others who engage in stereotyping engenders a

variety of negative consequences among stigmatized individuals (Townsend, Major, Gangi, & Mendes, 2011), including reducing their sense of belonging (Logel et al., 2009). Thus, we suggest that students' perceptions of their faculty's stereotype endorsement may be another path through which universal-nonuniversal meta-lay theories influence their sense of belonging to STEM. We explored students' perceptions of the extent to which professors endorse stereotypes as another mechanism in addition to social identity threat.

If universal-nonuniversal metatheories are particularly important for underrepresented students' sense of belonging to STEM contexts, then experimentally shaping these perceptions might also be a key point of intervention to boost belonging. This approach builds on past research on wise interventions (Cohen & Garcia, 2008; Walton, 2014), which has targeted students' sense of belonging by exposing them to communications from similar others who were also uncertain about their belonging (Stephens, Hamedani, & Destin, 2014; Walton & Cohen, 2007, 2011), communications from expert tutors (Lepper, 1988; Lepper, Woolverton, Mumme, & Gurtner, 1993), and role models from their own group (Dasgupta, 2011; Dasgupta & Asgari, 2004; Dennehy & Dasgupta, 2017; Stout, Dasgupta, Hunsinger, & McManus, 2010). We extend this body of research by investigating whether messages that shape underrepresented students' universal-nonuniversal meta-lay theories will influence their sense of belonging to STEM.

Relationship to Lay Theories about the Malleability of Intelligence

A well-established research tradition has highlighted lay theories about intelligence on a different dimension, that of malleability. That is, people also hold lay theories about whether intelligence is fixed or can be changed (Blackwell, Trzesniewski, & Dweck, 2007; Dweck, 1986, 2006; Paunesku et al., 2015). Theoretically, the universal-nonuniversal dimension is defined by its focus on the distribution of high potential across the population, whereas the fixed-growth

dimension is defined by whether people can exert effort to develop their intelligence over time. Empirically, past research has shown that although the fixed-growth and universal-nonuniversal dimensions of lay beliefs about intelligence are moderately correlated, they represent distinct dimensions of beliefs about intelligence (Rattan et al., 2012). Students' fixed-growth mindsets are powerful predictors of their academic outcomes (Blackwell et al., 2007; Dweck, 1986, 2006; Paunesku et al., 2015), particularly for students from underrepresented backgrounds (for a review, see Rattan & Georgeac, 2017). For example, a growth mindset about intelligence protects underrepresented students against the negative effects of stereotype threat on performance because it undercuts the diagnosticity of the situation (Aronson, Fried, & Good, 2002; Good, Aronson, & Inzlicht, 2003). Given that underrepresented students' own fixed-growth beliefs influence their vulnerability to social identity threat, we measure these lay theories in Studies 1-3 to test whether universal-nonuniversal meta-lay theories predict students' sense of belonging to STEM above and beyond their fixed-growth beliefs.

As the focus of the present work is on meta-lay theories, it is also critical to distinguish universal-nonuniversal metatheories from fixed-growth metatheories. We define meta-lay theories as perceptions of specific others' lay beliefs about intelligence. Notably, no previous research has investigated fixed-growth metatheories. Instead, past work has investigated students' generalized perceptions of fixed-growth lay theories in academic (Good, Rattan, & Dweck, 2012) and employment contexts (Emerson & Murphy, 2015) and how the actual fixed-growth lay theories that teachers and professors hold influence their pedagogical practices (e.g., the type of feedback that they provide to poor performers; Rattan, Good, & Dweck, 2012) or students' own fixed-growth lay theories (with mixed findings, Haimovitz & Dweck, 2017; Park et al., 2016). Research has also found that professors' actual beliefs about whether success in a

field requires innate talent, one expression of a fixed mindset (Dweck, 1999), relates to the proportion of women Ph.D.s received in their field (Leslie et al., 2015).

We theorize that the universal-nonuniversal and fixed-growth meta-lay theories will be related but distinct constructs. Universal-nonuniversal metatheories refer to students' perceptions about whether their faculty believe that everyone has high intellectual potential in STEM, and fixed-growth metatheories refer to students' perceptions of whether their faculty believe that intelligence in STEM can be increased over time. We suggest that neither meta-lay theory necessarily constrains the other. For example, it is possible that students perceive their faculty as holding nonuniversal and growth lay theories, that is, the belief that students' ability in STEM can grow but that only some people have the potential to achieve at the highest levels (i.e., while everyone can learn, not everyone can get an A+). It is also possible for students to perceive their faculty as holding universal and fixed lay theories, that is, the belief that everyone has high potential and that intelligence is fixed, with the implication that that variation in students' performance is likely driven by factors other than intelligence, such as their effort, preparation, and engagement with the field. Equally plausible is that students may perceive their faculty has holding nonuniversal-fixed beliefs (i.e., the belief that intelligence is fixed and that only some people have high potential), or universal-growth beliefs (i.e., thinking intelligence can be increased and that everyone has the same high potential). We propose that because the universal-nonuniversal dimension of metatheories speaks to negative stereotypes about students' ability in STEM, universal-nonuniversal metatheories will predict students' STEM belonging above and beyond fixed-growth metatheories, which also may be a predictor.

Overview of Studies

We conducted our investigation across the STEM higher education pipeline, from Ph.D.

candidates, to STEM majors and potential majors, to general undergraduate populations. Study 1 began with women and men Ph.D. candidates at a highly-ranked research university, testing whether women (but not men) Ph.D. candidates who hold universal metatheories would report greater belonging in STEM than those who hold nonuniversal metatheories (Study 1). Next an experiment tested the causal effect of meta-lay theories, that is, whether exposing women Ph.D. candidates in STEM to the idea that professors in their field hold universal rather than nonuniversal metatheories would increase their sense of belonging to STEM (Study 2). Study 3 investigated whether the beneficial effect of universal metatheories on women and minority students' sense of belonging would translate into higher performance in a "weed-out" STEM major introductory course. Study 4 sought to replicate the link between universal-nonuniversal meta-lay theories and sense of belonging to STEM among a larger sample of women STEM majors from diverse university backgrounds. Study 5 examined students not yet in the STEM pipeline, testing whether the African American-European American gap in attraction to a STEM course would be eliminated by leading undergraduate students to hold a universal (vs. nonuniversal) metatheory. Finally, Study 6 tested whether the experimental manipulation of students' metatheories could eliminate the gender gap in anticipated STEM belonging. The hypothesis across studies was that universal metatheories would predict greater STEM belonging, but only among members of underrepresented groups in STEM (women and historically underrepresented racial minorities), and we propose that this would be driven by lower social identity threat (proposed mechanism 1, Studies 1-3, 4, and 6) and by lower perceived stereotype endorsement (proposed mechanism 2, Studies 4 and 6).

Study 1

Study 1 tested whether women vs. men STEM Ph.D. candidates' metaperceptions of their

faculty's lay theories about the universality of scientific aptitude are associated with their sense of belonging to STEM and offers an initial test of social identity threat as a proposed mechanism.

Method

Participants. Our target sample size was 50 participants, half men and half women. We recruited 52 Ph.D. candidates in STEM fields at a highly ranked, private, Research 1 university. Participants were 25 men[1] and 27 women, 14 Asian/Asian Americans, 29 European American/Whites, 3 Latino American/Hispanics, and 6 biracial/multiracial/others (M_age=26.12, SD_age=3.18). Participants were paid $10 for completing the study.

Procedure. Participants provided informed consent, reported their Ph.D. field (e.g., computer science, mechanical engineering, physics, see SOM for a full list of majors in this and all subsequent studies), and then completed the following:

Measures

Meta-lay theories. To measure our key construct, participants were asked, "What do you think the professors in your department believe about scientific aptitude? Do the professors in your department believe that almost all people have the potential to attain the highest scientific aptitude at some point in their life, or that only some people have the potential to attain the highest scientific aptitude?" (1=almost all people, 20=only some people; adapted from Rattan et al., 2012, Study 2). We reverse-scored this measure such that higher numbers indicate more universal metatheories regarding professors' beliefs about scientific aptitude.

Sense of belonging. Participants were asked to indicate their sense of belonging to their Ph.D. field using a single item: "How much do you feel that you belong in [*self-reported Ph.D. field*]?" (1 = not at all, 6 = extremely; Cheryan & Plaut, 2010).

Social identity threat. Participants indicated how concerned they were about being

judged based on their gender: "At *[university]*, how much do you worry that people might draw conclusions about you based on what they think about your gender?", "How much do you think your gender affects people's impressions of your ability in [*self-reported Ph.D. field*]?", "How much do you think you face biased evaluations in [*self-reported Ph.D. field*] because of your gender?" and "How biased (sexist, racist, etc.) do you think the sciences, including [*self-reported Ph.D. field*], are?" (1 = not at all, 6 = extremely; α=.79; adapted from Steele & Aronson, 1995).

Alternative Explanations

       Self-beliefs about scientific aptitude. We assessed participants' own lay theories about whether everyone or not everyone has high scientific aptitude with a single item, "Do you believe that almost all people have the potential to attain the highest scientific aptitude at some point in their life, or that only some people have the potential to attain the highest scientific aptitude?" (1=almost all people, 20=only some people; adapted from Rattan et al., 2012). This measure was reverse coded so that higher numbers indicate a more universal self-belief.

       Fixed versus growth beliefs about intelligence. We measured participants' beliefs about the malleability of intelligence with four items from the standard scale (e.g., "People have a certain amount of intelligence, and they can't really do much to change it."; 1 = strongly agree, 6 = strongly disagree; α=.96; Dweck, 1999).

       Finally, participants completed a standard demographics questionnaire, questions about their experience in the study, and their payment information. We report all measures included in all studies (see Supplementary Online Materials).[2]

Results

       Table 1 presents the means, standard deviations, and correlations among all variables, separately for men and women. We first tested whether women and men's reports of their meta-

lay theories about scientific potential differed, and they did not, $t(49) = .59$, $p = .56$, Cohen's $d =$ .16, $M_{men} = 10.88$, $SD_{men} = 5.35$, $M_{women} = 10.0$, $SD_{women} = 5.23$. Next, we turned to the focal analysis for this study: We conducted separate regressions for each dependent measure. The predictor variables were universal-nonuniversal metatheories (mean-centered), participant's gender (men= -1, women = 1), and their interaction.

