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Does My Professor Think My Ability Can Change? Students' Perceptions of Their STEM Professors' Mindset Beliefs Predict Their Psychological Vulnerability, Engagement, and Performance in Class

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Two experiments and 2 field studies examine how college students' perceptions of their science, technology, engineering, and mathematics (STEM) professors' mindset beliefs about the fixedness or malleability of intelligence predict students' anticipated and actual psychological experiences and performance in their STEM classes, as well as their engagement and interest in STEM more broadly. In Studies 1 ($N = 252$) and 2 ($N = 224$), faculty mindset beliefs were experimentally manipulated and students were exposed to STEM professors who endorsed either fixed or growth mindset beliefs. In Studies 3 ($N = 291$) and 4 ($N = 902$), we examined students' perceptions of their actual STEM professors' mindset beliefs and used experience sampling methodology (ESM) to capture their in-the-moment psychological experiences in those professors' classes. Across all studies, we find that students who perceive that their professor endorses more fixed mindset beliefs anticipate (Studies 1 and 2) and actually experience (Studies 3 and 4) more psychological vulnerability in those professors' classes—specifically, they report less belonging in class, greater evaluative concerns, greater imposter feelings, and greater negative affect. We also find that in-the-moment experiences of psychological vulnerability have downstream consequences. Students who perceive that their STEM professors endorse more fixed mindset beliefs experience greater psychological vulnerability in those professors' classes, which in turn predict greater dropout intentions, lower class attendance, less class engagement, less end-of-semester interest in STEM, and lower grades. These findings contribute to our understanding of how students' perceptions of professors' mindsets can serve as a situational cue that affects students' motivation, engagement, and performance in STEM.

Keywords: academic achievement, experience sampling methodology, faculty mindset, motivation, STEM

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Data sharing is essential for transparency, replicability, and future meta-analysis. For the experimental studies (Studies 1 and 2), we have made the datasets and materials available on the OSF repository (https://osf.io/r5cef/). The longitudinal studies (Studies 3 and 4) contain students' academic records and are FERPA protected. Therefore, all deidentified data, code, and materials are available upon request and by IRB approval. In compliance with IRB policies, group characteristics will only be shared when there are 10 or more individuals within an identity group to preserve students' anonymity.

Data from Studies 3 and 4 were presented by Katherine Muenks as part of two symposia at the American Educational Research Association Annual Meeting in 2018. Data from Study 2 was presented at the Society for Personality and Social Psychology Annual Meeting in 2020.

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If the United States is to remain competitive in the global economy, it is essential to promote students' interest, participation, and retention in science, technology, engineering, and mathematics (STEM) fields (National Science Board, 2015). At the undergraduate level, researchers, policymakers, and practitioners are increasingly concerned with how to support students in the STEM pipeline—that is, how to keep students enrolled, engaged, and performing well in their STEM classes (Maltese & Tai, 2011; Mau, 2016). Students' psychological experiences in their STEM classes—the extent to which they feel positive, confident, and supported versus negative, uncertain, and stressed—are key to understanding students' interest and engagement with STEM (Ashcraft & Moore, 2009; Beasley & Fischer, 2012). In the present research, we examine the role that students' perceptions of a particular situational cue play in shaping their psychological experiences in STEM classes. Specifically, we explore how students' perceptions of their STEM professors' mindset beliefs about intelligence shape students' psychological experiences in class, and how those experiences in turn affect students' engagement, interest, and performance there.

Situational Cues Shape Students' Experiences

According to the cues hypothesis (e.g., Murphy, Steele, & Gross, 2007; Murphy & Taylor, 2012), people look to situational cues in their local environment to determine what is valued there. These situational cues can be communicated verbally—in group or one-on-one interactions—and nonverbally—by the materials, policies, and practices created by powerful people in a setting. Researchers have found that situational cues in the physical environment (e.g., Cheryan, Plaut, Davies, & Steele, 2009; Murphy et al., 2007), the cultural values espoused in a particular context (Browman & Destin, 2016; Stephens, Fryberg, Markus, Johnson, & Covarrubias, 2012), and the beliefs of salient individuals in a setting (Ashford, 1993; Canning, Muenks, Green, & Murphy, 2019) can influence people's psychological, cognitive, and physiological experiences.

People are especially attuned to the beliefs and behavior of powerful others in their environment (e.g., Fiske, 1993; Reich & Arkin, 2006). In classroom contexts the most powerful person in the room is often the professor, whom students rely on for evaluations and judgments about their competence and performance. In STEM classrooms—which are often perceived as difficult and competitive learning environments (e.g., Canning, LaCosse, Kroeper, & Murphy, 2019; Pew Research Center, 2017; Stodolsky, 1985)—students may be particularly vigilant to their professor and cues that they communicate suggesting whether they are "cut out" for the work or whether they belong there. Cues from a professor that suggest that students might not have what it takes to be successful in a particular course negatively influence students' motivation, psychological experiences, and performance (Canning, Muenks, et al., 2019; Good, Rattan, & Dweck, 2012; Leslie, Cimpian, Meyer, & Freeland, 2015). In the present studies, we examine how one situational cue in STEM classes—*students' perception of their professors' mindsets*—predicts students' experiences, engagement, and performance in those classes, as well as their interest in STEM more broadly.

Students' Perceptions of Professor Mindset Beliefs

According to Carol Dweck's mindset theory, people hold different *mindsets* or lay beliefs about the malleability of human traits such as intelligence (Dweck, 1999; Molden & Dweck, 2006). These lay beliefs influence people's behavior in important ways. People who hold more of a *fixed mindset* endorse the belief that intelligence is innate, fixed, and unchanging, whereas people who hold more of a *growth mindset* endorse the belief that intelligence is malleable and can be expanded and developed by persistence, help-seeking, and adopting the right strategies. For more than 20 years, most mindset research has conceptualized people's mindset beliefs as an individual difference—examining how people's personal mindset beliefs influence their own behavior, motivation, and achievement (see Molden & Dweck, 2006, for review). However, more recent research has examined how fixed or growth mindset beliefs can come to characterize a setting (such as a school or workplace) through the verbal and nonverbal behavior of powerful people in the setting (e.g., teachers in a classroom). These mindset beliefs can shape the psychological experiences, behavior, and performance of people within those contexts (Canning, Muenks, et al., 2019; Emerson & Murphy, 2015; Murphy & Dweck, 2010; Rattan et al., 2018).

Previous research has used different theoretical frameworks to conceptualize how students might perceive their classroom context—for example, some frameworks have focused on teacher expectancies (Raudenbush, 1984; Rosenthal & Jacobson, 1968), mastery versus performance goal structures (e.g., Ames & Archer, 1988; O'Keefe, Ben-Eliyahu, & Linnenbrink-Garcia, 2013), the cultural value of "brilliance" (Meyer, Cimpian, & Leslie, 2015), or how much teachers espouse "universal" (i.e., *everyone* can succeed) or "non-universal" (i.e., *only certain* people can succeed) beliefs (e.g., Rattan et al., 2018). Each of these theoretical perspectives demonstrate that students' perceptions of their teacher's beliefs and expectations strongly influence student outcomes. In the present studies, we focus on students' perceptions of their professors' mindset beliefs along the classic Dweckian dimension of the fixedness or malleability of intelligence (Dweck, 1999). That is, we examine how *students' perceptions of their STEM professors' mindset beliefs* influence students' classroom experiences, their engagement (e.g., class attendance and intentions to drop the course), their academic achievement, and their interest more generally in STEM. We theorize that, from the perspective of students, professors' mindset beliefs are salient cues as to both *what* is valued in the classroom (flawless, top performance vs. learning and development) as well as *who* is valued in the classroom (the innately smart students vs. the dedicated/improving students). Thus, we predict that students' perceptions of their professor's mindset beliefs would powerfully shape students' psychological experiences, engagement, and performance in their professor's class.

Negative Motivational and Performance Consequences of Fixed Mindsets

Decades of research has found that when students *themselves* endorse fixed mindset beliefs, it negatively influences their motivation and performance. That is, when students personally believe that intelligence is fixed and unchangeable, they tend to be less

motivated, exert less effort, and ultimately perform worse on challenging academic tasks compared with students who believe that intelligence is malleable (e.g., Haimovitz, Wormington, & Corpus, 2011; see Yeager & Dweck, 2012, for review). For example, Blackwell, Trzesniewski, and Dweck (2007) found that middle school students who personally endorsed fixed mindset beliefs were less motivated in school and had more negative performance trajectories over several years.

The mindset beliefs of powerful people in a setting can also reduce the motivation and engagement of people within that setting. Murphy and Dweck (2010) found that when people perceived that powerful individuals in an organizational context (an academic tutoring club) endorsed fixed (vs. growth) mindset beliefs, newcomers to that environment tended to present themselves as embodying the values of the fixed (vs. growth) mindset environment. That is, in fixed mindset tutoring clubs, newcomers highlighted their smarts and intelligence (and downplayed their motivation), whereas in growth mindset tutoring clubs, newcomers highlighted their motivation and history of overcoming challenges (and downplayed indicators of their intelligence; see also Canning et al., 2020; Emerson & Murphy, 2015). Taken together, this research suggests that fixed (vs. growth) mindset beliefs—both self-reported beliefs and those that are perceived to be espoused by others—are likely to result in less adaptive motivational, behavioral, and academic outcomes.

Student Experiences of Psychological Vulnerability

The present studies examine the influence of students' perceptions of STEM college professors' mindset beliefs on students' psychological experiences in their STEM classrooms. Research shows that most students care about being perceived as smart and competent by their teachers and professors (e.g., Covington, 2000; Ryan & Pintrich, 1997), so situational cues that threaten these competence perceptions—such as the fixed mindset beliefs of teachers or professors—should place students at risk for negative psychological experiences in the classroom. The evaluative concerns that result from perceiving one's professor to endorse more fixed mindset beliefs are not unfounded. In fact, previous research demonstrates that when faculty self-report endorsement of fixed mindset beliefs, they are more likely to diagnose students' math ability from a single performance (e.g., one negative test score means the student is not good at math), engage in demotivating pedagogical practices (Canning, Muenks, et al., 2019), and communicate that they have low expectations for struggling students (e.g., "It's okay—not everyone can be good at math"; Rattan, Good, & Dweck, 2012). Further, researchers have found that in evaluative situations, people's perceptions of others' fixed mindset beliefs predict greater self-doubt (Reich & Arkin, 2006), as well as lower feelings of belonging (Good et al., 2012).

Building from the concept of psychological safety in the organizational literature—defined as positive feelings of trust within an environment that make people feel safe enough to fully participate in a setting by speaking up, asking questions, and taking risks (e.g., Edmondson, 1999; Edmondson & Lei, 2014)—*psychological vulnerability* refers to the negative psychological experiences that result when psychological safety is low. The psychological experiences comprised by psychological vulnerability are multidimensional and include lower feelings of belonging, concerns about being negatively evaluated by others, feeling like an imposter in the setting, and experiencing greater negative affect (e.g., feeling more nervous, anxious, or distressed). When psychological vulnerability is high, it dampens motivation and causes people to doubt their competence in a setting. Importantly, powerful people in a setting—and people's perceptions of what these powerful individuals think and say—shape the environment; that is, powerful people in a setting create an environment of psychological safety or psychological vulnerability (Edmondson & Lei, 2014).

Previous research examining people's perceptions of others' mindset beliefs and students' classroom experiences has focused almost exclusively on students' sense of belonging (e.g., Good et al., 2012; Rattan et al., 2018), without exploring other aspects of psychological vulnerability. However, in classroom settings students' abilities are formally evaluated by their professor and these evaluations are quite consequential: shaping whether students can pursue certain course sequences, major pathways, and ultimately graduate with a degree. Thus, academic evaluative settings may engender several forms of psychological threat beyond sense of belonging. One significant critique of the psychological literature is that there is no single agreed-upon consensus about the optimal way to measure psychological threat. As is common across research domains, threat researchers have developed their own siloed interests—and those focused on belonging have focused on that particular instantiation without regard to other psychological concerns that are present in evaluative contexts (Murphy & Taylor, 2012). However, many other facets of psychological vulnerability exist and have been examined independently in the literature (see Murphy & Taylor, 2012, for a review). Thus, to move this literature forward, the present research goes beyond belonging to examine it as well as other components of psychological vulnerability that are specific to the academic domain, including students' evaluative concerns in the classroom, feelings of being an imposter in the classroom, and more diffuse experiences of negative affect. One of the contributions of this work is to examine psychological vulnerability as a measure of psychological threat that includes many theorized facets—and to show, at the same time, how each individual facet operates independently so that researchers can begin to consider psychological vulnerability as a multidimensional construct.

Specifically, we predict that when students perceive that their professor endorses more fixed mindset beliefs, they may feel that they do not *belong* in the classroom (Murphy & Zirkel, 2015) and may experience greater *evaluative concerns* such as being afraid of saying or doing the wrong thing lest they risk being outed as one of the students who is not "naturally intelligent" (e.g., Frost, Heimberg, Holt, Mattia, & Neubauer, 1993). Students may also worry about being discovered as an *imposter* if they struggle with the material or are unable to answer questions in class (e.g., Clance & Imes, 1978). They may experience more *negative affect* such as greater feelings of anxiety or distress while in that professor's class, such as when they hope they are not called on if they are uncertain about their answers (Pekrun & Linnenbrink-Garcia, 2012). Thus, we examine psychological vulnerability as a psychological threat to students' self-concepts of being smart, competent, and capable in school.

Given the hierarchical power structure of the classroom and the importance that students place on being perceived as competent in classroom settings, we predict that students' perceptions of their

professors' mindset beliefs might affect students' experiences of psychological vulnerability—even above and beyond their own personal mindset beliefs. That is, even if students personally believe that intelligence is changeable, they may still feel concerned and anxious in a classroom where the professor believes that intelligence is fixed. We directly examine these questions.

Psychological Vulnerability Suppresses Engagement and Performance

What are the consequences of experiencing psychological vulnerability in class? Prior research has found that lower belonging and greater evaluative concerns are associated with withdrawal and disengagement from the context (e.g., Pekrun & Linnenbrink-Garcia, 2012; Ryan & Pintrich, 1997; Walton & Cohen, 2007), lower interest (e.g., Meece, Wigfield, & Eccles, 1990), and lower performance (e.g., Derakshan & Eysenck, 2009; Pekrun, Elliot, & Maier, 2009). In the domain of STEM in particular, research demonstrates that if students lose interest, feel disengaged, or perform poorly in their STEM classes, they are more likely to leave STEM fields altogether (Chen, 2013; Maltese & Tai, 2011; Sadler, Sonnert, Hazari, & Tai, 2012). Thus, students' in-class experiences could have important consequences for their classroom engagement (i.e., course effort and attendance) and performance in those particular STEM classes and may ultimately affect their interest and decision to remain in—or drop out of—the STEM pipeline altogether.