<center><Insert Table 1></center>

Sense of belonging. There were no main effects of universal-nonuniversal metatheories, $B = .05$, $SE = .03$, 95% CI [-.009, .10], $t(47) = 1.68$, $p = .1$, or gender, $B = .15$, $SE = .03$, 95% CI [-.13, .43], $t(47) = 1.07$, $p = .29$, on sense of belonging. However, in support of our hypothesis, there was a significant metatheories X gender interaction, $B = .06$, $SE = .03$, 95% CI [.01, .11], $t(47) = 2.28$, $p = .027$. To deconstruct this interaction, we conducted simple slopes analyses (Aiken & West, 1991). As predicted, the more women Ph.D. candidates held universal metatheories the higher their sense of belonging to their STEM field, $B = .11$, $SE = .04$, 95% CI [.03, .18], $t(47) = 2.80$, $p = .007$ (see Figure 1). Men's sense of belonging was unrelated to their meta-lay theories, $B = -.02$, $SE = .04$, 95% CI [-.09, .06], $t(47) = -.44$, $p = .66$.

<center><Insert Figure 1></center>

Social identity threat. There was no main effect of universal-nonuniversal metatheories on participants' reported social identity threat, $B = -.04$, $SE = .02$, 95% CI [-.09, .01], $t(47) = -1.55$, $p = .13$. There was a main effect of participants' gender, indicating that women reported greater social identity threat than men, $B = .37$, $SE = .13$, 95% CI [.11, .63], $t(47) = 2.92$, $p = .005$. The metatheories X gender interaction was nonsignificant but trending, $B = -.04$, $SE = .02$, 95% CI [-.09, .006], $t(47) = -1.75$, $p = .09$. Given that this did not achieve significance, a simple slopes analysis is exploratory. The pattern indicated that women who held more nonuniversal

metatheories (one standard deviation below the mean) reported experiencing greater social identity threat both compared to women who held universal metatheories (one standard deviation above the mean), B = -.08, *SE* = .04, 95% *CI* -.15, -.01], *t*(47) = -2.33, *p* = .02, and men who held nonuniversal metatheories, B = .60, *SE* = .18, 95% *CI* [.23, .96], *t*(47) = 3.30, *p* = .002.

Alternative Explanations.

Self-beliefs about scientific aptitude. Participants' own universal-nonuniversal beliefs about scientific aptitude were correlated with their meta-lay theories such that more universal metatheories were associated with more universal self-beliefs, *r* = .42, *p* = .002. This moderate correlation indicates that the two beliefs are related, but not the same psychological construct. Furthermore, participants' own universal-nonuniversal beliefs about scientific aptitude did not predict their sense of belonging, *r* = -.02, *p* =.90 or social identity threat, *r* = .13, *p* = .36. Re-running the regressions of participants' universal-nonuniversal metatheories, participants' gender, and their interaction on the dependent variables, controlling for self-beliefs about scientific aptitude and controlling for the interaction between self-beliefs and gender, did not change the patterns of results or render any previously significant results non-significant. Together, these results suggest that meta-lay theories are indeed a distinct psychological construct from self-beliefs, with unique predictive power.

Fixed-growth beliefs about intelligence. Participants' fixed-growth beliefs did not correlate with their universal-nonuniversal metatheories, *r* = .08, *p* = .60, sense of belonging, *r* = -.02, *p* =.88, or social identity threat, *r* = .16, *p* =.26. Again, re-running the regressions of meta-lay theories, gender, and their interaction on the dependent variables, controlling for fixed-growth beliefs and the fixed-growth by gender interaction, did not change the patterns of results or render any previously significant results non-significant.

Discussion

Study 1 provides initial support for our key hypothesis that underrepresented students' universal-nonuniversal meta-lay theories predict their sense of belonging to STEM. The more women Ph.D. candidates in STEM disciplines at a top research university held universal metatheories, the higher their sense of belonging to their academic field. Men Ph.D. candidates' meta-lay theories were not related to their sense of belonging. Study 1 also offers initial evidence that universal-nonuniversal metatheories are distinct from students' own universal-nonuniversal beliefs and their fixed-growth mindsets, though we continue to test this in the studies that follow. This study also began to investigate social identity threat as a mechanism by which universal-nonuniversal metatheories might influence students' sense of belonging. Although the pattern of the gender by metatheory interaction on social identity threat was consistent with this idea, the marginal nonsignificant trend leaves this an open question to be investigated further.

Study 2

Study 2 used an experimental design to test whether universal-nonuniversal metatheories exert a causal influence on women Ph.D. candidates' sense of belonging to STEM.

Method

Participants. Our goal was to recruit as many women in STEM Ph.D. programs as possible from a list of 174 women graduate students a highly ranked, private, Research 1 university. We emailed the list multiple times and closed the study once emails yielded no further participation. Forty-seven women Ph.D. candidates in STEM fields participated, 21 self-identified as Asian/Asian-Americans, 22 as European Americans/Whites, 3 as Latino Americans/Hispanics, and 1 as mixed race ($M\_age = 25.4$, $SD\_age = 3.26$). Participants were paid $10. One additional person completed the study but identified as male at the end of the

study and so was excluded prior to all analyses. Two additional participants completed the study, but were excluded prior to data analysis because they failed to follow the instructions to complete the study in one sitting, as indicated by an extremely long (more than 3 standard deviations above the mean) time from start to end of the survey[2].

Procedure. Participants provided informed consent and then had to indicate that they were a graduate student at the university and that they had not previously completed the study in order to enter the survey.

Meta-lay theory manipulation. Participants were randomly assigned to either the *universal metatheory condition* or the *nonuniversal metatheory condition*. The manipulation was implemented using a biased questionnaire task in which participants are repeatedly exposed to a target belief and asked to indicate agreement with it (adapted from Rattan et al., 2012, Study 4). Participants assigned to the universal metatheory condition responded to 8 items communicating a universal metatheory (e.g., "Professors in *[participant's field]* believe that given the right environment, nearly EVERYONE can have high aptitude in this field of study"). Those assigned to the nonuniversal metatheory condition responded to 8 items communicating a nonuniversal metatheory (e.g., "Professors in *[participant's field]* believe that even in the right environment, NOT everyone can have high aptitude in this field of study"). The response scale for both conditions included only one disagreement option and four agreement options, which is an established procedure for pushing respondents toward agreement with the presented belief (Bryan, Walton, Rodgers, & Dweck, 2011; Job, Dweck, & Walton, 2010; Katz & Haas, 1988). After the experimental manipulation, we measured the following dependent variables.

Sense of belonging. Participants completed the measure described in Study 1.

Social identity threat. Participants completed the measure described in Study 1 ($\alpha=.89$).

Alternative Explanations

 Self-beliefs about scientific aptitude. Participants completed the measure described in Study 1.

 Fixed-growth beliefs about intelligence. Participants completed the measure described in Study 1.

 Finally, participants completed a standard demographics questionnaire, open-ended questions about their experience of taking the study, and were debriefed and paid.

Results

 Table 2 lists the means, standard deviations, and cell sizes by condition. There were no differences in participants' agreement with the items presented in the meta-lay theories experimental manipulation across conditions, universal metatheory condition $M = 3.16$, $SD = .65$, nonuniversal metatheory condition $M = 2.72$, $SD = 1.24$, $t(32.9) = -1.51$, $p = .14$, Cohen's $d = .44$, indicating that the universal metatheory items and the nonuniversal metatheory items did not significantly differ in the extent to which they elicited agreement from participants.

<center><Insert Table 2></center>

 Sense of belonging. As hypothesized, women Ph.D. candidates reported a significantly higher sense of belonging to their Ph.D. field in the universal metatheory condition, $M = 4.71$, $SD = .96$, than in the nonuniversal metatheory condition, $M = 3.83$, $SD = 1.15$, $t(45) = -2.86$, $p = .006$, Cohen's $d = .83$.

 Social identity threat. Women's reports of social identity threat did not differ by condition, $t(45) = -.17$, $p = .86$, Cohen's $d = .05$, universal metatheory condition $M = 2.54$, $SD = 1.13$, nonuniversal metatheory condition $M = 2.48$, $SD = 1.36$.

Alternative Explanations

Self-beliefs about scientific aptitude. The manipulation did not influence participants' own beliefs about whether everyone or not everyone has high scientific aptitude, $t(44) = .49$, $p = .62$, Cohen's $d = .15$, universal metatheory condition $M = 9.88$, $SD = 5.9$, nonuniversal metatheory condition $M = 10.68$, $SD = 5.10$. Moreover, including participants' own universal-nonuniversal scientific aptitude beliefs as a covariate in the analyses reported above did not change the pattern of the results or render any previously significant results nonsignificant.

Fixed-growth beliefs about intelligence. The manipulation did not shift participants' fixed-growth beliefs about intelligence, $t(44) = -.22$, $p = .83$, Cohen's $d = .06$, universal metatheory condition $M = 4.02$, $SD = .89$, nonuniversal metatheory condition $M = 3.96$, $SD = 1.11$. Controlling for participants' fixed-growth beliefs in the previously reported analyses did not change the pattern of the results or render any previously significant results nonsignificant.

Discussion

Study 2 demonstrated a causal effect of meta-lay theories on underrepresented students' STEM belonging: Women Ph.D. candidates reported a stronger sense of belonging to their STEM field when exposed to the universal, rather than nonuniversal, metatheory. These findings were not explained either by students' own universal-nonuniversal beliefs or by their fixed-growth mindsets. There was no effect of universal-nonuniversal meta-lay theories on social identity threat, but we continued to test this relationship in the subsequent studies.

Study 3

Study 3 tested whether students' universal-nonuniversal metatheories would be associated, not only with their sense of belonging, but also with their performance in science courses. We recruited underrepresented minority and women undergraduates from an introductory course in a STEM major at a highly ranked, private, Research 1 university. Students

had to complete the course and perform above a minimum standard as a requirement to pursue the major. The course was intensive, involving four lectures per week taught by the primary faculty and guest lecturers, in addition to a discussion section taught by a teaching assistant. By the terms of our agreement with the faculty in this major, we do not specify the major name, specific area of STEM, or the year in which these data were collected. Prior to conducting the study, we confirmed that women and minorities are underrepresented in careers in this STEM field nationally (National Science Board, 2012). Further, examining the composition of students who pursued independent research in the major and rates of pursuing further scientific research careers or STEM graduate programs, the faculty and head of the major characterized the persistent underrepresentation of women and racial minorities as an important challenge. Thus, we investigated whether students' perceptions of their professors' beliefs about whether most people (universal metatheory) or only some people (nonuniversal metatheory) have high scientific aptitude would be associated with their sense of belonging and course grades.