Thus, we predict that students' psychological vulnerability (i.e., lower belonging, greater evaluative concerns, imposter feelings, and negative affect) will reduce students' engagement, interest, and academic performance. That is, we predict that when students experience more psychological vulnerability in their STEM class they will be less likely to attend that class, consider dropping the class more often, report lower levels of interest in the class and the field, and anticipate and actually perform worse in these courses.

The Present Studies

The present studies examine how college students' perceptions of their STEM professors' mindset beliefs influence students' psychological experiences, behavior, and performance in their STEM classes. We recently showed that when STEM faculty endorse fixed (vs. growth) mindset beliefs, students perform more poorly in those professors' classes (Canning, Muenks, et al., 2019). There could be several plausible reasons for this finding. For example, the course might be structured such that an initial struggle or setback cannot be overcome, leading to lower grades among students who start off poorly. However, an equally plausible and more psychologically relevant mechanism is through the ways in which students' perceptions of their professors' mindset beliefs shape students' psychological experiences. This report is a deep dive into these psychological mechanisms examining *how* faculty mindset beliefs shape students' psychological experiences, engagement, and performance in class. Thus, a main contribution of this work is to offer greater insight into the role that students' perceptions of others' beliefs—an often ambiguous situational cue—can have on students' engagement and performance.

Studies 1 and 2 experimentally investigate the link between students' perceptions of STEM professors' mindset beliefs and students' anticipated psychological vulnerability in those professors' classrooms. These experiments help establish the internal validity of our conceptual model (see Figure 1). Study 1 manipulates STEM professors' mindset beliefs via first-day-of-class videos in which a professor introduces their course and reviews the syllabus, and measures two facets of psychological vulnerability (students' sense of belonging and their evaluative concerns) as well as their engagement, interest, and performance in that professor's class. Study 2 replicates Study 1 and includes all four facets of psychological vulnerability and two additional course outcomes that we assess in the field in Studies 3 and 4.

Studies 3 and 4 are two longitudinal field studies that establish the external validity of our model. That is, we examine whether college students' perceptions of their actual STEM professors' mindset beliefs predict their experiences in their actual STEM classes. Study 3 is a pilot study that we ran to establish the reliability of our measures and the feasibility of the experience-sampling methodology in these class contexts. Study 3 establishes an initial real-world link between students' perceptions of their STEM professors' mindset beliefs and students' in-the-moment

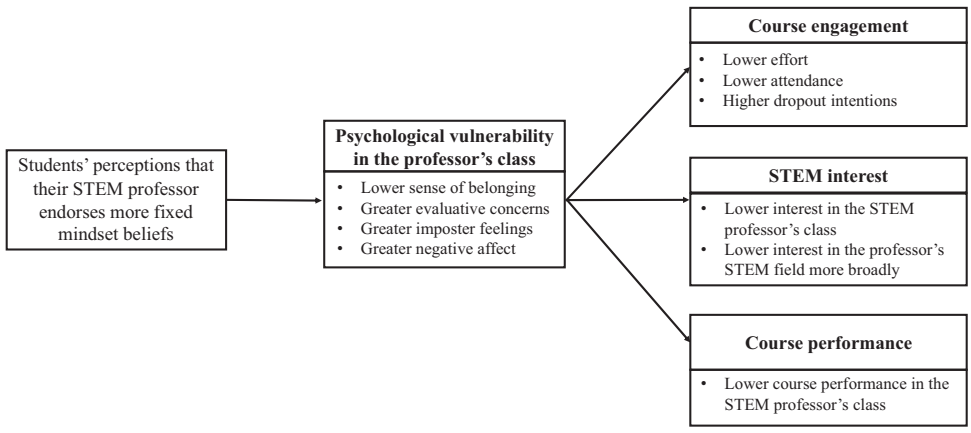

Figure 1. Theoretical Model: How students' perceptions of their professors' mindsets influence students' psychological experiences, engagement, interest, and performance. STEM = science, technology, engineering, and mathematics.

psychological vulnerability in STEM classes by examining the perceptions and psychological experiences of students enrolled in STEM classes at three U.S. universities. Study 4 improves on Study 3 by mapping students' perceptions of their professor's beliefs to their specific course-related achievement outcomes in a fourth university context and controlling for students' more general perceptions of how warm or competent their professor is. Study 4 finds consistent evidence for the link between perceived professor mindset and students' psychological vulnerability and extends Study 3 by examining how in-the-moment psychological vulnerability predicts students' downstream engagement, interest, and performance in their classes.

In these studies, we are able to examine how both *objective and subjective* information impact students' perceptions of their professors' beliefs. Whereas Studies 1 and 2 examine how *objective* information (i.e., what the professor says and does is held constant within condition and differs between conditions) impacts students' anticipated psychological experiences, motivation, and anticipated performance, Studies 3 and 4 examine how students' *subjective* perceptions of their professors' mindset beliefs—as they naturally exist in students' actual college classroom settings—predict these same outcomes in real-world learning environments. Across all studies, we hypothesize that students who learn or perceive that their STEM professors endorse more fixed mindset beliefs will experience greater in-the-moment psychological vulnerability (e.g., less belonging; more evaluative concerns, imposter feelings, and negative affect), which will, in turn, predict lower engagement and performance in courses taught by those particular STEM professors.

These studies innovate beyond prior research in several important ways. First, by examining both college students' experimentally manipulated (Studies 1 and 2) and naturally occurring (Studies 3 and 4) perceptions of their professors' mindset beliefs in classroom contexts, these studies extend previous research that simply manipulated the mindset of organizations in a laboratory environment via mission statements or club meeting minutes (e.g., Canning et al., 2020; Emerson & Murphy, 2015; Murphy & Dweck, 2010). Unlike in social and academic clubs (e.g., Murphy & Dweck, 2010), in classroom settings students' abilities are formally evaluated by their professors. Thus, we examine faculty mindsets as a novel situational cue that influences students' outcomes in evaluative academic settings.

Second, in Studies 3 and 4, we employ experience sampling methodology (ESM) to assess students' in-the-moment experiences of psychological vulnerability in their actual STEM classrooms in an ecologically valid way. This method allows students to report their experiences as they are happening, which provides more accurate assessments of what students are thinking, feeling, and doing in the moment compared with retrospective reports that suffer from common biases in retrieval. That is, in addition to asking students to anticipate how they would feel (as in Studies 1 and 2), the ESM method provides convergent evidence that captures students' actual experiences in their classrooms in real time (e.g., Zirkel, Garcia, & Murphy, 2015). To our knowledge, no other studies have used ESM methods when examining how students' perceptions of professors' mindset beliefs predict students' in-class psychological experiences.

Third, we innovate in the measurement of psychological vulnerability by assessing additional theorized facets of self-threat that may be particularly salient in academic contexts. We examine how psychological vulnerability—as a multidimensional construct—is shaped by students' perceptions of their professors' mindset beliefs. In addition to belonging (e.g., Good et al., 2012), we also examine students' evaluative concerns, imposter feelings, and affective experiences during class. Thus, one of the central contributions of this paper is that we more fully capture the range of students' psychological experiences that stem from perceived faculty mindsets—more so than any other report to date. Finally, Study 4 goes beyond previous research by examining how perceived faculty mindsets and psychological vulnerability longitudinally predict students' behavior and performance—including their class attendance, dropout intentions, grades, and field-specific interest more broadly.

In sum, extending this work to the educational domain, operationalizing mindset as a contextual factor in a college classroom setting as communicated directly by the professor through first-day-of-class lecture videos (Studies 1–2) or in students' actual classroom settings (Studies 3–4), and examining psychological vulnerability as an outcome that goes beyond belonging provide critical theoretical, empirical, and methodological contributions to the literature and our understanding of how perceived mindset beliefs function in academic contexts. Ultimately, this work has the potential to inform future interventions with faculty, staff, and administrators who can, perhaps unintentionally, communicate fixed mindset beliefs to students. Future interventions could work with these institutional leaders to help them understand the role that their mindset beliefs play in shaping students' experiences of psychological vulnerability, engagement, and performance. Such interventions could help institutional actors adopt and communicate their growth mindset beliefs, thereby creating a more psychologically safe learning environment for all students.

To maximize power and generalizability across studies, we collected data from diverse samples of college students, recruited through an online survey company (Studies 1 and 2) and from four different universities across the United States (Studies 3 and 4). We used theoretically driven measures with strong internal consistency across studies, and in our experimental studies (Studies 1 and 2) we included attention checks and excluded participants who failed these checks to minimize noise in the data (e.g., Oppenheimer, Meyvis, & Davidenko, 2009) and provide more precise estimates of our effects. We also reported sensitivity analyses for each study that provide an estimate of the smallest effect size that can be detected given particular conditions (e.g., sample size, power, alpha, type of test; Faul, Erdfelder, Buchner, & Lang, 2009). Sensitivity analyses are useful when studying novel effects or relationships, because they do not require researchers to specify a priori effect sizes. They are also useful for field studies (such as Studies 3 and 4), in which sample sizes were not predetermined or cut off at a certain number of participants (i.e., all participants who were eligible and agreed to participate were included in the sample).

Study 1

Study 1 was designed to provide an initial experimental test of the link between students' perceptions of STEM professors' mindset beliefs and their anticipated psychological vulnerability in those professors' classes, as well as their anticipated engagement, interest, and performance there. Students watched a short video

clip of a Calculus professor who either endorsed more fixed mindset beliefs (i.e., ability is fixed—you either have it, or you do not), more growth mindset beliefs (i.e., ability can be developed), or no mindset beliefs at all (i.e., a control professor). Because most college students care about being perceived as smart and competent (Covington, 2000; Ryan & Pintrich, 1997), we hypothesized that students would experience more psychological vulnerability (e.g., less belonging and greater evaluative concerns) when exposed to a STEM professor who endorsed more fixed (vs. growth) mindset beliefs, and compared with when they had no information about the STEM professor's mindset beliefs. Further, we hypothesized that greater anticipated psychological vulnerability would predict lower anticipated course engagement, interest, and performance.

Method

Participants. Participants were 255 Prolific workers who indicated in a prescreening survey administered by Prolific that they were currently enrolled in college. Three participants did not indicate their gender and were thus excluded from analyses, leaving a final sample size of 252 participants (M_{age} = 24.12 years; 50% female; 63.5% White, 7.5% African American/Black; 6.3% East Asian; 4.8% Southeast Asian; 3.2% Hispanic; 3.6% Indian Subcontinent; 0.4% Native American; 8.3% Mixed race; 0.4% Middle Eastern; 2.0% Other).[1] To ensure that we had adequate power to detect effects we performed a sensitivity analysis using G*Power 3.1 to obtain an estimate of the smallest detectable effect size given our sample size with a power of .80, alpha of 0.05, and two-tailed tests (Faul et al., 2009; Faul, Erdfelder, Lang, & Buchner, 2007). Results of this analysis confirmed that we were adequately powered to detect effect sizes as small as d = .39.

Procedure. Institutional Review Board (IRB) approval was obtained prior to data collection. Students were invited to participate in a study about their opinions of college courses. They were randomly assigned to watch one of three short video clips from the first day of a Calculus course in which the mindset manipulations were embedded. In these course introduction videos, the same actor (an older White man[2]) read several sections of his syllabus regarding his beliefs about what it took to do well in the class and his expectations of students (see the online supplemental materials for the class description and video scripts). Interspersed through the professor's remarks were comments suggesting that he either endorsed (a) fixed mindset beliefs (e.g., "In this course, you either know the concepts and have the skills, or you don't"), (b) growth mindset beliefs ("These assignments are designed to help you improve your skills throughout the semester"), or (c) no mindset beliefs. These faculty statements were generated by separate groups of college students (N = 40) who participated in focus groups and provided examples about the statements faculty made in class that caused them to believe that their professors endorsed more fixed or growth mindset beliefs.[3] After watching the randomly assigned video, students completed a brief survey that included our dependent variables, were debriefed, and compensated for their participation.

Measures. The full text of all measures and manipulations can be found in the online supplemental materials.

Professor mindset manipulation check. To assess whether students perceived the manipulation as intended, students responded to four items adapted from Dweck (1999) about their perceptions of the professor's mindset (e.g., "The professor in this class seems to believe that students have a certain amount of intelligence, and they really can't do much to change it") on a scale from 1 (*strongly disagree*) to 6 (*strongly agree*). Items were recoded so that higher values indicated stronger fixed mindset perceptions and averaged to form a composite (α = .90).

Demographics. Students self-reported their gender (0 = male, 1 = female) and race/ethnicity, which we then coded to denote underrepresented racial minority (URM) group membership (0 = White, East Asian, and Southeast Asian students; 1 = Black, Hispanic, Indian Subcontinent, Native American, Mixed race, Middle Eastern, and Other race students). Because previous research has found mean-level differences in students' belonging and evaluative concerns in STEM settings based on their gender and race (e.g., Murphy & Zirkel, 2015; Rudolph & Conley, 2005), we coded and controlled for these factors in our analyses so that we could observe the effect of faculty mindset above and beyond these potential group differences.

Personal mindset beliefs. Four items (Dweck, 1999) assessed students' own mindset beliefs (e.g., "You have a certain amount of intelligence, and you can't really do much to change it"; α = .90) rated on a scale from 1 (*strongly agree*) to 6 (*strongly disagree*). We recoded values such that higher values indicated greater fixed mindset beliefs. In our analyses, we controlled for students' personal mindset beliefs because much previous research has found that people's personal mindset beliefs influence their experiences and behavior (e.g., Blackwell et al., 2007; see Yeager & Dweck, 2012, for a review) and we aimed to examine the effect of faculty mindset above and beyond students' personal mindset beliefs.

[1] Due to a survey error, 65 participants did not report their age; the mean age here is based on N = 187 participants.

[2] We chose to feature the STEM professor as an older White man because that is who is most likely to teach STEM classes in college settings (e.g., Li & Koedel, 2017).