Method

   Participants. Women and historically underrepresented racial minority undergraduates in the science major introductory course were contacted by email with an invitation to participate and survey link, on Monday of Week 3 of the 10-week term. The deadline was Friday of that week to ensure that all participants completed the study in the third week of the term, before they received any performance feedback. This timeline determined our recruitment target—we aimed to get as many participants as possible within Week 3 of the term. In that time, 69 historically underrepresented minority and women undergraduates participated (3 men, 66 women). Eight self-identified as African American, 11 as Asian American/Pacific Islander, 32 as European American/White, 14 as Latino American/Hispanic, 3 as mixed/multiracial, and 1 declined to

report their race (M_age = 19.34, SD_age = .64). Six additional respondents who completed the

study were excluded prior to data analysis because they did not report underrepresented social

identities (gender or race) in the demographics survey. Participation was voluntary (i.e., no pay).

Procedure. Prior to informed consent, we asked whether respondents were currently

enrolled in the major (all were) or if they had previously completed the survey and re-entered it

(none had). Then participants provided informed consent and completed the following measures:

Meta-lay theories. Participants completed the item described in Study 1, adapted to

specify the major that students were enrolled in. This measure was reverse scored so that higher

numbers indicate perceptions of more universal meta-lay theories among faculty in the major.

Sense of belonging. Participants completed the measure described in Study 1, adapted to

reference the major that they were enrolled in.

Course grades. We requested participants' consent to retrieve their course grades from

the department at the end of the 10-week term.

Social identity threat. Participants completed the measure described in Study 1, adapted

to reference both gender and race (α=.73).

Alternative Explanations.

Self-beliefs about scientific aptitude. Participants completed the measure described in

Study 1. The measure followed the consent form and was prior to the meta-lay theories measure.

Fixed-growth beliefs about intelligence. Participants completed the fixed-growth

beliefs about intelligence measure described in Study 1, placed toward the end of the survey.

Participants completed a standard demographics questionnaire and open-ended questions

about their experience of taking the survey. Interspersed among the other measures were also

open-ended and survey items about the major and course content, which were included to offer

immediate feedback to the major faculty and not analyzed for research purposes (see SOM).

Results

Table 3 presents the means, standard deviations, and correlations among all study variables. We tested whether students' metatheories correlated with each dependent variable.

<Insert Table 3>

Sense of belonging. As predicted, the more women and minority students held universal metatheories, the higher their reported sense of belonging to this STEM major, $r = .37$, $p = .002$.

Course grades. Forty-four participants gave us consent to access their course grades. Office personnel (not the research team) matched course grades to participants' survey responses to ensure anonymity. The course grades were scored out of 100.

There was a marginal nonsignificant correlation between meta-lay theories, measured in week 3, and final course grades, $r = .28$, $p = .065$. Given that students start the course with different levels of ability and experience, a more appropriate analysis would control for starting ability level. The best proxy for their starting ability we had access to was their performance on the first assessment of the course. Thus, we regressed students' final grades on their meta-lay theories, controlling for midterm scores. Universal metatheories significantly predicted higher final grades, B = .19, $SE = .08$, 95% CI [.02, .36], $t(43) = 2.19$, $p = .03$, above and beyond their midterm scores, which were also predictive, B = .56, $SE = .05$, 95% CI [.45, .66], $t(43) = 10.79$, $p < .001$. To illustrate the size of this effect, a hypothetical student who held a universal metatheory (+1 SD) would score an 89.0 for their final grade, whereas another student who held a nonuniversal metatheory (-1SD) would score an 86.98. In the context of this course, the student who held a universal metatheory would outscore their peer by approximately one-third of a letter grade on average (e.g., B+ vs. B, estimated based on curved letter grades).

Students' metatheories were unrelated to midterm exam scores, which covered the material taught in weeks 1 to 5, $r = .13$, $p = .39$, suggesting that students were similar in their initial aptitude but performed differently over time as a function of their metatheories.

Tests of indirect effects through belonging. Given the pattern of results, we tested whether sense of belonging accounted for the direct effect of students' universal-nonuniversal metatheories on final course grades. We conducted this analysis using the Process Macro for SPSS (Hayes, 2012), Model 4, 5000 bootstrap estimations, 95% confidence intervals, with final course grades as Y, meta-lay theories as X, sense of belonging as M, and midterm scores as a covariate. The indirect effect of universal-nonuniversal metatheories through sense of belonging on students' final course grades was supported, indirect effect bootstrap coefficient = .08, $SE = .06$, 95% CI [.004, .24]. In other words, students who held universal metatheories felt a stronger sense of belonging to the major and thereby achieved higher course grades (see Figure 2). The reverse conditional indirect effect path, with sense of belonging as the predictor and universal-nonuniversal metatheories as the mediator, was not supported 95% CI [-.06, .75].

<Insert Figure 2>

Social identity threat. No differences in students' self-reported social identity threat emerged based on their universal-nonuniversal metatheories, $r = - .09$, $p > .45$.

Alternative Explanations.

Self-beliefs about scientific aptitude. Undergraduate students' self-beliefs about scientific aptitude correlated with their perceptions of faculty's beliefs about scientific aptitude, such that more universal metatheories were associated with more universal self-beliefs $r = .48$, $p < .001$. Women's and minorities' self-beliefs about scientific aptitude did not significantly predict their sense of belonging, although there was a nonsignificant trend $r = .22$, $p = .07$, and

did not predict their final course grade, $r = .14$, $p = .36$. The results reported above are essentially unchanged controlling for participants' own universal-nonuniversal scientific aptitude beliefs.

Fixed-growth beliefs about intelligence. Students' meta-lay theories did not correlate with their fixed-growth beliefs about intelligence, $r = .05$, $p = .66$. Growth mindsets of intelligence predicted greater sense of belonging, $r = .28$, $p = .02$, but fixed-growth beliefs did not predict final course grades, $r = -.001$, $p = .995$. All significant results reported above remained significant (with comparable patterns) controlling for fixed-growth beliefs.

Discussion

In a third study with a different sample of individuals underrepresented in STEM fields—undergraduate women and minorities—we again found that students' scientific aptitude meta-lay theories were associated with their sense of belonging. The more undergraduate women and minorities in a challenging introductory science course held a universal metatheory, the more they felt that they belonged in the major. The effect of students' meta-lay theories on their sense of belonging held above and beyond their lay theories about the malleability of intelligence and their own lay theories about the universality of scientific aptitude, both of which independently correlated with their sense of belonging. Moreover, controlling for initial performance, students who held more universal metatheories outperformed those who held more nonuniversal metatheories. This relationship was explained by their greater sense of belonging.

We found a suggestion of a link between meta-lay theories and social identity threat in Study 1, but no evidence for this link in Study 2 or 3. These mixed findings suggest that another investigation using a larger sample of underrepresented students is essential.

Study 4

Study 4 sought to improve upon the previous studies in three ways, by collecting a larger

sample than those in the earlier studies, by using a multi-item measure of meta-lay theories, and by investigating meta-lay theories on the fixed-growth dimension. The previous three studies empirically distinguished our focal construct, meta-lay theories about the universality of STEM intellectual potential, from two potential alternative predictors: students' own theories about the universality of STEM intellectual potential, and students' own fixed-growth beliefs about intelligence in STEM. We now test a third potential alternative predictor, students' fixed-growth meta-lay theories. In addition, Study 4 offers a test of both potential mechanisms: social identity threat and perceived stereotype endorsement. We predicted that the more underrepresented students endorse universal meta-lay theories, the greater their sense of belonging to STEM majors, the lower their sense of social identity threat, and the less likely they would be to perceive that their professors endorse negative stereotypes about underrepresented groups. Finally, we predicted that universal-nonuniversal meta-lay theories would predict these outcomes above and beyond fixed-growth meta-lay theories.

Method

      Participants. We recruited a Qualtrics panel of undergraduate students enrolled at a 4-year college or university, who classified their major as computer science, engineering, math, or natural sciences, were U.S. citizens, and identified as female. The target enrollment was 100, but 109 women ($M\_age = 22.19$, $SD\_age = 5.2$) completed the study; 72 self-identified as European American (White), 13 African American (Black), 3 Latina American, 11 East/South/Southeast Asian American, 1 Middle Eastern American, 2 other, and 7 multiracial.

      Procedure. After providing informed consent, participants completed the measures.[3]

      Meta-lay theories. Participants completed a 4-item measure of their meta-lay theories: "My professors in [major] believe that everyone has the potential to become very intelligent if

they really want to," "My professors in [major] believe that NOT everyone has the potential to become very intelligent even if they want to," "My professors in [major] believe that all people have the inborn potential to become very intelligent, but that not everyone ends up realizing their potential," "My professors in [major] believe that, to be honest, some people just don't have the potential to become highly intelligent," (1=Strongly Disagree – 6=Strongly Agree, α=.79). The items referred specifically to the major that participants had listed in an earlier free response item. The second and fourth items were reverse-coded such that higher numbers indicate a more universal meta-lay theory. Although the items referred to *intelligence* rather than *scientific aptitude*, we assumed that participants inferred that their professors would be primarily concerned with intelligence in the given major.

Sense of belonging. Participants responded to two items: "How much do you feel that you belong in [major]?" and "How much do you feel that you are a member of the [major] community?" (1=not at all, 6=extremely, $r = .57$, $p<.001$, Good et al., 2012).

Social identity threat. Participants completed the first 3 items of the social identity threat measure described in Study 1, which was adapted to refer to gender stereotypes (α=.88).

Perceived stereotype endorsement. Participants completed a 2-item measure of perceived stereotype endorsement, "How much do you think professors in [major] agree with negative stereotypes about women's abilities in science, technology, engineering, and math?" and "How much do you think professors in [major] see some truth in the idea that women have less ability in science and math than men?" (1=not at all – 6=extremely, $r = .83$, $p<.001$).

Alternative Explanations.