[3] We examined alternative post hoc explanations for our findings that perhaps the fixed and growth mindset professors differed on other dimensions (that might covary with faculty mindset). To examine this question, we asked an independent sample of students (N = 151) to rate the professor in the videos on the two primary person-perception dimensions of competence and warmth (Fiske, Cuddy, & Glick, 2007; competence: *intelligent*, *capable*, *competent*; warmth: *friendly*, *likeable, warm*) as well as students' willingness to trust the professor (e.g., *I would trust this professor*) and students' perceptions of the authenticity of the professor's behavior in the videos (e.g., *I think this professor was being authentic*). We found that none of the three competence perceptions varied by faculty mindset condition, ts(149) < 1.18; ps > .240. Of the warmth perceptions, *likeable* did not differ by condition, t(149) = 1.76, p = .080; however, the growth mindset professor was perceived as more *warm* and *friendly* than the fixed mindset professor, t(149) = 4.33, p < .001, and t(149) = 4.87, p < .001, respectively. We found no significant condition differences in response to the trust and authenticity perceptions, t(149) = 1.74, p = .083, and t(149) = 1.17, p = .243, respectively. Taken together, the fixed and growth mindset professors were perceived as equally intelligent, capable, competent, and likeable; students trusted them equally and perceived them to be behaving in equally authentic ways; however, the growth mindset professor was perceived as more warm and friendly than the fixed mindset professor. Given that these perceptions were relatively inconsistent across faculty mindset condition, it is unlikely that they account for the faculty mindset effects reported in Studies 1 and 2. However, in Study 4 we address this potential limitation directly by measuring perceived warmth and competence of the professor and controlling for these perceptions in our analyses. In Study 4, all faculty mindset effects with the exception of negative affect hold above and beyond these warmth and competence perceptions.

Psychological vulnerability. To assess students' anticipated psychological vulnerability in the professor's class, we measured their anticipated feelings of *belonging* using five items adapted from Murphy and Zirkel (2015; e.g., "How much would you feel that you 'fit in' during this class?"; $\alpha = .88$). We also measured their anticipated *evaluative concerns* using five items adapted from Wout, Murphy, and Steele (2010; e.g., "How much would you worry that you might say the wrong thing in class?"; $\alpha = .90$). Both scales ranged from 1 (*not at all*) to 7 (*extremely*). A composite was created by averaging the belonging and evaluative concerns items ($\alpha = .92$); higher numbers indicated greater anticipated psychological vulnerability in the professor's class.

Course engagement. Anticipated course engagement was assessed by asking students how motivated and willing they would be to put in effort in the professor's course using a three-item measure (e.g., "I think I would be willing to put in extra effort if the professor asked me to"; $\alpha = .79$). Items were rated on a scale ranging from 1 (*strongly disagree*) to 8 (*strongly agree*) and averaged to form a course engagement composite; higher scores indicate more course engagement.

Course interest. To assess anticipated course interest, students completed a three-item measure (e.g., "How interested would you be in taking a class taught by the professor?"; $\alpha = .95$). The scale ranged from 1 (*not at all*) to 6 (*extremely*) and items were averaged to form a course interest composite; higher scores indicate more course interest.

Course performance. To assess anticipated course performance, students completed a three-item measure ("I think I would get a good grade in this class"; $\alpha = .86$). The scale ranged from 1 (*strongly disagree*) to 8 (*strongly agree*); items were averaged to form an anticipated performance composite; higher scores indicate greater anticipated performance.

Results

Analysis plan. Table 1 includes descriptive statistics and correlations among all variables. To analyze the manipulation check, we used an analysis of covariance (ANCOVA) and for the remaining analyses, we employed analyses of covariance (ANCOVAs) with students' personal mindset beliefs ($M = 2.96$, $SD = 1.14$), their gender (0 = male, 1 = female), and their race (0 = White, East Asian, and Southeast Asian students; 1 = Black, Hispanic, Indian Subcontinent, Native American, Mixed race, Middle Eastern, Other race students) entered as covariates.[4] Table 2 includes summary statistics from the ANCOVA analyses across variables. For transparency, Table S1 in the online supplemental materials includes summary statistics for all analyses without covariates. The significance of the main effects of professor mindset and the pairwise condition comparisons were identical to what we report here, with the exception of the effect of the growth mindset (vs. control) professor on evaluative concerns, which became marginally significant ($p = .06$). Figure 2 depicts condition differences across variables.[5]

Professor mindset manipulation check. Before conducting the primary analyses, we examined whether students perceived the professor's manipulated mindset beliefs as intended. Results revealed a significant effect of condition, $F(2, 249) = 125.44$, $p < .001$, $d = 2.01$, such that the fixed mindset professor ($M = 4.10$, $SD = .90$) was perceived as endorsing significantly more fixed mindset beliefs than both the growth mindset professor ($M = 1.99$, $SD = .88$; $p < .001$, $d = 2.36$) and the control professor ($M = 2.91$, $SD = .79$; $p < .001$, $d = 1.40$). The control professor was also perceived as endorsing significantly more fixed mindset beliefs than the growth mindset professor ($p < .001$, $d = -1.10$).

Psychological vulnerability. To begin our primary analyses, we examined the facets of students' anticipated psychological vulnerability in the professor's course.

Belonging. Students anticipated feeling significantly less belonging in the course when it was taught by the fixed mindset professor ($M = 3.63$, $SE = .13$) compared with the growth mindset professor ($M = 4.82$, $SE = .13$; $p < .001$; $d = -1.02$) and the control professor ($M = 4.34$, $SE = .13$; $p < .001$; $d = -.61$). Moreover, students anticipated feeling significantly more belonging in the course when it taught by the growth mindset professor relative to the control professor ($p = .009$; $d = .41$).

Evaluative concerns. Students expected to experience significantly more evaluative concerns in the course when it was taught by the fixed mindset professor ($M = 4.62$, $SE = .15$) relative to both the growth mindset professor ($M = 3.24$, $SE = .15$; $p < .001$; $d = 1.01$) and the control professor ($M = 3.70$, $SE = .15$; $p < .001$; $d = .68$). However, students expected to experience significantly lower evaluative concerns when the course was taught by the growth mindset professor compared with the control professor ($p = .033$; $d = -.33$).

When we combined both facets of students' psychological experience into a psychological vulnerability composite we found that, in line with our predictions, students anticipated significantly more psychological vulnerability when the course was taught by the fixed mindset professor ($M = 4.50$, $SE = .13$) compared with the growth mindset professor ($M = 3.22$, $SE = .13$; $p < .001$; $d = 1.11$) and the control professor ($M = 3.68$, $SE = .13$; $p < .001$; $d = .71$). Moreover, students anticipated less psychological vulnerability when the course was taught by the growth mindset professor compared with the control professor ($p = .010$; $d = -.40$).

Course engagement. Students were significantly less likely to anticipate applying effort in the course when it was taught by the fixed mindset professor ($M = 4.87$, $SE = .15$) compared with the growth mindset professor ($M = 5.78$, $SE = .15$; $p < .001$;

[4] See Table S4 in the online supplemental materials for gender and race differences across all variables. Women reported higher psychological vulnerability and evaluative concerns and lower anticipated course performance than did men, overall. URM students reported more course engagement than did non-URM students.

[5] Although the experimental design allows us to examine how *objective* information about professors' mindset beliefs shapes students' outcomes, a reviewer pointed out that we are also able to examine whether students' *subjective* perceptions of their professors' mindset beliefs also predicted students' anticipated psychological vulnerability, engagement, and performance. To examine these subjective perceptions, we conducted regression analyses with the perceived professor mindset measure as a predictor (instead of condition). Results revealed that students' perceptions of the professor's mindset significantly predicted all outcome variables in both Study 1 and Study 2 (Bs $> .10$, ps $< .02$). Thus, objective information about faculty mindsets (i.e., the experimentally controlled videos) impacted students' subjective perceptions of their professors' mindset beliefs and, these subjective perceptions also influenced students' anticipated classroom experiences. See Table S5 in the online supplemental materials for the detailed results of these analyses.

Table 1
Means, Standard Deviations, Ranges, Reliability Coefficients, and Correlations for All Variables: Study 1

Variable	1	2	3	4	5	6	7	8	9	10
1. Perc. of fixed prof mindset										
2. URM	−.05									
3. Gender	−.03	.00								
4. Personal fixed mindset	−.01	−.09	−.11							
5. Vulnerability composite	.58**	.05	.11	−.05						
6. Belonging	−.57**	−.01	−.07	.04	−.91**					
7. Evaluative concerns	.50**	.08	.12	−.05	.94**	−.71**				
8. Course engagement	−.38**	.15*	−.04	−.13*	−.42**	.53**	−.28**			
9. Course interest	−.54**	.04	−.07	.01	−.62**	.70**	−.47**	.65**		
10. Course performance	−.43**	−.01	−.12*	−.07	−.70**	.71**	−.60**	.55**	.60**	
M	3.00	N/A	N/A	2.96	3.80	4.26	3.85	5.24	3.26	5.24
SD	1.21	N/A	N/A	1.14	1.27	1.26	1.48	1.42	1.37	1.54
Range	1–6	0–1	0–1	1–6	1–7	1–7	1–7	1–8	1–6	1–8
Reliability coefficient	.90	N/A	N/A	.90	.92	.88	.90	.79	.95	.86

Note. Perc = perception; prof = professor. Underrepresented racial minority (URM) status was coded 0 = White, East Asian, Southeast Asian, 1 = Black, Hispanic, Indian Subcontinent, Native American, Mixed race, Middle Eastern, Other race. Gender was coded 0 = male, 1 = female.
* $p < .05$. ** $p < .01$.

$d = -.74$). In addition, students were significantly less likely to anticipate applying effort when the course was taught by the control professor compared with the growth mindset professor ($M = 5.09$, $SE = .15$; $p = .001$; $d = -.51$). However, students' anticipated engagement did not significantly differ when the course was taught by the fixed mindset professor and the control professor ($p = .288$; $d = -.23$).

Course interest. Students were significantly less interested in taking the course when it was taught by the fixed mindset professor ($M = 2.53$, $SE = .14$) compared with the growth mindset professor ($M = 4.00$, $SE = .14$; $p < .001$; $d = -1.18$) and the control professor ($M = 3.27$, $SE = .14$; $p < .001$; $d = -.59$). Students were significantly more interested in taking the course when it was taught by the growth mindset professor compared with the control professor ($p < .001$; $d = .58$).

Course performance. Finally, we examined students' anticipated course performance. Students expected to perform significantly worse in the course when it was taught by the fixed mindset professor ($M = 4.59$, $SE = .16$) compared with the growth mindset professor ($M = 5.68$, $SE = .16$; $p < .001$; $d = -.75$) and the control professor ($M = 5.45$, $SE = .16$; $p < .001$; $d = -.59$). However, students anticipated performing equally well in the course when it was taught by the growth mindset professor and the control professor ($p = .302$; $d = .16$).[6]

Mediation analyses. Several mediation models examined whether faculty mindset condition predicted students' anticipated psychological vulnerability in class, which in turn predicted their anticipated course engagement, interest, and performance (Figure 1 depicts the theorized models). To conduct these analyses, we used the PROCESS macro in SPSS (Model 4; Hayes, 2017) with bias-corrected 95% confidence intervals computed with 5,000 bootstrap resamples. In each model, professor mindset (the dichotomous condition variable; 0 = growth, 1 = fixed) was entered as the predictor (X), psychological vulnerability was entered as the mediator (M), and separate models were run with anticipated course engagement, interest, and performance as the outcome (Y) variables. Consistent with the analyses above, all models controlled for underrepresented racial minority status, gender, and personal fixed mindset beliefs, although Table S3 in the online supplemental materials provides results without covariates (excluding covariates does not change the pattern of results).

Results revealed that students' anticipated psychological vulnerability had a significant indirect effect on all course outcomes. That is, students expected to experience more psychological vulnerability in the course when it was taught by the fixed (vs. growth) mindset professor, which in turn reduced their course engagement, *indirect effect* = −.58, *SE* = .17, 95% CI [−.96, −.28], interest in taking the course, *indirect effect* = −.80, *SE* = .14, 95% CI [−1.08, −.53], and anticipated performance, *indirect effect* = −1.05, *SE* = .21, 95% CI [−1.48, −.68].[7]

Discussion

Study 1 supported the prediction that students who are exposed to professors who endorse more fixed mindset beliefs anticipate significantly more psychological vulnerability (i.e., less belonging and more evaluative concerns) and more negative course outcomes (i.e., lower anticipated course engagement, interest, and performance) in the professor's class compared with a growth mindset professor's class and compared with when students had no information about the professor's mindset beliefs. Further, in support of our theoretical model (see Figure 1), professors' mindset beliefs had a significant indirect effect on students' course outcomes, with greater psychological vulnerability being associated with more negative course outcomes.

By including a no mindset beliefs control condition, this study design allowed us to learn that the observed effects are driven both

[6] We tested whether participant race or gender moderated any of these effects and found no evidence of moderation (see Table S6 in the online supplemental materials for these analyses).

[7] Although we report the central mediation models of interest in the main text (with the psychological vulnerability composite as a mediator), Table S2 in the online supplemental materials provides a summary of all results (including separate mediation models with each psychological component as a mediator in case readers are interested in just one component of psychological vulnerability).

Table 2
Summary ANCOVA Analyses Results: Study 1

	Condition			URM			Gender			Personal fixed mindset		
Variable	*F*(2, 246)	*p*	*d*	*F*(1, 246)	*p*	*d*	*F*(1, 246)	*p*	*d*	*F*(1, 246)	*p*	*d*
Vulnerability composite	25.58	<.001	.91	.93	.335	.13	6.03	.015	.31	.16	.649	.06
Belonging	21.25	<.001	.83	.09	.768	<.01	3.18	.076	.23	.12	.726	<.01
Evaluative concerns	21.42	<.001	.83	1.96	.163	.18	6.81	.010	.33	.13	.717	.06
Course engagement	10.05	<.001	.57	3.86	.051	.25	1.36	.244	.16	6.19	.013	.32
Course interest	27.94	<.001	.95	.13	.716	.06	3.46	.064	.24	.75	.389	.11
Course performance	12.69	<.001	.64	.07	.796	<.01	7.10	.008	.34	4.40	.037	.27

Note. ANCOVA = analysis of covariance. Underrepresented racial minority (URM) status was coded 0 = White, East Asian, Southeast Asian, 1 = Black, Hispanic, Indian Subcontinent, Native American, Mixed race, Middle Eastern, Other race. Gender was coded 0 = male, 1 = female. URM, gender, and personal fixed mindset were included as covariates.

by exposure to the fixed mindset professor who significantly *increased* students' psychological vulnerability relative to the control professor *and* by exposure to the growth mindset professor who significantly *decreased* students' psychological vulnerability relative to the control professor. Thus, it seems not only the case that perceiving a professor to have a fixed mindset will lead to more negative outcomes—but also that perceiving a professor to have a growth mindset will lead to more positive outcomes. This suggests that if professors wish to create psychologically safe learning environments, they should actively and affirmatively communicate stronger growth mindset beliefs.

Overall, the results of Study 1 suggest that the mindset beliefs that instructors communicate to their students shapes their anticipated psychological vulnerability and downstream course outcomes. However, Study 1 only examined two facets of students' experiences of psychological vulnerability (belonging and evaluative concerns) and three course outcomes (anticipated engagement, interest, and performance) and therefore may be missing other important psychological experiences and outcomes that are shaped by students' perceptions of their professor's mindset beliefs.

Study 2 includes two additional facets of psychological vulnerability that have been shown to predict students' motivation and

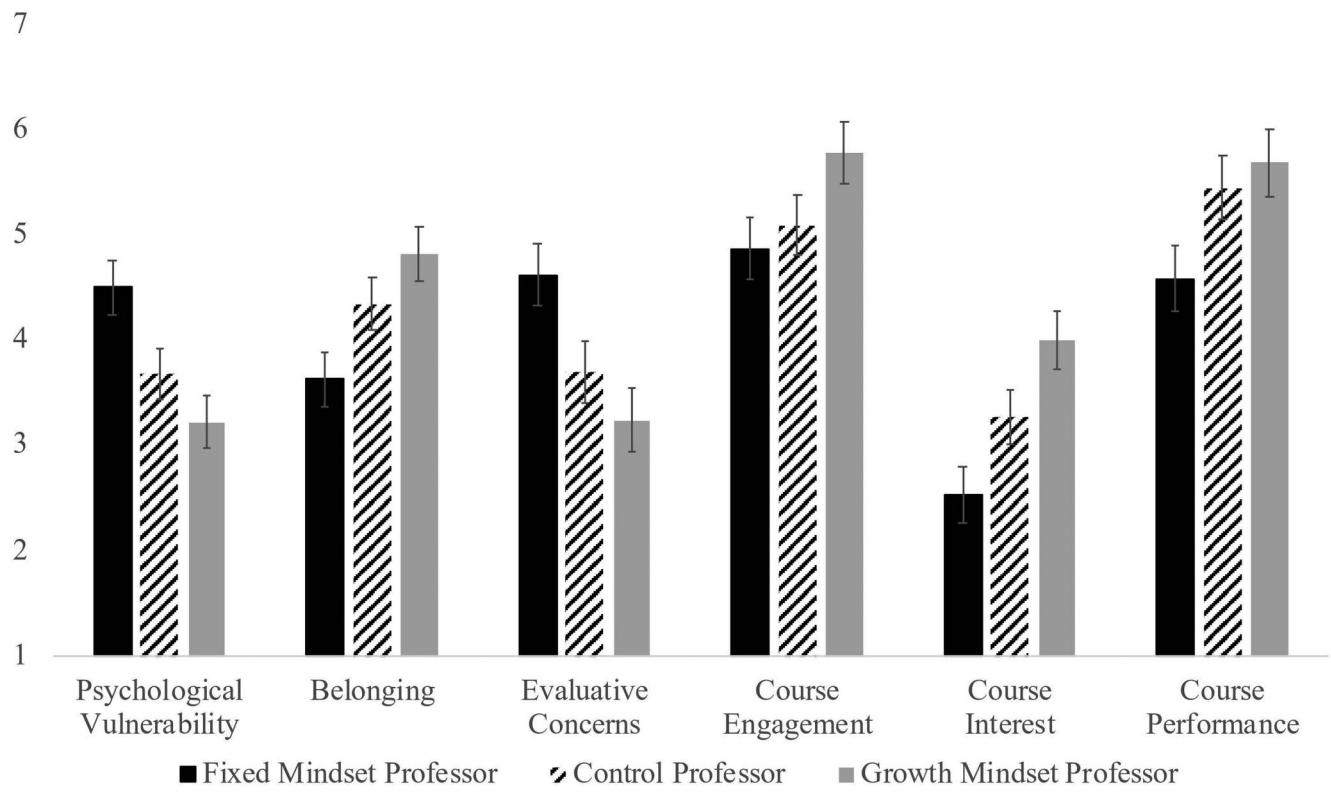

Figure 2. Study 1. Students anticipate more psychological vulnerability (lower belonging and greater evaluative concerns), less engagement and interest, and lower performance when a course is taught by a professor who endorses fixed (vs. growth) mindset beliefs. Bars represent 95% confidence intervals.

performance: students' concerns about being a fraud or imposter in class (e.g., Clance & Imes, 1978), and students' negative affect (such as feeling anxious or distressed; Pekrun & Linnenbrink-Garcia, 2012). We also examine two additional course outcomes that more directly relate to students' likely behavior: students' anticipated attendance in class and their intentions to drop the class. Even if students *feel* engaged or interested, they are unlikely to succeed if they do not attend class—and certainly will not succeed if they drop the class. Therefore, we were interested in whether students' anticipated psychological vulnerability would also predict these more behavioral course outcomes.

Study 2

The goal of Study 2 was to replicate and extend Study 1 by including two additional facets of psychological vulnerability (i.e., imposter feelings and negative affect) and two new course outcomes (i.e., course attendance and dropout intentions) that we also assessed in the field (Studies 3 and 4). The design and procedure were similar to Study 1: students watched a short video clip of a Calculus professor who either espoused fixed mindset beliefs (i.e., ability is fixed—you either have it, or you do not), or growth mindset beliefs (i.e., ability can be developed). Because Study 1 established the validity of the professor's mindset manipulation by demonstrating that both were significantly different from control, we only focused on the two main conditions of interest—fixed and growth mindset beliefs—in Study 2.

We expected to replicate Study 1's results such that students who were exposed to a STEM professor who endorsed more fixed (vs. growth) mindset beliefs would anticipate more psychological vulnerability, which would in turn predict lower anticipated course engagement and performance. We also predicted that the expanded measure of psychological vulnerability (that also included students' feelings of being an imposter in class and students' anticipated negative affect) would predict the new anticipated behavioral outcomes of students' attendance and dropout intentions.

Method

Participants. Data was collected from 244 Prolific workers who indicated in a prescreening survey administered by Prolific that they were currently enrolled in college. Eighteen participants failed the attention check and were excluded from analyses, and two participants did not report their gender. Therefore, our final sample consisted of 224 students (M_{age} = 24.81 years; 50.4% female; 73.66% White, 4.5% Indian Subcontinent; 4.0% African American/Black; 3.1% Hispanic; 2.2% Southeast Asian; 2.7% East Asian; 1.8% Middle Eastern; 7.1% Mixed Race; 0.9% Other race). As in Study 1, we performed a sensitivity analysis to obtain an estimate of the smallest detectable effect size given our sample size with a power of .80, alpha of 0.05, and two-tailed tests (Faul et al., 2007, 2009). Results of this analysis confirmed that we were adequately powered to detect effect sizes as small as d = .38.

Procedure. IRB approval was obtained prior to data collection. The procedure was similar to Study 1. Students were invited to participate in a study about their opinions of college courses and were randomly assigned to watch either the growth or fixed mindset video clip described in Study 1 (the online supplemental materials include the class description and video scripts). After watching the randomly assigned video, students completed a brief survey that included our dependent variables, including the two additional facets of psychological vulnerability (imposter feelings and negative affect) and two additional course outcomes (anticipated course attendance and dropout intentions) that were not included in Study 1. They were then debriefed and compensated for their participation.

Measures. The full text of all measures and manipulations can be found in the online supplemental materials.

Professor mindset manipulation check. The same four-item measure was used to assess students' perceptions of the professor's mindset beliefs manipulation (α = .92).

Demographics. Students reported their gender and URM status using the same measures as Study 1. We controlled for gender and URM status in all analyses.

Personal mindset beliefs. Students reported their personal mindset beliefs with the same four items as Study 1 (α = .88). We controlled for students' personal mindset beliefs in all analyses.

Psychological vulnerability. To assess students' anticipated psychological vulnerability, we measured their feelings of *belonging* (five items; α = .89) and *evaluative concerns* (five items; α = .91) using the same items as Study 1. We also added additional facets of psychological vulnerability from the literature that we also measured in the field (Studies 3 and 4): feeling as though one is an imposter in the class and general negative affect. *Imposter feelings* were assessed using four items adapted from Leary, Patton, Orlando, & Funk, (2000; e.g., "I think I would feel like people might find out that I am not as capable as they think I am"; α = .86) rated on a scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). *Negative affect* was assessed using three items adapted from Watson and colleagues (1988; e.g., "In this class, I would feel nervous, distressed, upset"; α = .85) rated on a scale ranging from 1 (*not at all*) to 4 (*extremely*).[8] A psychological vulnerability composite was created by *z*-scoring (because response scales differed) and then averaging the belonging, evaluative concerns, imposter feelings, and negative affect composites (α = .94), with higher numbers indicating greater anticipated psychological vulnerability in the professor's class.

Course outcomes. Students reported their anticipated course engagement (α = .85), course interest (α = .94), and course performance (α = .87) using Study 1's measures.

Course attendance. To assess students' anticipated course attendance, students responded to one item using a 1 (*never*) to 5 (*always*) scale: "In this class, how often would you attend class?"

Dropout intentions. To assess students' thoughts about dropping the course, students responded to one item using 1 (*never*) to 5 (*always*) scale: "In this class, how often would you think about dropping out of the class?"

[8] We also measured positive affect in this study and in Studies 3 and 4. Although perceived professor fixed mindset negatively influenced students' experiences of positive affect in Study 2, perceived professor mindset beliefs did not predict students' experiences of positive affect in the field (Studies 3 and 4). This suggests that faculty mindset beliefs more strongly shape students' anticipated *negative* psychological experiences (i.e., psychological vulnerability). The positive affect results are reported in full across all studies in the online supplemental materials (p. 11; Tables S19–S22).

Results

Analysis plan. Table 3 provides descriptive statistics and bivariate correlations among all variables. We analyzed the manipulation check using an independent samples *t* test and, as in Study 1, the remaining analyses use ANCOVA with students' personal fixed mindset ($M = 2.75$, $SD = 1.07$), URM status (0 = White, East Asian, and Southeast Asian students; 1 = Black, Hispanic, Indian Subcontinent, Mixed race, Middle Eastern, and Other race students), and gender (0 = male, 1 = female) included as covariates.[9] Table 4 provides a summary of all ANCOVA analyses, and Table S7 in the online supplemental materials provides a summary of analyses without covariates. Without covariates, the pattern of results was unchanged. Finally, Figure 3 depicts condition differences for all outcomes.

Professor mindset manipulation check. As in Study 1, the faculty mindset manipulations were perceived as intended. The fixed mindset professor ($M = 4.05$, $SD = 1.06$) was perceived to endorse significantly greater fixed mindset beliefs than the growth mindset professor ($M = 2.13$, $SD = .85$; $F(1, 222) = 224.99$, $p < .001$, $d = 2.01$).

Psychological vulnerability. Replicating the results of Study 1, analyses revealed that students expected to experience significantly less belonging, $F(1, 219) = 28.58$, $p < .001$, $d = .72$, and more evaluative concerns, $F(1, 219) = 56.05$, $p < .001$, $d = 1.01$, when the course was taught by the fixed (vs. growth) mindset professor (see Table 4). Extending Study 1, and in line with predictions, students also expected to experience more imposter feelings, $F(1, 219) = 16.76$, $p < .001$, $d = .55$, and more negative affect, $F(1, 218) = 27.03$, $p < .001$, $d = .70$, when the course was taught by the fixed (vs. growth) mindset professor.

When we combined all psychological experience facets into a psychological vulnerability composite, we found, in line with our predictions, that students expected to experience significantly more psychological vulnerability when the course was taught by the fixed (vs. growth) mindset professor, $F(1, 219) = 41.64$, $p < .001$, $d = .87$.

Course engagement, interest, and behavioral intentions. Consistent with Study 1, students anticipated being significantly less engaged, $F(1, 219) = 10.10$, $p = .002$, $d = .43$, and having lower course interest when it was taught by the fixed (vs. growth) mindset professor, $F(1, 219) = 30.97$, $p < .001$, $d = .75$. New to Study 2, students reported greater intentions of dropping the fixed (vs. growth) mindset professor's course, $F(1, 219) = 9.38$, $p = .002$, $d = .41$. However, students' anticipated class attendance did not significantly differ by faculty mindset condition, $F(1, 219) = 0.04$, $p = .843$, $d = <.01$.

Course performance. Students reported lower anticipated course performance when the course was taught by the fixed (vs. growth) mindset professor, $F(1, 219) = 19.00$, $p < .001$, $d = .59$.[10]

Mediation. To examine our hypothesized process model, we used the PROCESS macro in SPSS (Model 4; Hayes, 2017) with bias-corrected 95% confidence intervals computed with 5,000 bootstrap resamples. In each model, professor mindset (the dichotomous condition variable; 0 = growth; 1 = fixed) was entered as the predictor (X), psychological vulnerability was entered as the mediator (M), and course engagement, interest, anticipated course performance, and dropout intentions were entered separately in different models as the outcome (Y) variables. We did not examine anticipated attendance as an outcome variable in these analyses because our previous analyses indicated that there were no significant differences by professor's mindset condition. All models controlled for URM status, gender, and personal fixed mindset, allowing us to examine these processes independent of these factors. Table S9 in the online supplemental materials includes a summary of results without covariates; without covariates, the pattern of results is unchanged.

Results revealed psychological vulnerability had a significant indirect effect on all course outcomes. That is, students expected to experience more psychological vulnerability in the course when it was taught by the fixed (vs. growth) mindset professor, which in turn lowered students' anticipated course engagement, *indirect effect* = −.60, *SE* = .13, 95% CI [−.86, −.36], interest in the course, *indirect effect* = −.60, *SE* = .12, 95% CI [−.84, −.39], course performance, *indirect effect* = −.83, *SE* = .15, 95% CI [−1.14, −.55], and increased their dropout intentions, *indirect effect* = .54, *SE* = .10, 95% CI [.35, .76].[11]

Discussion

The results of Study 2 replicated all of Study 1's findings. It also extended the results of Study 1 by demonstrating that professors' mindset beliefs impact two additional facets of psychological vulnerability (i.e., imposter feelings and negative affect) and the behavioral intention of dropping out of the course. However, we did not find the expected effect between faculty mindset beliefs and anticipated course attendance, perhaps because attendance for a hypothetical class may be difficult for students to accurately estimate and almost all college students might intend to attend class prospectively. Indeed, most students stated that they would attend class frequently ($M = 4.40$ out of 5, $SD = 0.83$), which is consistent with the idea that this null result could stem from a measurement issue (e.g., ceiling effect). Overall, Study 2 strengthens our confidence in the theory that when professors communicate fixed mindset beliefs, they create a negative learning environment with greater psychological vulnerability among students. Moreover, the psychological vulnerability that fixed mindset professors engender has important consequences. These fixed mindset beliefs can reduce students' interest in taking and staying in a course, create an unwillingness to apply effort to course material, and reduce students' expectations about how well they will likely perform in the course. But do these effects of perceived faculty mindset replicate in the field? Studies 3 and 4 examine this question.