Fixed-growth meta-lay theories. After completing a filler measure in which they rated how much time they spent on various hobbies, participants went on to complete a 4-item

measure that was matched to the universal-nonuniversal meta-lay theories items, but assessed perceptions of professor's beliefs about whether intelligence is fixed or can grow, i.e., their fixed-growth meta-lay theories. Participants indicated their agreement with the following items: "My professors in [major] believe that people have a certain amount of intelligence, and they can't do much to change it," "My professors in [major] believe that people can always substantially change how intelligent they are," "My professors in [major] believe that people can learn new things, but they can't really change their basic intelligence, "My professors in [major] believe that people can change even their basic intelligence level considerably," (1 = strongly disagree, 6 = strongly agree, α = .84, adapted from Dweck, 1999). The first and third items were reverse-coded such that higher numbers indicate a more growth meta-lay theory. Finally, participants completed two reading check items, and a standard demographics form.

Results

Table 4 presents the means, standard deviations, and correlations among all study variables. First, we conducted confirmatory factor analyses (CFA) to ensure that the two predictors—universal-nonuniversal metatheories and fixed-growth metatheories—represent distinct constructs. A two-factor model fitted the data ($RMSEA = .11$, $CFI = .93$, $\chi^2(df = 19) = 45.29$) better than a one-factor model ($RMSEA = .17$, $CFI = .84$, $\chi^2(df = 20) = 80.91$, $\Delta\chi^2(df = 1) = 35.62$, $p < .001$). We next tested whether the two potential mechanisms—social identity threat and perceived stereotype endorsement—represent distinct constructs. As expected, a two-factor model fitted the data ($RMSEA = .087$, $CFI = .99$, $\chi^2(df = 4) = 7.32$) better than a one-factor model ($RMSEA = .25$, $CFI = .91$, $\chi^2(df = 5) = 39.12$, $\Delta\chi^2(df = 1) = 31.80$, $p < .001$). Thus, the two predictors represent distinct constructs, and the two potential mechanisms also represent distinct constructs. We next tested whether women's meta-lay theories correlated with their

sense of belonging, social identity threat, or perceived stereotype endorsement.

<center><Insert Table 4></center>

Sense of belonging. The more participants held a universal metatheory, the higher their reported sense of belonging to their major, $r = .28$, $p = .003$.

Social identity threat. The more participants held a universal metatheory, the less they reported a sense of social identity threat, $r = -.33$, $p = .001$. The more participants reported feeling social identity threat, the lower their sense of belonging, although this relationship was nonsignificant but trending, $r = -.16$, $p = .09$. We tested whether social identity threat accounted for the relationship between meta-lay theories and sense of belonging. Entering meta-lay theories as X, social identity threat as M, and sense of belonging as Y in Model 4 of the PROCESS macro (Hayes, 2012), we did not find support for the indirect effects, effect $= .03$, $SE = .03$, 95% CI [-.03, .11]. In fact, social identity threat was not significantly related to belonging, Coeff. $= -.06$, $SE = .08$, $p = .41$, 95% CI [-.22, .09] when accounting for meta-lay theories, Coeff. $= .25$, $SE = .10$, $p = .01$, 95% CI [.06, .45].

Perceived stereotype endorsement. The more participants held a universal metatheory, the less they perceived their faculty as agreeing with negative stereotypes about their gender, $r = -.37$, $p < .001$. Perceived stereotype endorsement was related to lower sense of belonging, $r = -.18$, $p = .056$. We tested whether perceived stereotype endorsement accounted for the relationship between meta-lay theories and sense of belonging. Entering meta-lay theories as X, perceived stereotype endorsement as M, and sense of belonging as Y into Model 4 of the Process macro (Hayes, 2012), we did not find support for the indirect effects, effect $= .03$, $SE = .05$, 95% CI [-.03, .14]. In fact, perceived stereotype agreement was not significantly related to belonging, Coeff. $= -.08$, $SE = .09$, $p = .36$, 95% CI [-.26, .10] when accounting for meta-lay theories, Coeff.

= .25, *SE* = .10, *p* = .02, 95% *CI* [.05, .45].

Fixed-growth meta-lay theories. The universal-nonuniversal meta-lay theories

significantly correlated with the fixed-growth meta-lay theories, *r* = .61, *p* < .001. Next, we

entered universal-nonuniversal metatheories and fixed-growth metatheories as predictors of each

outcome in a regression. In this regression, universal-nonuniversal meta-lay theories predicted

sense of belonging significantly, B = .25, *SE* = .12, *t*(108) = 2.09, *p* = .04, while fixed-growth

meta-lay theories did not, B = .06, *SE* = .12, *t*(108) = .48, *p* = .63. In another regression,

universal-nonuniversal meta-lay theories were a nonsignificant but marginal predictor of social

identity threat, B = -.27, *SE* = .15, *t*(108) = -1.85, *p* = .06, while fixed-growth meta-lay theories

did not predict social identity threat, B = -.25, *SE* = .15, *t*(108) = 1.62, *p* = .11. In a final

regression, we found that universal-nonuniversal meta-lay theories predicted stereotype

endorsement significantly, B = -.35, *SE* = .13, *t*(108) = -.2.76, *p* = .007, while fixed-growth meta-

lay theories did not, B = -.12, *SE* = .13, *t*(108) = -.87, *p* = .39.

Discussion

A fourth study, using a larger sample, again found that universal-nonuniversal meta-lay

theories predicted women's sense of belonging totheir STEM majors. This relationship held even

after controlling for women's fixed-growth metatheories. In addition to offering a replication, the

current study investigated two possible mechanisms underlying the link between students' meta-

lay theory and their sense of belonging to STEM. Contrary to our hypotheses these variables did

not explain the link between universal-nonuniversal metatheories and belonging. Given that

correlational designs have limitations for testing mechanism we next turned to experimental

methods and revisit the question of mechanism in Study 6.

Study 5

Study 5 tested a more ecologically valid method of communicating meta-lay theories, a scenario manipulation that described the lay theories of a hypothetical STEM professor, compared to the biased-questionnaire paradigm of Study 2. We recruited undergraduates at a public State University in the U.S. Midwest that reported over 30% historically underrepresented minorities in its undergraduate population in the year the research was conducted (a so-called critical mass), yet faces low minority representation in introductory STEM courses. Therefore, we examined the racial gap in students' attraction to a STEM course between the two largest racial groups at the undergraduate level at this university – African American and European American students. We predicted a condition (meta-lay theory: universal vs. nonuniversal) by participant race (European American vs. African American) interaction on students' attraction to an introductory STEM course, with a racial gap in students' attraction to the STEM course in the nonuniversal metatheory condition, but not in the universal metatheory condition.

Method

Participants. The population was undergraduate students enrolled in an introductory psychology course at a public research university in the U.S. Midwest. Our stopping rule was 200 participants, though we ran all participants who signed up each week. As previous studies using the same subject pool had an about equal representation of European American and African American students, we expected to recruit about 100 students of each race. Two hundred and twenty undergraduates completed the study and received course credit for their participation. Thirty-five of these were excluded because they identified with racial groups other than African American or European American or were multiracial. Thus, 185 qualified students completed the study (101 women, 84 men; 90 African American, 95 European American; $M\_age = 18.65$, $SD\_age = 1.2$). Prior to data analyses, we excluded 16 participants who reported that they were

not completely fluent in English, and three who were not U.S. citizens.

Procedure. This study was run in an on-campus research lab on lab computers. Participants provided informed consent and then were randomly assigned to either the universal or the nonuniversal metatheories condition.

Meta-lay theories manipulation. Participants in both conditions first read the following, "Imagine that it is the first day of a semester. You are enrolled in a new class that you have heard is pretty difficult, but interesting. The class provides an interdisciplinary introduction to topics in science, technology, math, and engineering. You arrive at class on time, take a seat, and wait for the professor to begin. Once students have arrived and are settled in, and it is time for the class to start, your professor begins with the following introduction: 'Welcome to my course. Before I review the major topics related to science, technology, math, and engineering that we will cover this term, I want to share with you my teaching philosophy. I know that this class has a reputation for being hard, and that's a well-deserved reputation. This will not be easy.'"

In the *universal metatheory condition*, participants next read, "I know that each and every one of you has the potential to perform at the highest level in this course. Whether or not you discover your potential is up to you, but the potential is there in every one of you. I base this philosophy on watching students come through my class year after year, and I am confident about it. I look forward to going on this journey of discovery together." In other words, the professor communicated that everyone in the course has scientific aptitude.

In the *nonuniversal metatheory condition*, participants instead read, "I know that only some of you have the potential to perform at the highest level in this course. Whether or not you discover your potential is up to you, but the potential is there in some of you. I base this philosophy on watching students come through my class year after year, and I am confident

about it. I look forward to going on this journey of discovery together." In other words, the professor communicated that not everyone in the course has scientific aptitude.

Next, participants completed measures of the target dependent variable, attraction to the STEM course, and exploratory dependent variables.

Attraction to STEM. We measured students' attraction to the hypothetical introductory STEM class. Participants completed a 6-item measure that assessed two components that we thought important for students' attraction to STEM: their liking of the course, "How likely would you be to want to continue in the class?", "How likely is it that you would recommend this professor's class to other students you know"; and their feelings of support from the professor: "To what extent do you think this professor supports students' success in the class?", "How much do you like this professor?", "How much do you think this professor cares about the students in the class", "How good of a professor do you think this person is?" (1 = not at all, 7 = extremely). These items were highly correlated, α=.91. A principal components analysis found that a single factor explained 70.71% of the variance (eigenvalue = 4.24), with subsequent factors accounting for 12.61%, 4.84%, 4.64%, 4.10%, and 3.11% of the variance (eigenvalues < .76). Thus, both the scree plot and the conventional cut off of eigenvalue < 1 indicate that a one factor model is the best fit, suggesting these items cohere together as a scale.

Alternative explanations. To test whether the manipulation shifted only the targeted belief, we asked participants to respond to single item measures of their perceptions of the targeted metatheory, the professor's universal-nonuniversal beliefs ("Do you believe that PROFESSORS at [university] believe that almost all [university] students have the potential to become highly intelligent during college, or that only some [university] students have the potential to become highly intelligent?"), as well as other non-targeted constructs: their fixed-

growth meta-lay theory ("Do you believe that PROFESSORS at [university] believe that people can increase their intelligence much over time, or that students cannot change their intelligence much over time?"), their own universal-nonuniversal beliefs about scientific aptitude and their own fixed-growth beliefs about scientific aptitude (which adapted the items above to reference the self), and their perceptions of other students' universal-nonuniversal beliefs about scientific aptitude and their perceptions of other students' fixed-growth beliefs about scientific aptitude (which adapted the items above to reference other students at the university). All measures were administered on 20-point bipolar scales based on the format used in Study 1.