[9] See Table S10 in the online supplemental materials for gender and race differences across all variables. There were no gender or race differences on any variables in this study (*p*s > .23).

[10] We tested whether participant race or gender moderated any of the effects and found some evidence of moderation by gender, though moderation was inconsistent across the different outcomes (see Table S11 in the online supplemental materials).

[11] Again, we report the central mediation models of interest in main text (with psychological vulnerability as the mediator); however, Table S8 in the online supplemental materials provides a summary of all mediation results with each individual psychological experience as a mediator for those interested in mediation by particular, individual experiences.

Table 3
Means, Standard Deviations, Ranges, Reliability Coefficients, and Correlations for All Variables: Study 2

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Perc. of fixed prof mindset														
2. URM	−.02													
3. Gender	−.08	−.01												
4. Personal fixed mindset	.13	.003	.10											
5. Vulnerability composite	.58**	.01	.02	.08										
6. Belonging	−.52**	−.05	−.05	−.07	−.85**									
7. Evaluative concerns	.60**	.01	.04	.02	.89**	−.67**								
8. Imposter feelings	.41**	−.08	.02	.10	.86**	−.58**	.73**							
9. Negative affect	.49**	.07	.03	.08	.88**	−.70**	.69**	.66**						
10. Course engagement	−.41**	.01	−.04	−.05	−.54**	.69**	−.37**	−.35**	−.45**					
11. Course interest	−.51**	.03	−.01	−.09	−.61**	.72**	−.47**	−.40**	−.51**	.74**				
12. Course performance	−.43**	−.03	−.03	−.09	−.79**	.75**	−.61**	−.67**	−.69**	.58**	.54**			
13. Course attendance	−.17**	−.08	.08	−.05	−.24**	.31**	−.10	−.18**	−.23**	.40**	.26**	.31**		
14. Course dropout	.34**	.02	.06	.03	.62**	−.55**	.50**	.53**	.58**	−.46**	−.50**	−.61**	−.26**	
M	3.11	N/A	N/A	2.75	−.004	4.21	3.88	3.29	2.07	4.47	3.22	4.63	4.40	2.40
SD	1.36	N/A	N/A	1.07	.87	1.34	1.55	1.36	.84	1.36	1.36	1.30	.83	1.05
Range	1–6	0–1	0–1	1–6	−1.74, 2.37	1–7	1–7	1–7	1–4	1–7	1–6	1–7	1–5	1–5
Reliability coeff.	.92	N/A	N/A	.88	.87	.89	.91	.86	.85	.85	.94	.87	N/A	N/A

Note. Perc = perception; prof = professor; coeff. = coefficient. Underrepresented racial minority status (URM) was coded 0 = White, East Asian, Southeast Asian, 1 = Black, Hispanic, Indian Subcontinent, Mixed race, Middle Eastern, Pacific Islander, Other race. Gender was coded 0 = male, 1 = female.
** $p < .01$.

Table 4
ANCOVA Analyses: Study 2

	Condition					URM			Gender			Personal fixed mindset		
Variable	Fixed mindset instructor (n = 114) *M* (*SE*)	Growth mindset instructor (n = 110) *M* (*SE*)	*F*(1, 219)	*p*	*d*	*F*(1, 219)	*p*	*d*	*F*(1, 219)	*p*	*d*	*F*(1, 219)	*p*	*d*
Vulnerability composite	.34 (.08)	−.35 (.08)	41.64	<.001	.87	.19	.667	.06	.39	.531	.09	.74	.390	.11
Belonging	3.77 (.12)	4.67 (.12)	28.58	<.001	.72	.95	.330	.13	1.25	.265	.16	.53	.466	.09
Evaluative concerns	4.57 (.13)	3.17 (.13)	56.05	<.001	1.01	.11	.742	<.01	1.17	.281	.14	.04	.844	<.01
Imposter feelings	3.64 (.12)	2.92 (.13)	16.76	<.001	.55	1.24	.266	.16	.13	.722	.06	1.67	.198	.18
Negative affect	2.34 (.07)	1.79 (.08)	27.03	<.001	.70	1.74	.189	.18	.14	.706	.06	1.11	.293	.14
Course engagement	4.19 (.13)	4.77 (.13)	10.10	.002	.43	.003	.960	<.01	.07	.799	<.01	.28	.599	.06
Course interest	2.75 (.12)	3.71 (.12)	30.97	<.001	.75	.07	.788	<.01	.17	.679	.06	1.17	.281	.14
Course performance	4.27 (.12)	5.01 (.12)	19.00	<.001	.59	.32	.571	.06	.29	.588	.06	1.30	.256	.16
Course attendance	4.39 (.08)	4.41 (.08)	0.04	.843	<.01	1.52	.219	.17	1.64	.201	.17	.74	.391	.11
Course dropout	2.61 (.10)	2.19 (.10)	9.38	.002	.41	.14	.711	.06	1.06	.305	.14	.02	.902	<.01

Note. ANCOVA = analysis of covariance. Means represent values for individuals with average personal fixed mindset (M = 2.75). Underrepresented racial minority status (URM) was coded 0 = White, East Asian, Southeast Asian, 1 = Black, Hispanic, Indian Subcontinent, Mixed race, Middle Eastern, Pacific Islander. Gender was coded 0 = male, 1 = female. URM, gender, and personal fixed mindset were included as covariates.

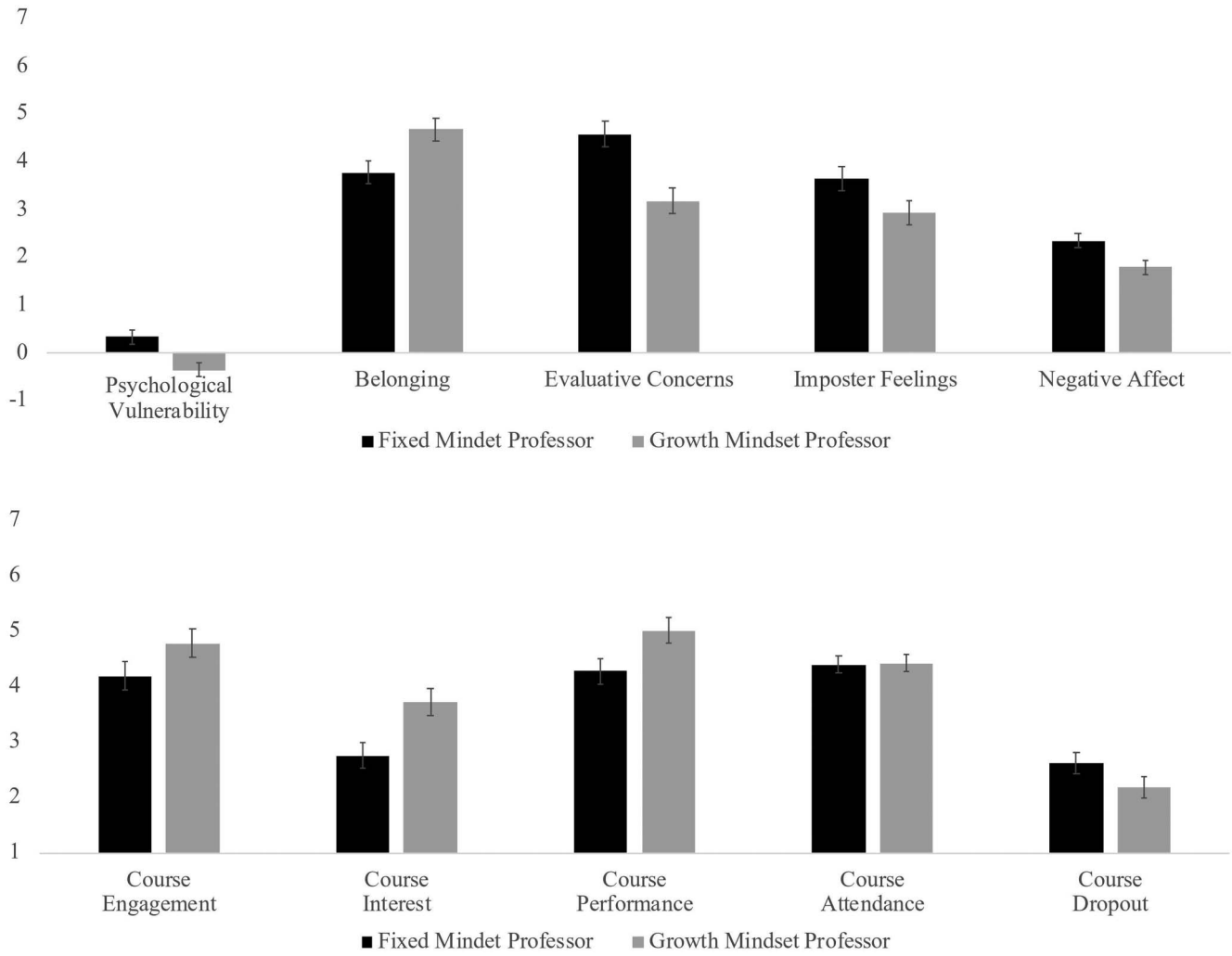

Figure 3. Study 2. Students anticipate more psychological vulnerability (lower belonging and greater evaluative concerns, imposter feelings, and negative affect), less engagement and interest, lower performance, and greater dropout intentions when a course is taught by a professor who endorses fixed (vs. growth) mindset beliefs. Bars represent 95% confidence intervals.

Study 3

We conducted an initial pilot field study to examine the link between college students' perceptions of their STEM professors' mindset beliefs and their in-the-moment psychological experiences when students were actually embedded in their STEM college classes. That is, rather than manipulating students' perceptions of professors' mindset beliefs and asking students to report how they might feel in that professor's class (as in Studies 1 and 2), we measured students' perceptions of their actual professors' mindset beliefs and asked them to report their in-the-moment experiences in their STEM classes for two weeks using ESM. The ESM method is unique in that it captures students' real-time, lived experiences in their classroom environments—allowing us to examine the external validity of our theoretical model. As a first step, we wanted to investigate whether the measures of belonging, evaluative concerns, imposter feelings, and negative affect used in Study 2 would be internally reliable in an ESM context. Because students are completing these surveys in-the-moment on electronic devices, the measures need to be short to retain students' attention and motivation to continue responding over the 2-week assessment period (Zirkel et al., 2015). Further, we investigated the feasibility of doing such a study with students in their actual class environments. We wanted to establish whether students would indeed respond to the surveys and whether we would find initial evidence for the predicted associations between students' perceptions of their professors' mindset beliefs and students' psychological experiences.

Method

Participants. Participants were 291 first-year and sophomore undergraduate students (M_{age} = 18.27 years; 59.8% female; 46.5% White, 23% Asian/Asian American, 11.7% Hispanic, 8.2% Biracial, 5.5% Black, 5.1% Other) at one of three U.S. universities: an urban public university in the Midwest, a STEM-focused technical

university on the West coast, and a women's college on the West coast. To recruit participants, study invitations were sent to as many students as possible via student listservs and large, introductory STEM classes. Interested students were asked to complete a short survey in which they reported basic demographic information, their course schedule, and their level of math identification. All first-year students who were enrolled in at least one nonremedial STEM class and who reported being highly identified with math (those who agreed with the items: "I am good at math tasks" and "It is important to me that I do well on math tasks"; Spencer, Steele, & Quinn, 1999) were invited to participate. We conducted a sensitivity analysis using Monte Carlo power simulations in Mplus Version 8.1 (Muthén & Muthén, 2017) as recommended for multilevel models. These simulations provide an estimate of the smallest detectable effect size given our sample size with a power of .80 and alpha of .05. Results of this sensitivity analysis indicated that we had adequate power to detect effect sizes (standardized regression coefficients) as small as $r = .13$.

Procedure. IRB approval was obtained prior to data collection. Students completed a survey a few weeks into the semester where they reported their perceptions of their STEM professors' mindset beliefs, their own demographic characteristics, their SAT scores, and their personal mindset beliefs. Students completed the survey after the drop deadline of the term so that they had some experience of their professor in class. Because they did not drop the course by the drop deadline, we had some confidence that participating students intended to stay in the class throughout the semester. After they completed the survey, students were provided an iPod Touch on which they completed ESM surveys every day for two to four weeks directly following their classes. Using an event-contingent design, students received notifications immediately following their STEM classes, asking them to complete the ESM survey. In these ESM surveys, students reported their psychological experiences in their classes. Although students indicated on the ESM surveys whether they had been in a STEM class, they did not indicate the *specific* STEM class they had attended (a design limitation that we addressed in Study 4). Thus, students' perceptions of their STEM professors' mindset beliefs, as well as their psychological experiences in their STEM classes, were averaged across all the STEM classes they were enrolled in during the semester of participation.

Measures. The full text of all measures can be found in the online supplemental materials.[12]

Perceptions of STEM professors' mindset beliefs. Students were asked to list each class they were enrolled in during the semester of participation. For each class (including labs), they responded to five items adapted from Dweck (1999) about their perceptions of that professor's mindset (e.g., "The professor [or TA] in this class seems to believe that students have a certain amount of intelligence, and they really can't do much to change it"; αs ranged from .86 to .93) on a scale from 1 (*strongly disagree*) to 6 (*strongly agree*). For each student, we averaged their perceptions of their STEM instructors' mindset beliefs; higher values indicated greater fixed mindset beliefs. For our purposes, we included STEM disciplines that are categorized by the National Science Foundation (NSF) as STEM. These include physical sciences, biological sciences, social sciences, computer science, engineering, and math (National Science Board, 2015). On average, these highly math-identified students were enrolled in 4.75 STEM classes (including lectures and labs).

Demographics. Students self-reported their gender and race. We created a participant gender variable that was coded 0 = male, 1 = female and a URM (i.e., underrepresented minority) status variable that was coded 0 = White or Asian, 1 = Black, Hispanic, Biracial, or Other. As in Studies 1 and 2, we controlled for students' gender and race in all analyses.

SAT scores. Students self-reported their SAT and/or ACT scores. If students only reported their ACT scores, the ACT scores were converted to SAT scores, which ranged from 400–1600. In all analyses, we controlled for students' SAT scores.

Personal mindset beliefs. Students reported their own personal mindset beliefs by responding to two items (e.g., "You have a certain amount of intelligence, and you can't really do much to change it") from Dweck (1999) using a scale from 1 (*strongly agree*) to 6 (*strongly disagree*). Items were averaged to form a personal mindset composite; higher values indicated greater fixed mindset beliefs ($\alpha = .80$). In all analyses, we controlled for students' personal mindset beliefs.

Psychological vulnerability. Students responded to items on the ESM surveys that assessed their feelings of *belonging* ($\alpha = .88$) and *evaluative concerns* ($\alpha = .93$) using the same measures as Studies 1 and 2 except rated on a 6-point scale ranging from 1 (*not at all*) to 6 (*extremely*). Measures of *imposter feelings* ($\alpha = .84$) and *negative affect* ($\alpha = .80$) in that class were also identical to those administered in Study 2. A psychological vulnerability composite was created averaging responses to the belonging, evaluative concerns, imposter feelings, and negative affect composites ($\alpha = .79$); higher numbers indicate greater psychological vulnerability in class.

Results

Experience sampling data. On average, students were enrolled in approximately 4.75 STEM classes (including lectures and labs) in the semester/quarter of participation. Classes met 1–3 times per week, resulting in an average of 19 ESM surveys sent per person during the 2-week experience-sampling period (range = 2–48 surveys/person). During the experience-sampling period, students completed, on average, 17.14 ESM surveys ($SD = 6.97$, range = 1–44) for a total of 4,850 ESM surveys. Once students began an ESM survey, they almost always completed it; of the 4,850 surveys that were started, missing data for any individual item ranged from 0% (0 missing observations) to 0.45% (22 missing observations).

[12] In Study 3 (administered at three universities) and Study 4 (administered at an additional, fourth university), participants were recruited as part of two larger NSF-funded longitudinal studies examining first- and second-year undergraduate students' experiences in introductory STEM courses and their experiences in college over time. There were no experimental interventions or manipulations in either of these larger studies and perceived faculty mindset was just one situational cue that the studies were designed to assess. Other cues that were examined include the structures of introductory STEM courses (e.g., prerequisite policies) and how they relate to students' experiences and persistence in STEM over time. All measures and data related to the perceived faculty mindset research question are included in this report and there are no exclusions of university settings or student responses. All items and scales that were analyzed for the present studies are reported in the online supplemental materials.

Analysis plan. We used hierarchical linear modeling (HLM), conducted with the lmer package (Bates, 2010) in R Studio Version 1.0.136 (R Core Team, 2016) to account for the nested structure of our data. Students' psychological experiences on the ESM survey were treated as Level 1 units, which were nested within persons, the Level 2 units. Thus, students' perceptions of STEM professors' mindset beliefs, students' SAT scores, gender, race, and personal mindset beliefs were at Level 2. Restricted maximum likelihood models were used for all analyses, as recommended for this type of data (Raudenbush & Bryk, 2002). All Level 2 continuous variables were *z* scored prior to conducting the HLM analyses, so that coefficients from the multilevel models can be interpreted as effect sizes (Lorah, 2018).

ESM data can be analyzed in many different ways. For example, some researchers use these data to examine differences between trait versus state variability (Nett, Bieg, & Keller, 2017), whereas other researchers assess how the associations between the predictors and outcomes change on a day-to-day basis (Mendoza-Denton, Downey, Purdie, Davis, & Pietrzak, 2002). In Studies 3 and 4, we chose to measure students' perceptions of their professors' mindset beliefs (our predictor) a few weeks into the semester when students had enough information to make an informed judgment and we used ESM to measure students' in-class psychological experiences in the weeks following the faculty mindset assessment. We chose this design for several reasons: First, we did not expect participants' perceptions of their professor's mindset to change rapidly on a day-to-day basis because previous research shows that first impressions of powerful people in a context are relatively stable (Rule & Ambady, 2010) and test–retest stability of mindset beliefs is quite high (Schmidt, Shumow, & Kackar-Cam, 2015). Second, we wanted to separate measurement of the theorized predictor and dependent variables to avoid potential problems with inflated correlations between measures and to allow for a longitudinal analysis. Third, as suggested by Bolger and Laurenceau (2013), we wanted to take care to minimize the likelihood that participants would figure out what our associative hypotheses were (examining how perceptions of faculty mindset are related to students' psychological experiences). Therefore, the purpose of using ESM in Studies 3 and 4 was to measure students' classroom experiences in a reliable, ecologically valid way and predict these experiences from students' perceptions of their professors' mindset beliefs.

To test whether students' perceptions of their STEM professors' mindset beliefs predicted their in-class psychological vulnerability, we ran five HLM models in which students' perceptions of their STEM professors' mindset beliefs (measured at Level 2) predicted their in-class experiences (measured at Level 1). We ran four models with the individual psychological vulnerability facets as outcomes (evaluative concerns, belonging, imposter feelings, and negative affect), and one model with the psychological vulnerability composite as the outcome. All models included seven control variables (all measured at Level 2): two school indicator dummy variables (that controlled for university context), number of ESM surveys taken (controlling for possible fatigue owing to completing many surveys; e.g., Sanchez & Garcia, 2009), students' SAT scores, gender, race, and personal mindset beliefs. Specifically, we estimated the following models:

Level 1 (Observation)

$$\text{Psychological Vulnerability}_{ij} = \beta_{0i} + R_{ij}$$

Level 2 (Student)

$$\begin{aligned}\beta_{0i} = {} & \gamma_{00} + \gamma_{01}(\text{Dummy for School 1}) \\ & + \gamma_{02}(\text{Dummy for School 2}) \\ & + \gamma_{03}(\text{Number of ESMsurveys}) + \gamma_{04}(\text{SAT}) + \gamma_{05}(\text{Female}) \\ & + \gamma_{06}(\text{URM}) + \gamma_{07}(\text{Personal mindset beliefs}) \\ & + \gamma_{08}(\text{Perception of STEM professors' mindset beliefs}) \\ & + U_{0j}\end{aligned}$$

The final model is as follows:

$$\begin{aligned}\text{Psychological Vulnerability}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{Dummy for School 1}) \\ & + \gamma_{02}(\text{Dummy for School 2}) \\ & + \gamma_{03}(\text{Num of ESM surveys}) \\ & + \gamma_{04}(\text{SAT}) + \gamma_{05}(\text{Female}) \\ & + \gamma_{06}(\text{URM}) \\ & + \gamma_{07}(\text{Personal mindset beliefs}) \\ & + \gamma_{08}(\text{Perception of STEM professors' mindset beliefs}) \\ & + U_{0j} + R_{ij}\end{aligned}$$

Descriptives and correlations. Means, standard deviations, ranges, reliability coefficients, and bivariate correlations among all variables can be found in Table 5 (Level 1) and Table 6 (Level 2).

Psychological vulnerability. To determine how much of the variance in psychological experiences occurred within- and between-persons, we first ran unconditional models with no predictors and calculated the intraclass correlation coefficient (ICC) for each individual component of psychological vulnerability and the composite. The ICCs for belonging (0.54), evaluative concerns (0.45), imposter feelings (0.58), negative affect (0.42), and the psychological vulnerability composite overall (0.55) indicated that between-person variance accounted for approximately 50% of the total variance in these variables, and the remaining 50% of the variance occurred within-persons.

See Table 7 for results from all HLM analyses. Consistent with our hypotheses, students who perceived their STEM professors to endorse more fixed mindset beliefs experienced significantly

Table 5
Means, Standard Deviations, Ranges, Reliability Coefficients, and Correlations for All Variables at Level 1: Study 3

Variable	1	2	3	4	5
1. ESM vulnerability composite					
2. ESM belonging	−.73**				
3. ESM evaluative concerns	.80**	−.39**			
4. ESM imposter feelings	.82**	−.45**	.63**		
5. ESM negative affect	.79**	−.44**	.51**	.54**	
M	1.95	4.23	1.56	1.71	1.76
SD	.75	1.00	.95	.89	.98
Range	1–6	1–6	1–6	1–6	1–6
Reliability coefficient	0.79	0.88	0.93	0.84	0.80

Note. ESM = experience sampling methodology.
** $p < .01$.

Table 6
Means, Standard Deviations, Ranges, Reliability Coefficients, and Correlations for All Variables at Level 2: Study 3

Variable	1	2	3	4	5
1. Perc. of fixed prof mindset					
2. SAT scores	.07				
3. Female	−.13*	−.19**			
4. URM	−.11	−.32**	.07		
5. Personal fixed mindset	.43**	.16*	−.11	−.18**	
M	2.27	1223.28	.61	.26	2.70
SD	.73	159.37	.49	.44	1.15
Range	1–6	400–1600	0–1	0–1	1–6
Reliability coefficient	0.86–0.93	N/A	N/A	N/A	0.80

Note. Perc = perception; prof = professor. Female was coded 0 = male, 1 = female. Underrepresented racial minority status (URM) was coded 0 = White, Asian, 1 = Black, Hispanic, Biracial, Native American.
* $p < .05$. ** $p < .01$.

greater evaluative concerns, $B = .10$, $SE = .05$, $p = .048$, and marginally greater imposter feelings, $B = .10$, $SE = .05$, $p = .051$, and negative affect in their STEM classes, $B = .10$, $SE = .05$, $p = .060$. Contrary to our hypothesis, students' perceptions of their professors' mindset beliefs did not significantly predict students' in-the-moment experiences of belonging, $B = -.05$, $SE = .05$, $p = .395$. Combining students' psychological experiences to examine their psychological vulnerability as a whole, we found that students who perceived their STEM professors to endorse more fixed mindset beliefs experienced significantly greater psychological vulnerability in their STEM classes, $B = .09$, $SE = .04$, $p = .045$, even controlling for students' SAT scores and personal mindset beliefs.[13] Table S12 in the online supplemental materials reports all analyses without covariates. When not including covariates, all psychological variables are significantly predicted by students' perceptions of their STEM instructors' fixed mindset beliefs.

Discussion

As an initial pilot field study, Study 3 helped establish the reliability of our measures using ESM and tested the feasibility of conducting an ESM study with college students in their actual college classrooms. Moreover, this study suggested a real-world link between students' perceptions of STEM professors' mindset beliefs and their psychological vulnerability in these classes. These results provide field evidence that students' perceptions of their STEM professors' mindset beliefs in actual classrooms and outside of controlled faculty performance in the lab predicts their in-the-moment experiences of psychological vulnerability. Across three U.S. universities, when college students perceived their STEM professors to endorse more fixed mindset beliefs, they experienced significantly more psychological vulnerability in their STEM classes. This psychological vulnerability was driven by greater evaluative concerns, greater concerns about being outed as an imposter in class, and more negative affect in STEM classes taught by faculty perceived to endorse more fixed (vs. growth) mindset beliefs.

Study 4

Study 4 sought to replicate and improve upon Study 3 in several important ways. First, Study 4 examines the link between students' perceptions of their STEM professors' mindset beliefs and students' psychological vulnerability with a much larger sample, and with more precision over a longer time course. A limitation of Study 3 is that students did not indicate in the ESM surveys which specific STEM course they had just attended; therefore, students' mindset perceptions and their classroom experiences could not be linked at the class level. That is, Study 3 can only speak to students' perceptions and experiences, on average, in their STEM classes. Although this contribution is valuable as an initial (conservative) test of the hypothesis, Study 4 addresses this limitation by replicating the field study in a new university context and intentionally linking students' perceptions of their *particular STEM professors'* mindset beliefs and students' psychological vulnerability in *those particular professors' classes*. Specifically, with this new study design, we could test whether different students' perceptions of the same professor's mindset beliefs predicted variance in students' psychological vulnerability in that professor's course. This allows a more targeted and precise test of the association between perceived professor mindset and students' psychological vulnerability and performance in a much larger sample.

Second, in Study 4, to rule out the possibility that perceptions of STEM professors' mindsets are impacting or conflated with more general beliefs about the professor (e.g., how friendly, warm, mean, competent, and/or smart the professor is), we asked students to report their perceptions of their professor's warmth and competence. We controlled for these perceptions in our analyses to ensure that these perceptions did not account for students' perceptions of their professors' mindset beliefs. This allowed us to directly examine whether students' perceptions of their professors' mindset beliefs uniquely predicted their psychological vulnerability and course outcomes in that professor's class, above and beyond their general perceptions of the professor.

Third, because of the longitudinal design of this new study, we were able to examine the downstream consequences of students' in-the-moment psychological vulnerability. That is, we examined how students' perceptions of their STEM professor's mindset beliefs, and their psychological vulnerability in that professor's class, predicted students' behavioral engagement (i.e., class attendance, dropout intentions), field interest, and their actual end-of-semester class performance. This allowed us to test the full process model (see Figure 1) in which students' perceptions of their professors' mindset beliefs predict students' in-class psychological vulnerability, which in turn predict students' behavior and performance, in real-world classroom contexts.

Method

Participants. Participants were 902 first-year and sophomore undergraduate students ($M_{age} = 18.51$ years; 65.2% female; 70.5% White, 11.9% Biracial, 9.2% Asian/Asian American, 4.0% Black,

[13] We tested whether the association between students' perceptions of their professors' mindset beliefs and students' in-class experiences were moderated by students' gender or race; consistent with the bulk of mindset theory and research (Dweck, 1999), no significant interactions were found suggesting that perceiving STEM professors to endorse more fixed (vs. growth) mindset beliefs are predictive of students' classroom experiences regardless of students' gender or racial group membership (see Table S13 in the online supplemental materials).

Table 7
HLM Results: Study 3

Fixed	Vulnerability composite			Belonging			Evaluative concerns			Imposter feelings			Negative affect		
	B	*SE*	*t* value	*B*	*SE*	*t* value	*B*	*SE*	*t* value	*B*	*SE*	*t* value	*B*	*SE*	*t* value
Intercept	1.99***	.08	25.81	4.04***	.10	41.24	1.49***	.09	16.18	1.76***	.09	18.68	1.77***	.09	19.42
School 1	−.09	.09	−1.02	.14	.11	1.25	.02	.11	.20	−.17	.11	−1.53	−.07	.10	−.70
School 2	−.002	.12	−.02	.21	.16	1.30	.15	.15	.99	.04	.15	.29	.02	.15	.12
Num ESM	−.03	.04	−.66	.05	.05	1.08	−.004	.05	−.09	−.04	.05	−.84	−.002	.05	−.05
SAT	−.03	.04	−.79	.05	.05	.89	−.05	.05	−.90	.01	.05	.23	−.05	.05	−1.04
Female	.05	.08	.60	.10	.10	1.02	.13	.10	1.38	.10	.10	.96	.06	.10	.67
URM	−.17†	.10	−1.76	.13	.12	1.07	−.19†	.12	−1.68	−.17	.12	−1.44	−.18	.11	−1.58
Personal fixed mindset	.11**	.04	2.76	−.14**	.05	−2.64	.10*	.05	2.02	.16**	.05	3.21	.05	.05	1.09
Perc. of fixed prof mindset	.09*	.04	2.01	−.05	.05	−.85	.10*	.05	1.99	.10†	.05	1.96	.10†	.05	1.89
Random															
Group		.30			.47			.41			.44			.40	
Residual		.25			.44			.50			.34			.53	
N students		231			231			231			231			231	
N observations		4012			4012			4012			4010			4010	

Note. HLM = hierarchical linear modeling; Num ESM = number of experience sampling methodology surveys completed; perc = perception; prof = professor; *B* = unstandardized coefficient; *SE* = standard error. School 1 and School 2 are dummy variables. Female is coded 0 = male, 1 = female. Underrepresented racial minority status (URM) is coded 0 = White, Asian, 1 = Black, Hispanic, Native American, Other = 1. All continuous variables (number of ESM surveys, SAT, personal fixed mindset, perception of fixed professor mindset) were *z* scored. Separate HLM models were run for each outcome.
† $p < .1$. * $p < .05$. ** $p < .01$. *** $p < .001$.