Manipulation check. To identify inattentive individuals, participants were asked to select which of two messages they had received from the professor, either "That ONLY SOME students have the potential to perform at the highest level in this course" or "That ALL students have the potential to perform at the highest level in this course". Seventeen participants who answered this question incorrectly were excluded prior to data analysis[4].

Finally, participants completed a standard demographics form and questions about their experience of taking the survey, and were debriefed.

Results

Table 5 lists the means and standard deviations for all study variables and cell sizes, separately by participants' race and experimental condition.

<Insert Table 5>

Attraction to the STEM course. We conducted a 2 (meta-lay theories manipulation: universal vs. nonuniversal) X 2 (participant race: African American vs. European American) ANOVA on students' attraction to the introductory STEM course described in the scenario. We found a main effect of experimental condition, $F(1, 145) = 48.9$, $p < .001$, $n_p^2 = .26$. Across race,

participants were more attracted to the course in the universal metatheory condition, $M = 5.13$,

$SD = 1.12$, compared to the nonuniversal metatheory condition, $M = 3.85$, $SD = 1.22$. There was

also a main effect of participant race, $F(1, 145) = 4.23$, $p = .04$, $n_p^2 = .03$, such that European

American students, $M = 4.67$, $SD = 1.26$, were more attracted to the STEM course than African

American students, $M = 4.30$, $SD = 1.40$. Both of these main effects were qualified by a

condition X participant race interaction, $F(1, 145) = 5.49$, $p = .014$, $n_p^2 = .04$ (see Figure 3).

Pairwise comparisons revealed that European American undergraduates, $M = 4.22$, $SE = .18$,

were significantly more attracted to the introductory STEM course than African American

undergraduates, $M = 3.38$, $SE = .21$, in the nonuniversal metatheory condition, $F(1,142) = 9.42$, p

$= .003$, $n_p^2 = .06$. However, this racial difference disappeared in the universal metatheory

condition, in which both European American and African American students were similarly and

highly attracted to the introductory STEM course, $F(1,142) = .04$, $p = .84$, $n_p^2 < .001$,

$M_{AfricanAmerican} = 5.16$, $SE = .20$, $M_{EuropeanAmerican} = 5.11$, $SE = .18$.

<center><Insert Figure 3></center>

Alternative explanations. As expected, the experimental manipulation influenced the

targeted belief but not other beliefs. Participants in the universal metatheory condition were

significantly more likely to indicate that their professors held a universal belief than those in the

nonuniversal metatheory condition, $t(138) = 2.69$, $p = .008$, Cohen's $d = .45$, $M_{nonuniversal} = 10.15$,

$SD = 5.63$, $M_{universal} = 7.65$, $SD = 5.36$. However, the manipulation did not shift students' fixed-

growth metatheories, $t(134) = -.95$, $p = .34$, their own universal-nonuniversal beliefs about

scientific aptitude, $t(143) = 1.19$, $p = .24$, their fixed-growth beliefs about scientific aptitude,

$t(138) = .44$, $p = .66$, or their normative perceptions of other students' universal-nonuniversal,

$t(137) = 1.05$, $p = .30$ or fixed-growth beliefs, $t(134) = -.38$, $p = .70$. The condition X participant

race interact was not significant for any of these variables. Additionally, even controlling for each alternative metatheory in turn, the main effects and interaction of condition and race on attraction to the STEM course remained significant.

Discussion

Study 5 further generalized the findings of Studies 1 to 4 by showing that universal metatheories can benefit students even earlier in the pipeline, potentially helping promote diversity at a key entry point in STEM higher education—college students who could consider exploring STEM fields. When a hypothetical professor conveyed the belief that not everyone possesses scientific aptitude, there was a majority-minority racial gap in students' attraction to a STEM course, which mirrors the broader patterns of enrollment in STEM education nationally (National Science Board, 2012). However, exposing students to the idea that their professor believes that everyone in the class possesses scientific aptitude eliminated the racial gap in attraction to a STEM course. Exploratory analyses (see SOM) also suggest that the universal (vs. nonuniversal) meta-lay theory manipulation had similar benefits for women's attraction to the STEM course. This study demonstrates one way in which educators can shape students' meta-lay theories if they want to intervene to encourage all students in STEM—clearly communicating to students early on in a course that they believe that scientific aptitude is widely distributed.

It is notable that Study 1 found no relationship between universal-nonuniversal metatheories and belonging among majority group members, but the present study found that both minority and majority students were encouraged by the message that everyone has high scientific aptitude, although the relationship was stronger for minority students. Future research should investigate whether STEM meta lay-theories more strongly influence students regardless of their background at earlier stages when they have not yet committed to a major.

Study 6

The previous study offers initial support for the idea that a universal meta-lay theory causes an improved outlook on STEM among underrepresented students. However, it is important to note that the measure of attraction to STEM used in that study, though informative, is not a direct measure of sense of belonging to STEM, the key focus of this paper. Therefore, in the final study, we used a validated sense of belonging scale. In addition, we returned to the question of mechanism, again measuring both social identity threat and perceived stereotype endorsement as potential mechanisms through which we theorize universal-nonuniversal meta-lay theories may shift students' sense of belonging. We exposed men and women STEM undergraduates to either the universal or nonuniversal meta-lay theory. We hypothesized that there would be a gender gap between men and women's belonging in the STEM course in the nonuniversal metatheory condition, but that this gap would be eliminated in the universal metatheory condition. We similarly hypothesized a condition X gender interaction on social identity threat and perceived stereotype endorsement, and tested each as potential mechanisms explaining the link between students' meta-lay theories and their sense of belonging.

Method

Participants. We recruited a panel of undergraduate students through Qualtrics, Inc. Our target sample size was 400, 200 men and 200 women. The final sample size was 420 participants, 210 men and 210 women. Participants were undergraduate students at a 4-year college or university who classified their major as computer science, engineering, math, or the natural sciences, and were U.S. citizens, *Mean_age* = 24.2, *SD_age* = 6.26, 262 self-identified as European-American (White), 41 African American, 26 Latin American, 3 Native American, 41 Asian American, 3 Middle Eastern American, 9 Other, and 35 multiracial.

Procedure. After providing informed consent, participants were randomly assigned to either the universal meta-lay theory condition or the nonuniversal meta-lay theory condition.

Meta-lay theories manipulation. Participants read a streamlined version of the scenario, in Study 5, but with some adaptations given that the current sample were STEM majors. All participants read, "Imagine that it is the first day of a semester. You are enrolled in a new class that you have heard is pretty difficult, but interesting. The class provides an interdisciplinary approach to next generation technical challenges in science, technology, engineering, and math innovation. You arrive at class on time, take a seat, and wait for the instructor to begin. Once students have arrived and are settled in, and it is time for the class to start, your instructor begins with the following introduction. 'Welcome to my course. Before I review the major topics related to science, technology, engineering, and math innovation challenges that we will cover this term, I want to share with you my teaching philosophy. I know that this class has a reputation for being hard, and that's a well-deserved reputation. This will not be easy.'"

In the *universal meta-lay theory condition*, participants next read, "I know that everyone has high intellectual potential in science, technology, engineering, and math. What this means is that the potential is there in all of you. I want each and every one of you to realize your potential. I base this philosophy on watching students come through my class year after year, and I am confident about it. I look forward to going on this journey of discovery together." In other words, the professor communicated that everyone in the course has scientific aptitude.

In the *nonuniversal meta-lay theory condition*, participants instead read, "I know that not everyone has high intellectual potential in science, technology, engineering, and math. What this means is that the potential is there in some of you. I want those of you who have this potential to realize it. I base this philosophy on watching students come through my class year after year, and

I am confident about it. I look forward to going on this journey of discovery together." In other words, the professor communicated that not everyone in the course has scientific aptitude.

Next, participants completed the following measures:

Sense of belonging. Participants completed a 20-item measure of sense of belonging to STEM, adapted from the sense of belonging scale developed by Good et al. (2012). Participants reported their anticipated sense of membership (4 items, "I would feel that I belong"), acceptance (8 items, "I would feel accepted"), and affect (8 items, "I would feel anxious" reverse coded) in the STEM course (1 = strongly disagree, 8 = strongly agree), α = .95.

Social identity threat. As in Study 4, participants completed the 3-item measure of social identity threat, adapted to refer to gender stereotypes (α = .93).

Perceived stereotype endorsement. We measured perceived stereotype endorsement using 4 items (α = .86). The first 2 items were those used in Study 4, "How much do you think professors in [major] agree with negative stereotypes about women's abilities in science, technology, engineering, and math?" and "How much do you think professors in [major] see some truth in the idea that women have less ability in science and math than men?" (1 = not at all – 6 = extremely). The latter two items stated, "When this professor thinks of people who are very good at science, technology, engineering, and math, he is…" and "When this professor thinks of people who are scientists, mathematicians and engineers, he is..." with a scale ranging from the professor being much more likely to think of men than women (1) to much more likely to think of women than men (5) (from Dasgupta, Scircle, & Huntsinger, 2015; Stout et al., 2011). For the composite, the latter two items were reverse coded and all items were standardized given the different response scales. Higher numbers indicate more perceived stereotype endorsement.

Manipulation check. All participants correctly selected the statement summarizing what

the professor in the scenario had said out of four possibilities: an item endorsing the universal meta-lay theory, an item endorsing the nonuniversal meta-lay theory, an item endorsing the fixed meta-lay theory, and an item endorsing the growth meta-lay theory.

Finally, participants completed two reading check items, a standard demographics form, questions about their experience taking the survey, and were debriefed.

Results

Table 6 lists the means and standard deviations for the study variables and cell sizes, separately by participants' gender and experimental condition. As in Study 4, we conducted CFAs to test whether the two potential mechanisms—social identity threat and perceived stereotype endorsement—represent distinct constructs. As expected, a two-factor model fitted the data ($RMSEA = .17$, $CFI = .93$, $\chi^2(df = 13) = 176.73$) better than a one-factor model ($RMSEA = .24$, $CFI = .85$, $\chi^2(df = 14) = 360.09$, $\Delta\chi^2(df = 1) = 183.36$, $p < .001$).