3.8% Hispanic, 0.6% Other) from a large, public Midwestern university who were enrolled in one of 37 introductory-level STEM courses (e.g., math, physical science, computer science, social science). We recruited participants from the largest introductory STEM courses on campus that had the highest enrollment of first-years and sophomores. All first-years and sophomores in these 37 courses were eligible to participate. Each student was linked to a single instructor—that is, students were enrolled in only one of the 37 participating classes. All instructors were professors; none was a TA. On average, there were 24 student participants in each course. As in Study 3, we conducted a sensitivity analysis using Monte Carlo power simulations in Mplus Version 8.1 (Muthén & Muthén, 2017) to determine an estimate of the smallest detectable effect size given our multilevel model and sample size with a power of .80 and alpha of .05. Results of this analysis confirmed that we were adequately powered to detect effect sizes (standardized regression coefficients) as small as $r = .06$.

Procedure. IRB approval was obtained prior to data collection. At the beginning of the semester, and after the drop deadline of the term, students completed a survey in which they reported their perceptions of their STEM professor's mindset beliefs, warmth, and competence. They completed the survey between the second and fourth week of the semester so that they had some initial experiences of the professor from which to draw. Then, during a 2-week period starting in the sixth or seventh week of the semester, students received text messages immediately following their specific STEM class, asking them to complete the ESM surveys. Students responded to the ESM surveys using their smartphones; students who did not own smartphones ($n = 3$) were provided with a smart device on which to receive the text messages and complete the ESM surveys. Thus, the ESM design was again event-contingent and surveys were triggered based on the specific STEM class schedule. Students reported their psychological experiences (as in Study 3)—belonging, evaluative concerns, imposter feelings, and negative affect—in their particular STEM class. In the fourteenth or fifteenth week of the semester, students completed an end-of-semester survey in which they reported how often they attended their STEM class, how often they thought about dropping the STEM class, as well as their interest in both the specific STEM class, and the broader field that the STEM class focused on (e.g., chemistry, biology, etc.). Students' end-of-semester grades in the STEM class, and their SAT scores, were retrieved from university records.

Measures. See the online supplemental materials for the full text of all measures.

Perceptions of STEM professors' mindset beliefs. Students' perceptions of their STEM professors' mindset beliefs were assessed with six items adapted from Dweck (1999) (e.g., "The professor in this class seems to believe that students have a certain amount of intelligence, and they really can't do much to change it"; $\alpha = .87$) on a scale from 1 (*strongly disagree*) to 6 (*strongly agree*).

Demographics. Students self-reported their gender (coded 0 = male, 1 = female) and race. We created a URM variable that was coded 0 = White and Asian, 1 = Black, Hispanic, Biracial, Other. As in all studies, we controlled for students' gender and race in all analyses.

SAT scores. Students' SAT scores were collected via academic records. These scores ranged from 400–1600. In all analyses, we controlled for students' SAT scores.

Personal mindset beliefs. Students' personal mindset beliefs were assessed using the same two-item measure administered in Study 3 ($\alpha = .89$); higher scores indicate more fixed mindset beliefs. In all analyses, we controlled for students' personal mindset beliefs.

Perceptions of STEM professors' warmth. Students' perceptions of their STEM professors' warmth were measured by asking students to rate on a scale from 1 (*not at all*) to 6 (*very much*) how

warm, friendly, and mean (reverse-coded) they perceived their professor to be (α = .73). In all analyses, we controlled for students' perceptions of their STEM professors' warmth to uniquely identify the role of perceptions of professors' mindset beliefs.

Perceptions of STEM professors' competence. Students' perceptions of their STEM professors' competence were measured by asking students to rate on a scale from 1 (*not at all*) to 6 (*very much*) how competent and smart they perceived their professor to be (α = .70). In all analyses, we controlled for students' perceptions of their STEM professors' competence to uniquely identify the role of perceptions of professors' mindset beliefs.

Psychological vulnerability. Students completed ESM surveys on their smartphones directly after their specific STEM class of interest. They responded to the same measures as in Study 3. These assessed students' experiences of *belonging* (α = .89), *evaluative concerns* (α = .94), *imposter feelings* (α = .88), and *negative affect* (α = .80; see the online supplemental materials). A psychological vulnerability score was created by *z*-scoring (because response scales differed) and then averaging students' responses to the belonging, evaluative concerns, imposter feelings, and negative affect composites (α = .82), with higher numbers indicating greater psychological vulnerability in the specific STEM class of interest.

Course outcomes.

Attendance. To assess students' behavioral engagement in their STEM class over the course of the semester, students responded to one item ("In [specific STEM class] this semester, how often did you attend class?") using a scale ranging from 1 (*never*) to 5 (*always*).

Dropout intentions. To assess students' thoughts about dropping the STEM class, students responded to one item ("In [specific STEM class] this semester, how often do you think about dropping out of the class?") using a scale ranging from 1 (*never*) to 5 (*always*).

STEM field-specific interest. Students responded to two items that assessed their field-specific interest. One question asked about their interest in the specific STEM course and the other asked about their interest in the broader STEM field of the course ("This course fascinates me" and "I think this field is very interesting"). Students responded using a scale from 1 (*strongly agree*) to 7 (*strongly disagree*). Because the correlation between the field interest items was very high (*r* = .89), these items were averaged to form a field interest composite and recoded so that higher values reflect greater field-specific interest.

Grades. Students' final grades in their specific STEM course were retrieved from the university's academic records and were coded using the university's GPA scale (A = 4.0, A− = 3.7, B+ = 3.3, B = 3.0, B− = 2.7, C+ = 2.3, C = 2.0, C− = 1.7, D+ = 1.3, D = 1.0, D− = 0.7, *F* = 0).

Results

Experience sampling data. Students' STEM classes met two to five times per week, but students were only asked to complete the surveys twice per week. On average, students started 3.31 ESM surveys (*SD* = 1.37, range = 1–10) during the 2-week period[14] for a total of 2,554 ESM surveys—2,447 of which were completed immediately following class. The first question on the ESM survey asked, "Were you just in class?" If students responded "no," they were asked why they did not attend class and were then routed to the end of the survey. Of the 2,554 surveys that were started, students reported that they were not in class in 107 of the surveys (4.2%). Once students responded that they were in class and began the ESM survey, they almost always completed it; of the 2,447 class surveys that were taken, missing data for any individual item ranged from 1.8% (44 missing observations) to 3.0% (74 missing observations).

Analysis plan.

Psychological vulnerability. As in Study 3, we first tested the associations between perceived professor mindset on students' psychological vulnerability with HLM analyses. Because students' observations on the ESM survey (Level 1) were nested within students (Level 2), which were nested within professors (Level 3), we ran three-level HLM regression models using the lme4 library (Bates, 2010) in R Studio Version 1.0.136 (R Core Team, 2016). Restricted maximum likelihood models were used for all analyses, as recommended for this type of data (Raudenbush & Bryk, 2002). All Level 1 and Level 2 continuous variables were *z* scored prior to conducting the HLM analyses, so that coefficients from the multilevel models can be interpreted as effect sizes (Lorah, 2018).

To test whether students' perceptions of their STEM professors' mindset beliefs predicted their in-class psychological vulnerability, we conducted HLM models in which students' perceptions of their STEM professors' mindset beliefs (measured at Level 2) predicted their in-class psychological vulnerability (measured at Level 1). We first ran four models in which students' perceptions of their STEM professors' mindset beliefs predicted the individual components of psychological vulnerability (i.e., belonging, evaluative concerns, imposter, and negative affect). Then, we ran a model in which students' perceptions of their STEM professors' mindsets predicted the psychological vulnerability composite. All models controlled for seven control variables (all at Level 2) including the number of ESM surveys taken (that controlled for possible survey fatigue), students' SAT scores, gender, race, and personal mindset beliefs, and students' perceptions of their STEM professor's warmth and competence. Specifically, we estimated the following models:

Level 1 (Observation)

$$\text{Psychological Vulnerability}_{ijk} = \pi_{0jk} + \varepsilon_{ijk}$$

Level 2 (Student)

$$\begin{aligned}\pi_{0jk} = {} & \beta_{00k} + \beta_{01k}(\text{Number of ESM surveys}) + \beta_{02k}(\text{SAT}) \\ & + \beta_{03k}(\text{Female}) + \beta_{04k}(\text{URM}) \\ & + \beta_{05k}(\text{Personal mindset beliefs}) \\ & + \beta_{06k}(\text{Perception of STEM professor's warmth}) \\ & + \beta_{07k}(\text{Perception of STEM professor's competence}) \\ & + \beta_{08k}(\text{Perception of STEM professor's mindset beliefs}) \\ & + r_{0jk}\end{aligned}$$

[14] During the first semester of data collection, a few students (*N* = 30) took ESM surveys for three or four weeks and were asked to complete the survey up to three times per week because of a survey application error that was corrected for the remainder of data collection.

Level 3 (Professor)

$$\beta_{00k} = \gamma_{000} + U_{00k}$$
$$\beta_{01k} = \gamma_{010}$$
$$\beta_{02k} = \gamma_{020}$$
$$\beta_{03k} = \gamma_{030}$$
$$\beta_{04k} = \gamma_{040}$$
$$\beta_{05k} = \gamma_{050}$$
$$\beta_{06k} = \gamma_{060}$$
$$\beta_{07k} = \gamma_{070}$$
$$\beta_{08k} = \gamma_{080}$$

The final model is as follows:

$$\begin{aligned}\text{Psychological Vulnerability}_{ijk} = {} & \gamma_{000} \\ & + \gamma_{010}(\text{Number of ESM surveys}) \\ & + \gamma_{020}(\text{SAT}) + \gamma_{030}(\text{Female}) \\ & + \gamma_{040}(\text{URM}) \\ & + \gamma_{050}(\text{Personal mindset beliefs}) \\ & + \gamma_{060}(\text{Perception of STEM professor's warmth}) \\ & + \gamma_{070}(\text{Perception of STEM professor's competence}) \\ & + \gamma_{080}(\text{Perception of STEM professor's mindset beliefs}) \\ & + U_{00k} + r_{0jk} + \varepsilon_{ijk}\end{aligned}$$

Mediation. To test the full mediation model in which students' perceptions of their STEM professors' mindset beliefs predicted their in-class psychological vulnerability, which in turn predicted their engagement and performance, we ran HLM models using the lmer package (Bates, 2010) in R Studio Version 1.0.136 (R Core Team, 2016). In the mediator models, the mediator (i.e., belonging, evaluative concerns, imposter, negative affect, or the psychological vulnerability composite) is regressed on the predictor (students' perceptions of their professors' mindset beliefs) and the control variables (number of ESM surveys taken, students' SAT scores, gender, race, personal fixed mindset beliefs, and students' perceptions of their STEM professor's warmth and competence). In the outcome models, the outcome (attendance, dropout intentions, STEM field-specific interest, or grades) is regressed on the predictor, mediator, and control variables. We then used the mediate package (Tingley, Yamamoto, Hirose, Keele, & Imai, 2014) in R Studio Version 1.0.136 to compute the average mediation effects.

A prerequisite of multilevel mediation analysis is that the outcome variable is measured at the lowest level of data (Krull & MacKinnon, 2001). Because our outcomes were at the student-level, we averaged students' ESM observations across the 2-week ESM period so that our mediators were also at the student-level. Thus, we ran two-level mediator and outcome models in which students (Level 1) were nested within professors (Level 2). All Level 1 continuous variables were *z*-scored prior to conducting the HLM analyses. We estimated the following models:

Mediator models:

Level 1 (Observation)

$$\text{Mediator}_{ij} = \beta_{0i} + R_{ij}$$

Level 2 (Student)

$$\begin{aligned}\beta_{0i} = {} & \gamma_{00} + \gamma_{01}(\text{Number of ESM surveys}) + \gamma_{02}(\text{SAT}) \\ & + \gamma_{03}(\text{Female}) + \gamma_{04}(\text{URM}) + \gamma_{05}(\text{Personal mindset beliefs}) \\ & + \gamma_{06}(\text{Perception of STEM professor's warmth}) \\ & + \gamma_{07}(\text{Perception of STEM professor's competence}) \\ & + \gamma_{08}(\text{Perception of STEM professor's mindset beliefs}) \\ & + U_{0j}\end{aligned}$$

The final mediator model is as follows:

$$\begin{aligned}\text{Mediator}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{Num of ESM surveys}) + \gamma_{02}(\text{SAT}) \\ & + \gamma_{03}(\text{Female}) + \gamma_{04}(\text{URM}) \\ & + \gamma_{05}(\text{Personal mindset beliefs}) \\ & + \gamma_{06}(\text{Perception of STEM professor's warmth}) \\ & + \gamma_{07}(\text{Perception of STEM professor's competence}) \\ & + \gamma_{08}(\text{Perception of STEM professor's mindset beliefs}) + U_{0j} + R_{ij}\end{aligned}$$

Outcome models:

Level 1 (Observation)

$$\text{Outcome}_{ij} = \beta_{0i} + R_{ij}$$

Level 2 (Student)

$$\begin{aligned}\beta_{0i} = {} & \gamma_{00} + \gamma_{01}(\text{Number of ESM surveys}) + \gamma_{02}(\text{SAT}) \\ & + \gamma_{03}(\text{Female}) + \gamma_{04}(\text{URM}) + \gamma_{05}(\text{Personal mindset beliefs}) \\ & + \gamma_{06}(\text{Perception of STEM professor's warmth}) \\ & + \gamma_{07}(\text{Perception of STEM professor's competence}) \\ & + \gamma_{08}(\text{Perception of STEM professor's mindset beliefs}) \\ & + \gamma_{09}(\text{Mediator}) + U_{0j}\end{aligned}$$

The final model is as follows:

$$\begin{aligned}\text{Outcome}_{ij} = {} & \gamma_{00} + \gamma_{01}(\text{Num of ESM surveys}) + \gamma_{02}(\text{SAT}) \\ & + \gamma_{03}(\text{Female}) + \gamma_{04}(\text{URM}) \\ & + \gamma_{05}(\text{Personal mindset beliefs}) \\ & + \gamma_{06}(\text{Perception of STEM professor's warmth}) \\ & + \gamma_{07}(\text{Perception ofSTEM professor's competence}) \\ & + \gamma_{08}(\text{Perception of STEM professor's mindset beliefs}) + \gamma_{09}(\text{Mediator}) + U_{0j} + R_{ij}\end{aligned}$$

Descriptives and correlations. See Tables 8 (Level 1) and 9 (Level 2) for means, standard deviations, ranges, reliability coefficients, and bivariate correlations among all variables for Study 4.