<Insert Table 6>

Sense of belonging. We conducted a 2 (meta-lay theories manipulation: universal vs. nonuniversal) X 2 (participant gender: men vs. women) ANOVA on students' sense of belonging. We found a main effect of condition, $F(1, 419) = 34.74$, $p < .001$, $n_p^2 = .08$. Overall, participants exhibited greater belonging in the universal condition, $M = 5.87$, $SD = 1.04$, than the nonuniversal condition, $M = 5.18$, $SD = 1.42$. There was also a main effect of participant gender, $F(1, 419) = 3.75$, $p = .05$, $n_p^2 = .009$, whereby men, $M = 5.65$, $SD = 1.13$, reported a greater belonging to the STEM course than women, $M = 5.49$, $SD = 1.39$. Both of these main effects were qualified by a condition X participant gender interaction, $F(1, 419) = 12.16$, $p = .001$, $n_p^2 = .03$ (see Figure 4). Pairwise comparisons revealed that in the nonuniversal meta-lay theory condition men, $M = 5.49$, $SE = .12$, reported significantly greater belonging to the STEM course

than women, $M = 4.84$, $SE = .13$, $F(1,416) = 13.03$, $p < .001$, $n_p^2 = .03$. However, this gender gap

in belonging disappeared in the universal metatheory condition, in which both men and women

students exhibited similar and relatively high levels of belonging to the STEM course, $F(1,416)$

$= 1.38$, $p = .24$, $n_p^2 = .003$, $M_{men} = 5.78$, $SE = .11$, $M_{women} = 5.96$, $SE = .11$.

<Insert Figure 4>

Social identity threat. The 2 (meta-lay theories manipulation: universal vs.

nonuniversal) X 2 (participant gender: men vs. women) ANOVA on social identity threat yielded

both main effects and a significant interaction. As would be expected, women, $M = 2.06$, $SD =$

1.33, reported higher social identity threat than did men, $M = 1.66$, $SD = 1.02$, $F(1, 419) = 18.74$,

$p < .001$, $n_p^2 = .04$. Those in the nonuniversal condition, $M = 2.18$, $SD = 1.36$ reported greater

social identity threat than those in the universal condition, $M = 1.61$, $SD = .99$, $F(1, 419) = 28.04$,

$p < .001$, $n_p^2 = .06$. These main effects were qualified by a condition X gender interaction, $F(1,$

$419) = 16.16$, $p < .001$, $n_p^2 = .04$. Pairwise comparisons revealed that in the nonuniversal meta-

lay theory condition men, $M = 1.73$, $SE = .12$, reported a significantly lower sense of social

identity threat in the STEM course than women, $M = 2.66$, $SE = .12$, $F(1,416) = 30.87$, $p < .001$,

$n_p^2 = .07$, but, women's and men's social identity threat did not differ in the universal condition,

$F(1,416) = .055$, $p = .82$, $n_p^2 < .001$, $M_{men} = 1.59$, $SE = .11$, $M_{women} = 1.63$, $SE = .10$.

To investigate mechanism, we tested whether social identity threat might mediate the

effect of the meta-lay theory by gender interaction on sense of belonging. We used Process

Model 8 with 1000 bootstrap iterations (Hayes, 2012), entering condition as X, gender as the

moderator W, social identity threat as M, and sense of belonging as the dependent variable.

Social identity threat was a significant predictor of belonging, Coeff. $= -.42$, $SE = .05$, $p < .001$,

95% CI [-.51, -.32], the condition X gender interaction remained significant, Coeff. $= -.23$, $SE =$

.11, p = .04, 95% CI [-.45, -.008], and there was also support for the conditional indirect effect,

index = -.19, SE = .05, 95% CI [-.29, -.08]. Specifically, the conditional indirect effect of

condition on belonging through social identity threat was supported among women, Coeff. = .22,

SE = .05, 95% CI [.13, .32], but not among men, Coeff. = .03, SE = .03, 95% CI [-.03, .09]. In

sum, the results suggest that the effect of the condition by gender interaction on sense of

belonging can be partially explained by shifts in social identity threat among women.

Perceived stereotype endorsement. The 2 (meta-lay theories manipulation: universal vs.

nonuniversal) X 2 (participant gender: men vs. women) ANOVA on perceived stereotype

endorsement yielded both main effects and a significant interaction. Women, M = .17, SD = .93,

reported more perceptions of stereotype endorsement on the part of the STEM professor than did

men, M = -.17, SD = .70, $F(1, 419)$ = 23.64, $p<$ .001, n_p^2 = .05. Those in the nonuniversal

condition, M = .27, SD = .99 reported greater perceptions of stereotype endorsement from the

professor than those in the universal condition M = -.21, SD = .63, $F(1, 419)$ = 40.88, $p <$ .001,

n_p^2 = .09. Both of these main effects were qualified by a condition X participant gender

interaction, $F(1, 419)$ = 6.55, p = .01, n_p^2 = .02. Pairwise comparisons revealed that in the

nonuniversal meta-lay theory condition men, M = -.01, SE = .08, reported a significantly lower

perceived stereotype endorsement from the STEM professor than women, M = .57, SE = .08,

$F(1,416)$ = 24.39, $p <$ .001, n_p^2 = .06. However, women and men did not exhibit significantly

differential degrees of perceived stereotype endorsement in the universal meta-lay theory

condition, $F(1,416)$ = 3.05, p = .08, n_p^2 = .007, M_{men} = -.30, SE = .07, M_{women} = -.12, SE = .07.

We proposed perceived stereotype endorsement might also function as the process by

which the meta-lay theory by gender interaction influences sense of belonging. We used Process

Model 8 with 1000 bootstrap iterations (Hayes, 2012) to test this, entering condition as X, gender

as the moderator W, perceived stereotype endorsement as M, and sense of belonging as the

dependent variable. In the full model, perceived stereotype endorsement was a significant

predictor of belonging, Coeff. = -.5, *SE* = .07, *p* < .001, 95% *CI* [-.64, -.36], the condition X

gender interaction also remained significant, Coeff. = -.32, *SE* = .11, *p* = .005, 95% *CI* [-.54, -

.09], and the conditional indirect effect was supported, index = -.10, *SE* = .05, 95% *CI* [-.21, -

.02]. Here, both conditional indirect effects of condition on belonging through stereotype

endorsement were supported, suggesting that this is a significantly stronger relationship among

women, Coeff. = .17, *SE* = .05, 95% *CI* [.09, .28], than among men, Coeff. = .07, *SE* = .03, 95%

CI [.03, .14]. Thus, the condition by gender interaction on sense of belonging can also be

partially explained by shifts in perceived stereotype endorsement, among both men and women.

Discussion

In the nonuniversal meta-lay theory condition, undergraduate women in STEM majors

felt a lower sense of belonging to the hypothetical STEM course than men, but this gender gap

closed in the universal meta-lay theory condition. Further, in the nonuniversal meta-lay theory

condition, women participants felt more social identity threat and were more likely to believe

that the professor endorsed negative stereotypes than men, but these differences were

nonsignificant in the universal meta-lay theory condition. When tested separately, both social

identity threat and stereotype endorsement partially mediated the link between the universal

metatheories and sense of belonging.

<p align="center">**Mini Meta-Analysis of Direct Effects**</p>

Although meta-analysis are typically performed on data collected from a large number of

studies, techniques for meta-analyzing effects across studies within a single paper have recently

been developed (known as mini meta-analysis, Goh, Hall, & Rosenthal, 2016). These meta-

analytic techniques offer the opportunity to obtain more accurate estimates of the size and

reliability of direct effects for pairs of variables for which the researchers had directional

hypotheses (Goh et al., 2016). We ran five mini meta-analyses on the current studies to estimate

five different effects. As we had hypothesized directional relationships between the study

variables only for underrepresented students, the meta-analyses that follow only used data from

underrepresented students.

For these mini meta-analyses, we followed the procedures outlined in Goh et al. (2016)

and used the associated annotated spreadsheet that they provided. We first obtained Pearson's

correlations for the relevant effects, which were Fisher's z transformed for the analyses and then

converted back to Pearson correlations for presentation. We present mean effect sizes weighted

by sample sizes, and also fully random effects models (i.e., mean effect sizes not weighted by

sample sizes. See Table 7 for information regarding how we derived the effect size estimate for

each study, the actual effect size estimates, and samples sizes used to compute the mini-meta

analyses.

<center><Insert Table 7></center>

Mini Meta-Analysis 1: The core effect under investigation in this manuscript was the

direct effect of universal-nonuninversal meta-lay theories on sense of belonging to STEM (or

attraction in Study 5). Across the six studies, the mean effect weighted by sample size was

significant, $M\ r = .42$, $z = 8.79$, $p < .001$, two-tailed, such that among underrepresented students,

more universal metatheories were reliably associated with a higher sense of belonging to STEM.

The fully random effects model offered a similar conclusion, $M\ r = .41$, $p < .001$, two-tailed.

Mini Meta-Analysis 2: We assessed the effect of universal-nonuniversal meta-lay

theories on social identity threat across the five studies that included this measure. The mean

effect weighted by sample size was significant, *M r* = -.29, *z* = -6.42, *p* < .001, such that more universal metatheories were associated with lower social identity threat among underrepresented students. The fully random effects model offered a similar conclusion, *M r* = -.19, *p* = .04, two-tailed.

Mini Meta-Analysis 3: We assessed the effect of universal-nonuniversal meta-lay theories on stereotype endorsement across the two studies that included this measure, although only having two studies limits the strength of conclusions that can be drawn. The mean effect weighted by sample size was significant, *M r* = -.39, *z* = 6.57, *p* < .001, such that universal metatheories were associated with lower perceptions of stereotype endorsement by professors than nonuniversal metatheories among underrepresented students. The fully random effects model offered a similar conclusion, *M r* = -.26, *p* = .001, two-tailed.

Mini Meta-Analysis 4: We assessed the effect of social identity threat on sense of belonging across the five studies that included both measures. The mean effect weighted by sample size was significant, *M r* = -.43, *z* = -9.11, *p* < .001, such that greater social identity threat was associated with a lower sense of belonging to STEM among underrepresented students. The fully random effects model offered a similar conclusion, *M r* = -.28, *p* = .006, two-tailed.

Mini Meta-Analysis 5: We assessed the effect of students' perceptions of professors' stereotype endorsement on students' sense of belonging across the two studies that included both measures, although again, the smaller number of studies limits the strength of conclusions that can be drawn. The weighted mean meta-analytic effect was significant, *M r* = -.,44 *z* = -5.39, *p* < .001, such that greater perceived stereotype endorsement was associated with lower sense of belonging to STEM among underrepresented students. However, the fully random effects model was nonsignficant, *M r* = -.38, *p* = .26, two-tailed, indicating caution in interpreting the findings.

Although recent methodological developments may offer improved statistics for calculating effect size estimates for indirect effects (Lachowitz, Preacher, and Kelley, 2017; see also Preacher & Kelley, 2011), established techniques for using such statistics to analyze indirect effects across studies have not yet emerged in social psychology (Goh, personal communication, June 21, 2017). Simply averaging the indirect effect sizes across multiple studies would not be sufficient because it is also necessary to estimate the standard error or confidence interval of the indirect effect to assess its significance, and to our knowledge, no such procedure has yet been established. Thus, we are unable to offer a mini meta-analysis of the indirect effects because we lack an established method for mini meta-analyzing the indirect effects of universal-nonuniversal meta-lay theories on sense of belonging through either social identity threat or perceived stereotype endorsement. While the mini meta-analyses of the *direct* effects from each proposed mechanism to sense of belonging above offer some understanding into the relationships between these variables, they cannot speak to the reliability of the indirect effects.

General Discussion

Six studies found that underrepresented students who perceived that their professors believe that nearly everyone has scientific aptitude were more likely to feel that they belong to STEM than those who perceived that their professors believe that only some people have scientific aptitude. These effects emerged both when the beliefs were measured (Studies 1, 3, 4) and manipulated (Studies 2, 5, 6), among both women and racial minority group members, and across Ph.D. candidates at top research universities (Studies 1-2), undergraduate majors in STEM at diverse undergraduate institutions (Studies 3-4, 6), and undergraduates enrolled in a psychology course at a state university (Study 5). The results of a mini-meta analysis offer further support in favor of the hypothesis that universal-nonuniversal meta-lay theories predict

sense of belonging to STEM among underrepresented students. Further, controlling for initial performance, underrepresented students who held more universal metatheories at week 3 achieved higher grades at the end of the course, an effect that was driven by their greater sense of belonging (Study 3). Potential alternative predictors were ruled out across studies, including students' own universal-nonuniversal scientific aptitude beliefs (Studies 1-3, 5), their metaperceptions of their professors' beliefs about whether intelligence is fixed or can grow (Study 4), and their own beliefs about whether intelligence is fixed or can grow (Studies 1-3, 5). Thus, the new construct of universal-nonuniversal meta-lay theories investigated in this manuscript represents a meaningful and distinct predictor of sense of belonging to STEM.

We tested two possible mechanisms explaining the link between universal-nonuniversal meta-lay theories and underrepresented students' sense of belonging to STEM: their experience of social identity threat and the extent to which they thought that professors endorse negative stereotypes. The results of mini meta-analyses of the direct effect of universal-nonuniversal meta-lay theories on social identity threat and on perceived stereotype endorsement support the hypothesized relationships between metatheories and the proposed mechanisms. The findings from analyzing the indirect effects of metatheories to belonging through each of the proposed mechanisms were inconclusive from study to study. While it was not possible to mini meta-analyze the indirect effects, we were able to mini meta-analyze the direct effects from social identity threat to belonging, which was supported, and from perceived stereotype endorsement to belonging, which had mixed support. From this pattern of results, we conclude that social identity threat is reliably shaped by universal-nonuniversal meta-lay theories, and social identity threat reliably relates to minorities' and women's sense of belonging to STEM, which together are consistent with our proposed causal model. At the same time, we suggest that more research

must be done to more fully understand whether perceived stereotype endorsement plays a role in the metatheory-belonging relationship.

Implications

By integrating theoretical perspectives on mindsets and on metaperceptions, the present research identified a new construct – meta-lay theories. Our studies found that students' metaperceptions of their professor's lay theories about scientific aptitude were distinct from self-theories (universal-nonuniversal and fixed-growth) and meta-lay theories on the fixed-growth dimension. Given this, we suggest that metaperceptions of important others' beliefs may be a meaningful new construct that merits further study. Future research could consider when and why each level of belief (self vs. meta) emerges as most influential, and how these different levels of beliefs may interact (cf. Rattan & Georgeac, 2017). Further research can also develop our understanding of meta-lay theories about other important characteristics, such as personality or prejudice (Carr, Dweck, & Pauker, 2012; Neel & Shapiro, 2012; Rattan & Dweck, 2010) and whether they drive meaningful psychological outcomes. Such research might also study the conjunction of students' universal-nonuniversal metatheories and their fixed-growth metatheories about intelligence, as it could be the case that the different intersections of the dimensions of lay theories function to bolster (or alternatively, undermine) students' outcomes.

The present research further highlights that beliefs and understandings outside the intergroup context (i.e., beliefs that on the surface have nothing to do with gender, race, or class, such as the meta-lay theories of scientific potential) can still have substantial relevance for intergroup outcomes, influencing gender and race gaps in belonging to STEM (also see Rattan et al., 2012). Thus, this research suggests that one part of the appraisal and sense-making processes that underrepresented students engage in when evaluating whether contexts are threatening has to

do with the broader understandings of the nature of STEM intelligence. We suggest that these meta-lay theories may be particularly powerful because they are seemingly innocuous, subtly either reinforcing or undercutting negative stereotypes about group ability. This may be encouraging, insofar as it identifies a potential source of negative influence, and therefore points of intervention, that might otherwise have been overlooked through a sole focus on group-based beliefs and concerns. Simultaneously, it suggests that approaches to resolving threats to the self that women and minorities face in the context of STEM may require re-evaluating how STEM fields represent the nature of STEM ability (Good et al., 2012; Leslie et al., 2015).

Some people might ask whether communicating that everyone possesses scientific aptitude might misrepresent the nature of scientific potential to students. In response, we first point out that the nature of scientific potential is not yet fully understood. Certainly, measures of ability at any given time point exist (e.g., WISC-V, Wechsler, 2014). However, potential refers to what someone *can* achieve at some point in their life given appropriate circumstances, opportunities, and effort, and therefore it would be nearly impossible to experimentally determine whether potential is universal or nonuniversal. Further, given that a variety of experimental manipulations can increase students' performance (Aronson et al., 2002; Good et al., 2003; Cohen et al., 2006, 2009; Nguyen & Ryan, 2008; Shapiro, Williams, & Hambarchyan, 2012; Steele & Aronson, 1995; Walton & Cohen, 2007, 2011), students' potential may be more than what would be predicted by existing ability measures (Walton & Spencer, 2009). To be sure, our research cannot speak to the actual nature of intellectual potential, but it does seem to reveal conditions under which students' capacity to reveal whatever potential they have is promoted or undermined.

Limitations and Future Directions

The present research indicates that there are multiple mechanisms underlying the metatheories – belonging link. Given that we have already identified that this process is multiply determined, a priority for future research will be to further investigate other possible moderators (e.g., stage of STEM pipeline, university type) and other potential mechanisms behind the link between universal-nonuniversal meta-lay theories and STEM belonging for underrepresented students in order to offer a full picture of how student's perceptions of their faculty's lay beliefs shape their outcomes. Given that our work draws on and extends work in the tradition of wise feedback interventions (Cohen & Garcia, 2008; Cohen & Steele, 2002; Cohen, Steele, & Ross, 1999; Yeager et al., 2014), we suggest that one additional potential mechanism future research ought to investigate may be interpersonal trust between students and faculty, which could theoretically drive the lower social identity threat and lower perceived stereotype endorsement observed in the current studies. In addition, Shapiro and Neuberg (2007) identified a framework for understanding multiple sources and multiple targets of social identity threats. They highlight that threats can emerge from the self, from outgroup members, and from ingroup members, and that threats can target the self-concept or one's group as a whole. Interventions tailored to the type of threat that underrepresented students face tend to be most effective (Shapiro, Williams, & Hambarchyan, 2012). In the present research, the source of the threat is outgroup members, and the target of the threat is the self. As a next step for future research, we suggest examining whether the universal-nonuniversal meta-lay theories relate to measures of threat that focus on the group as a target (Shapiro et al., 2012). It may be that together, measures of threat that consider the self-as-target (as we did) and the group-as-target (as we propose) will offer a fuller explanation of the metatheory-belonging link among underrepresented students. Further, we suggest that considerations of mechanism should investigate whether the processes differ across

stage of the STEM pipeline or university type. We suggest that at earlier stages and at universities with generally more threatening academic environments, the dynamics under investigation here may be more pronounced.

Future research should further investigate what types of interventions can be done to shape universal meta-lay theories over the long term and in real-world academic contexts, if faculty so desire. Research could investigate what types of speech, behavior, reactions, or course polices communicate mindsets to students, and with the manipulations used in the final two studies as a starting point, research could also develop ecologically valid interventions for shaping students' metatheories. It is likely that such communications will only be effective if seen as authentic, however, so future research will also have to investigate how to implement beliefs that are seen as credible by students in the context. In a similar vein, research should also test how the universal-nonuniversal metatheories shape (or are shaped by) poor performance or difficulty in learning course content. Although we did find a link between universal metatheories and performance in Study 3, longitudinal research that follows students over time would offer a fuller perspective on whether the benefits of universal meta-lay theories hold over the long-term, and whether they are sustained even in times of struggle with the academic content.

In addition to considering what faculty are expressing and how these messages shape students' meta-lay theories, future research might also consider whether there are student-side factors that lead them toward one versus the other meta-lay theory. In Study 3, we found that students in the same classroom came to hold different metatheories, suggesting that there may be some aspects of their past experiences driving these perceptions. Perhaps students with greater identity-based rejection sensitivity (Mendoza-Denton, Downey, Purdie, Davis, & Pietrzak, 2002; London, Downey, Romero-Canyas, Rattan, & Tyson, 2012), or students who view their

academic environments as being suffused with stereotypes (Wout, Shih, Jackson, & Sellers, 2009) might be more likely to perceive nonuniversal metatheories. Answering this question might help identify underrepresented individuals who would most benefit from a universal metatheory intervention.

We want to clearly state that neither the universal belief nor the nonuniversal belief is clearly "right" or "accurate"—faculty should be free to hold and communicate whichever idea they truly believe in. The present research offers the opportunity to do so while fully understanding the potential benefits and costs of communicating either belief. It will be for future research to further develop our understanding of what faculty actually believe, and what factors drive their beliefs about the nature of scientific aptitude, particularly given the power of teachers' beliefs, even when unstated, to influence students' experiences and outcomes (Cohen et al., 1999; Rosenthal & Jacobson, 1968; van den Bergh, Denessen, Hornstra, Voeten, & Holland 2010). One function of the present research might be to spark a conversation about people's beliefs about the nature of intellectual potential. It may be that the majority of faculty in colleges and universities view their students as possessing high potential – after all, higher education is a selective and highly competitive context. However, if they fail to clearly signal their beliefs, perfectly well-meaning faculty who want to foster students' interest and engagement in STEM might end up inadvertently communicating messages that have detrimental effects for students' interest.

Conclusion

We identified an understudied yet psychologically meaningful construct, meta-lay theories of intellectual potential. Across six studies, we found evidence that universal metatheories are protective whereas nonuniversal metatheories are undermining to historically

underrepresented minorities and women in STEM. We highlight this new construct as both

theoretically and practically important, and hope that our investigation contributes to a

developing literature as well as to everyday classroom pedagogy.

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Footnotes

1. Only one male participant held a negatively stereotyped racial identity (Latino American). We grouped him with other men in the data given that this study focused on gender stereotypes in STEM. The patterns of results and significance levels remain the same even if this participant is excluded from the analyses reported in the main text.

2. The results reported in Study 2 are essentially unchanged if we include the two participants who qualified but were excluded (i.e., all significant effects remain significant and in the same direction, all nonsignificant effects remain nonsignificant).

3. We included two additional items that were intended as a part of the perceived stereotype endorsement measure, but these items were rendered unusable because the survey program did not save edits to the response scale, rendering the response scale nonsensical, ranging to and from the same values. Given this technical error, we did not analyze the data from these items.

4. Including the 37 participants who were excluded for a lack of comfort with the English language, for not being citizens, and for not reading the manipulation yielded the following: For the condition X participant race interaction on attraction to the STEM course, the main effects of condition, $F(1,182) = 53.44$, $p < .001$, $n_p^2=.17$, and race, $F(1,182) = 9.03$, $p = .003$, $n_p^2=.05$, still emerged, but the interaction was nonsignificant, $F(1,182) = .27$, $p = .60$, $n_p^2=.002$. Examining the pairwise comparisons, though, we still find a significant race gap in the nonuniversal condition, $F(1, 179) = 5.97$, $p = .016$, $n_p^2= .03$, but marginal and nonsignificant in the universal condition, $F(1, 179) = .3.22$, $p = .07$, $n_p^2= .02$.

Acknowledgements

Table 1

Study 1: Means, Standard Deviations, and Correlations by Participant Gender.

Women Participants						
Variables	*M*	*SD*	1	2	3	4
1. Meta-lay theories	11.00	5.23				
2. Sense of belonging	4.67	1.21	.45*			
3. Social identity threat	2.59	1.02	-.41*	-.37+		
4. Self-beliefs about scientific aptitude	8.81	4.70	-.29	.03	-.06	
5. Fixed-Growth beliefs about intelligence	4.04	1.13	-.09	.009	.21	-.26
Men Participants						
Variables	*M*	*SD*	1	2	3	4
1. Meta-lay theories	10.12	5.35				
2. Sense of belonging	4.32	.80	-.11			
3. Social identity threat	1.85	.84	.03	.14		
4. Self-beliefs about scientific aptitude	11.80	4.60	-.54**	.15	.04	
5. Fixed-Growth beliefs about intelligence	3.79	1.19	.22	-.12	.03	-.43*

Note. N = 26-27 women participants (because 1 participant did not provide full data) and 25 men participants. All tests are two-tailed.

$^{+}p<.06,$ $^{*}p < .05.$ $^{**}p < .01.$ $^{***}p < .001.$

Table 2

Study 2: Means and Standard Deviations of Variables and Cell Sizes by Condition

Variables	Universal Meta-Lay Theory Condition N = 24		Non-Universal Meta-Lay Theory Condition N = 23	
	M	*SD*	*M*	*SD*
Agreement with the manipulation	3.16	.65	2.72	1.24
Sense of belonging**	4.71	.96	3.83	1.15
Social identity threat	2.54	1.13	2.48	1.36
Self-beliefs about scientific aptitude	9.88	5.90	10.68	5.10
Fixed-growth beliefs about intelligence	4.02	.89	3.96	1.11

Note: Variables that are starred (**) show a significant difference between conditions, $p < .01$. There were no condition differences for all other variables.

Table 3

Study 3: Means, Standard Deviations, and Correlations.

Variables	*M*	*SD*	1	2	3	4	5	6
1. Meta-lay theories	14.55	5.17						
2. Sense of belonging	4.48	1.18	.37**					
3. Final course grade	87.99	5.96	.28+	.43**				
4. Midterm grade	82.37	8.92	.13	.27+	.86***			
5. Social identity threat	2.05	.96	-.09	-.29*	-.23	-.22		
6. Self-beliefs about scientific aptitude	11.80	5.16	.48***	.21+	.14	.18	-.05	
7. Fixed-growth beliefs about intelligence	4.09	1.05	.05	.28*	-.001	.11	-.05	.41***

Note. $N = 69$ women and underrepresented minority participants for variables measured at week 3, reduced to $N = 44$ for final course grade and midterm grade (due to consent for access to grades). All tests are two-tailed.

[+] $p<.1$, [*] $p < .05$. [**] $p < .01$. [***] $p < .001$.

Table 4

Study 4: Means, Standard Deviations, and Correlations.

Variables	*M*	*SD*	1	2	3	4
1. Meta-lay theories	4.45	.98				
2. Sense of belonging	4.47	.98	.28**			
3. Social identity threat	2.41	1.26	-.33**	-.16+		
4. Perceived stereotype endorsement	1.95	1.10	-.37***	-.18+	.76***	
5. Fixed-growth meta-lay theories	4.03	.94	.61***	.21*	-.32***	-.29**

Note. N = 109 women participants. All tests are two-tailed.

+*p*<.1, *p* < .05. **p ≤.01. ***p < .001.

Table 5

Study 5: Means and Standard Deviations of Variables and Cell Sizes by Condition and Participant Race

| | Universal Meta-Lay Theory Condition N = 75 | | | | Non-Universal Meta-Lay Theory Condition N = 71 | | | |
| | African American Participants (N = 33) | | White American Participants (N = 42) | | African American Participants (N = 31) | | White American Participants (N = 40) | |
Variables	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Attraction to the STEM course*	5.16 a	1.07	5.11 a	1.17	3.38 b	1.09	4.22 c	1.20
Universal-nonuniversal meta-lay theories	7.25	4.82	7.97	5.80	10.74	6.26	9.65	5.23
Fixed-growth meta-lay theories	13.97	5.47	14.47	5.37	14.88	5.28	12.28	5.06
Self-beliefs about scientific aptitude	5.79	5.61	6.90	5.33	7.45	5.46	7.28	4.86
Fixed-growth beliefs about scientific aptitude	15.52	5.12	14.40	5.17	16.11	4.20	14.54	4.14
Other students' beliefs about scientific aptitude	10.75	6.03	10.64	5.32	11.96	5.58	11.29	5.62
Other students' fixed-growth beliefs about scientific aptitude	12.06	5.10	11.33	5.21	11.96	4.87	11.10	5.43

Note: Variables that are starred (*) show a significant Condition x Participant Race interaction (*p* < .05). If there was a significant Condition x Participant Race interaction, the differences between cells are indicated by subscripts; cells in a row that do not share a subscript are significantly different from each other.

Table 6

Study 6: Means and Standard Deviations of Variables and Cell Sizes by Condition and Participant Gender

	Universal Meta-Lay Theory Condition N = 237				Non-Universal Meta-Lay Theory Condition N = 183			
	Women Participants (N = 122)		Men Participants (N = 115)		Women Participants (N = 88)		Men Participants (N = 95)	
Variables	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Sense of belonging*	5.96 b	1.07	5.78 b	1.01	4.85 a	1.53	5.49 b	1.24
Social identity threat*	1.63 b	1.04	1.59 b	.95	2.66 a	1.45	1.73 b	1.11
Perceived stereotype endorsement*	-.12 c	.69	-.30 c	.56	.57 a	1.07	-.005 b	.82

Note: Variables that are starred (*) show a significant Condition x Participant Gender interaction (p < .05). If there was a significant Condition x Participant Gender interaction, the differences between cells are indicated by subscripts; cells in a row that do not share a subscript are significantly different from each other.

Table 7
Studies 1-6: Explanations of how standardized effect sizes (r) were calculated standardized effect sizes (r) used for mini meta-analyses, and sample sizes.

Method for calculating standardized effect size *r*	Study Number	Standardized effect size *r*	N
Direct effect of universal-nonuniversal meta-lay theories on underrepresented students' sense of belonging to STEM			
Correlation between variables among women	1	0.45	26
Cohen's *d* converted to *r*	2	0.38	47
Correlation between variables	3	0.37	69
Correlation between variables	4	0.28	109
Cohen's *d* converted to *r* among African Americans	5	0.64	64
Cohen's *d* converted to *r* among women	6	0.38	210
Direct effect of universal-nonuniversal meta-lay theories on underrepresented students' social identity threat			
Correlation between variables among women	1	-.32	26
Cohen's *d* converted to *r*	2	.02	47
Correlation between variables	3	-.09	69
Correlation between variables	4	-.33	109
Cohen's *d* converted to *r* among women	6	-.38	210
Direct effect of universal-nonuniversal meta-lay theories on underrepresented students' perceived stereotype endorsement			
Correlation between variables	4	.37	109
Cohen's *d* converted to *r* among women	6	.37	210
Direct effect of social identity threat on underrepresented students' sense of belonging to STEM			
Correlation between variables among women	1	-.295	27
Correlation between variables (collapsing across conditions)	2	-.27	50
Correlation between	3	-.29	69

variables			
Correlation between variables	4	-.16	109
Correlation between variables among women (collapsing across conditions)	6	-.57	210
Direct effect of perceived stereotype endorsement on underrepresented students' sense of belonging to STEM			
Correlation between variables	4	-.18	109
Correlation between variables among women (collapsing across conditions)	6	-.52	210