Psychological vulnerability. To determine how much of the variance in psychological vulnerability occurred at each level of analysis, we first ran unconditional models with no predictors and calculated the ICC for each individual component of psychological vulnerability (i.e., belonging, evaluative concerns, imposter, and negative affect) and the psychological vulnerability composite at the student-level and professor-level. The ICCs at the student-level

Table 8
Means, Standard Deviations, Ranges, Reliability Coefficients, and Correlations for All Variables at Level 1: Study 4

Variable	1	2	3	4	5
1. ESM vulnerability composite					
2. ESM belonging	−.82**				
3. ESM evaluative concerns	.81**	−.56**			
4. ESM imposter feelings	.85**	−.61**	.61**		
5. ESM negative affect	.76**	−.49**	.44**	.54**	
M	.002	5.26	1.10	2.11	.67
SD	.81	1.36	1.48	1.01	.82
Range	N/A	0–7	0–7	1–6	0–4
Reliability coefficient	0.82	0.89	0.94	0.88	0.80

Note. Perc = perception; prof = professor; ESM = experience sampling methodology.
** $p < .01$.

were as follows: belonging (0.74), evaluative concerns (0.67), imposter (0.70), negative affect (0.43), and psychological vulnerability composite (0.75). Thus, between 43% and 76% of the variance in psychological vulnerability occurred between-students. The ICCs at the professor-level were as follows: belonging (0.08), evaluative concerns (0.07), imposter (0.07), negative affect (0.09), and vulnerability composite (0.09). Thus, between 7% and 9% of the variance in psychological vulnerability occurred between-professors.

Next, we ran the three-level HLM analyses. See Table 10 for results. We found that students who perceived their professor to endorse stronger fixed mindset beliefs reported significantly lower belonging, $B = -.13$, $SE = .05$, $p < .01$, greater evaluative concerns, $B = .11$, $SE = .05$, $p = .02$, and greater imposter feelings, $B = .09$, $SE = .03$, $p < .01$. Students' perceptions of their professors' mindset beliefs did not predict their experiences of negative affect, $B = .03$, $SE = .03$, $p = .31$. Combining all psychological experiences into the psychological vulnerability composite, we found that students who perceived their professor to endorse greater fixed mindset beliefs experienced more psychological vulnerability in class, $B = .07$, $SE = .03$, $p < .01$.[15] Table S14 in the online supplemental materials reports all analyses without covariates. In these analyses, perceived professor fixed mindset does significantly predict students' negative affect; otherwise, results remain consistent.

Mediation. Next, we tested a full model (see Figure 1) in which students' perceptions of their professor's mindset beliefs predict students' psychological vulnerability in class, which in turn predict students' downstream engagement and performance in that particular professor's STEM class.[16] We first report analyses with the psychological vulnerability composite as the mediator and then summarize the effects of the component experiences individually.

Class attendance. Students' perceptions of their STEM professor's mindset beliefs predicted students' class attendance via students' experiences of psychological vulnerability in class, *indirect effect* = −.01, 95% CI [−.02, .00], $p = .03$. Thus, students who perceived that their STEM professor endorsed more fixed mindset beliefs experienced more psychological vulnerability in that professor's class, which in turn predicted lower self-reported class attendance. When looking at the components of psychological vulnerability individually (see Table S17 on p. 28 of the online supplemental materials), this indirect effect was driven by students' feelings of belonging and imposter feelings in the class; the indirect effect for evaluative concerns was marginal, and there was no indirect effect of negative affect.

Dropout intentions. For dropout intentions, we found a significant indirect effect of students' perceptions of their professor's mindset beliefs on students' dropout intentions via their psychological vulnerability in class, *indirect effect* = .03, 95% CI [.002, .06], $p = .04$. This indirect effect was driven by students' feelings of belonging and imposter feelings; as with class attendance, the indirect effect for evaluative concerns was marginal and there was no indirect effect of negative affect (see Table S17 on p. 28 of the online supplemental materials). Students who perceived their professor to endorse more fixed mindset beliefs experienced more psychological vulnerability in class—that is, lower belonging and higher evaluative concerns and imposter feelings—which in turn predicted more frequent thoughts about dropping the course.

STEM field-specific interest. We found a significant indirect effect of students' perceptions of their professor's mindset beliefs on STEM field-specific interest via their experiences of psychological vulnerability in class, *indirect effect* = −.02, 95% CI [−.05, .00], $p = .03$. This indirect effect was driven by belonging concerns; there was no indirect effect of evaluative concerns, imposter feelings, or negative affect (see Table S17 on p. 28 of the online supplemental materials). Students who perceived their professor to endorse more fixed mindset beliefs reported lower belonging, which in turn predicted lower STEM field-specific interest.

Grades. Finally, we found a significant indirect effect of students' perceptions of their professor's mindset beliefs on their grades in that particular professor's STEM class via their psychological vulnerability in class, *indirect effect* = −.01, 95% CI [−.02, .00], $p = .04$. This indirect effect was driven largely by students' imposter feelings; belonging was marginally significant. There was no indirect effect of evaluative concerns or negative affect (see Table S17 on p. 28 of the online supplemental materials). Students who perceived their professor to endorse more fixed mindset beliefs reported more imposter feelings and less belonging in class, which in turn

[15] We tested whether the association between students' perceptions of their professors' mindset beliefs and students' in-class experiences were moderated by student gender or race; again, no significant interactions were found suggesting that perceiving STEM professors to endorse fixed (vs. growth) mindset beliefs are predictive of students' classroom experiences, regardless of students' gender or racial group membership. We also tested whether this association was moderated by professor gender and found only one significant interaction. The interaction emerged only for negative affect, such that perceiving a professor to endorse more fixed mindset beliefs was more strongly related to negative affect when the professor was male (see Table S15 in the online supplemental materials). We did not run moderation analyses with professor race because only 8% of the professors in the sample were underrepresented racial or ethnic minorities.

[16] We also tested direct effects of perceived professor mindset on engagement and performance. We found no significant direct effects of students' perceptions of professor mindset beliefs on attendance, dropout, STEM field–specific interest, or grades (see Table S16 in the online supplemental materials), suggesting that these effects emerge indirectly as a function of students' psychological experiences in class.

Table 9
Means, Standard Deviations, Ranges, Reliability Coefficients, and Correlations for All Variables at Level 2: Study 4

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Perc. of fixed prof mindset											
2. SAT scores	−.01										
3. Female	−.05	−.17**									
4. URM	−.004	−.28**	.05								
5. Personal fixed mindset	.35**	.16**	−.05	−.08*							
6. Perc. of prof warmth	−.35**	−.06	.05	−.002	−.15**						
7. Perc. of prof competence	−.31**	.05	.08*	−.01	−.09*	.49**					
8. Attendance	−.07	−.01	.02	−.09*	−.03	.07	.14**				
9. Dropout intentions	.08*	−.17**	.04	.13*	.05	−.13**	−.06	−.20**			
10. STEM interest	−.05	.05	−.05	−.02	−.10*	.11**	.15**	.18**	−.30**		
11. Grades	−.08*	.37**	−.03	−.16**	.04	.05	.05	.29**	−.46**	.25**	
M	2.19	1234.14	N/A	N/A	2.69	5.31	5.54	4.57	1.52	4.64	3.17
SD	0.94	158.37	N/A	N/A	1.31	0.77	0.68	0.74	1.02	2.00	0.92
Range	1–6	400–1600	0–1	0–1	1–6	1–6	1–6	1–5	1–5	1–7	0–4
Reliability coefficient	0.87	N/A	N/A	N/A	0.89	0.73	0.70	N/A	N/A	0.94	N/A

Note. Perc = perception; prof = professor; STEM = science, technology, engineering, and mathematics. Female is coded 0 = male, 1 = female. Underrepresented racial minority status (URM) is coded 0 = White, Asian, 1 = Black, Hispanic, Native American, Other = 1.
* $p < .05$. ** $p < .01$.

predicted lower grades—even when controlling for prior performance (SAT scores).[17]

Discussion

Study 4 replicated and extended the findings of Study 3 using a larger sample and linking students' perceptions to their psychological experiences and performance in their specific college STEM courses. Replicating Study 3, we found that students' perceptions of their STEM professors' mindset beliefs predicted their psychological vulnerability in that professor's particular class and found that this association was not simply driven by students' general positive perceptions of their professor (i.e., warmth and competence). Students experienced lower belonging and greater evaluative concerns and imposter feelings when they perceived their STEM professor to endorse more fixed mindset beliefs. Extending Study 3 with a longitudinal design, we found that students' psychological vulnerability in class predicted their course engagement (i.e., attendance, thoughts about dropping out), STEM field-specific interest, and their actual grades in that particular STEM class. When looking at the individual components of psychological vulnerability, students' feelings of belonging and feelings of being an imposter in the class seemed particularly important in driving the associations between students' perceptions of their professor's mindset beliefs on their course engagement and performance.

General Discussion

The present studies used experimental, experience-sampling, and longitudinal methods to examine how college students' perceptions of their STEM professors' mindset beliefs influence their psychological vulnerability in STEM courses. Psychological vulnerability, in turn, predicts students' behavioral course engagement, STEM field interest, and end-of-semester performance. Across all studies ($N = 1669$ students)—two experiments (Studies 1 and 2) and two field studies (Studies 3 and 4)—we find that college students who perceive their STEM professors to endorse more fixed mindset beliefs about ability anticipate experiencing (Studies 1 and 2) and actually experience (Studies 3 and 4) greater psychological vulnerability during their STEM classes. That is, students who perceive their STEM professors to endorse the belief that intelligence is fixed anticipate and actually experience lower in-the-moment belonging, greater evaluative concerns (i.e., feeling afraid of doing or saying the wrong thing), greater imposter feelings (i.e., feeling like a fraud), and more negative affect (i.e., nervousness; distress) in their STEM classes. Taken together, these studies provide evidence that the perceived beliefs of powerful others in an evaluative setting (i.e., professors) that are communicated through what the professors say or do serves as a novel situational cue that influences students' psychological vulnerability in their STEM classrooms. This work adds to the literature on situational cues that shape students' psychological experiences in educational settings (e.g., Cheryan et al., 2009; Master, Cheryan, & Meltzoff, 2016; McDowell, Grubb, & Geho, 2015; Murphy et al., 2007; Purdie-Vaughns, Steele, Davies, Ditlmann, & Crosby, 2008; Stephens et al., 2012).

Students' experiences of psychological vulnerability also predict their anticipated (Studies 1 and 2) or actual (Study 4) downstream behavioral engagement, interest, and performance in STEM. These downstream associations were found both in laboratory experiments (Studies 1 and 2) and in the longitudinal field study where it could be explored (Study 4), demonstrating strong internal and external validity. The more students perceived that their STEM professor endorsed fixed mindset beliefs, the more psychological vulnerability they anticipated and actually experienced in class, and the lower their anticipated and actual behavioral engagement, interest, and performance. Importantly, these associations held even when controlling for students' prior performance (i.e., SAT scores), suggesting that these associations are not simply driven by low- or high-achieving students.

[17] When not including covariates in any of the mediation analyses, the pattern of results is unchanged (see Table S18 in the online supplemental materials).

Table 10
Effects of Perception of Professor Fixed Mindset on Psychological Vulnerability: Study 4

	Vulnerability composite			Belonging			Evaluative concerns			Imposter feelings			Negative affect		
Fixed	*B*	*SE*	*t* value	*B*	*SE*	*t* value	*B*	*SE*	*t* value	*B*	*SE*	*t* value	*B*	*SE*	*t* value
Intercept	−.04	.05	−.83	5.38***	.09	62.81	1.10***	.10	11.55	2.06***	.07	31.53	.64***	.05	12.41
Num ESM	−.02	.03	−.80	−.02	.04	−.46	−.05	.05	−1.10	−.06†	.03	−1.80	−.01	.02	−.33
SAT	−.06*	.03	−2.26	.12**	.05	2.61	−.06	.05	−1.17	−.06†	.03	−1.88	−.04	.03	−1.43
Female	.09†	.05	1.72	−.14	.09	−1.57	.11	.10	1.10	.11†	.07	1.66	.06	.05	1.21
URM	.11	.07	1.56	−.37**	.12	−3.00	−.04	.14	−.30	.16†	.09	1.70	.06	.07	.81
Personal fixed mindset	.15***	.03	5.94	−.23***	.04	−5.31	.21***	.05	4.39	.20***	.03	6.08	.09***	.02	3.62
Perc. of prof warmth	−.22***	.03	−7.54	.34***	.05	6.94	−.36***	.05	−6.54	−.20***	.04	−5.22	−.17***	.03	−6.11
Perc. of prof competence	−.04	.03	−1.45	.13*	.05	2.52	−.05	.06	−.97	−.03	.04	−.77	−.01	.03	−.42
Perc. of fixed prof mindset	.07**	.03	2.64	−.13**	.05	−2.77	.11*	.05	2.26	.09**	.03	2.70	.03	.03	1.01
Random															
Group: Student		.35			.96			1.13			.55			.21	
Group: Professor		.03			.07			.09			.04			.04	
Residual		.17			.48			.72			.31			.38	
N prof		37			37			37			37			37	
N students		735			735			735			734			734	
N observations		2319			2309			2319			2296			2295	

Note. Num ESM = number of experience sampling methodology surveys completed; perc = perception; prof = professor; *B* = unstandardized coefficient; *SE* = standard error. Female is coded 0 = male, 1 = female. Underrepresented racial minority status (URM) is coded 0 = White, Asian, 1 = Black, Hispanic, Biracial, Native American. All continuous variables (number of ESM surveys, SAT, personal fixed mindset, perception of professor warmth, perception of professor competence, perception of fixed professor mindset) were *z* scored. Separate hierarchical linear modeling (HLM) models were run for each outcome.
† $p < .1$. * $p < .05$. ** $p < .01$. *** $p < .001$.

Across all studies, we controlled for students' personal mindset beliefs and found that, even while controlling for these personal beliefs, students' perceptions of their professors' mindset beliefs predicted their anticipated and experienced psychological vulnerability in class. In other words, students' *perceptions* of what powerful people in the environment (e.g., their professors) believe about intelligence predict students' psychological experiences and performance in that environment—regardless of what students themselves *personally* believe about intelligence. These findings are consistent with existing literature on organizational mindsets (Emerson & Murphy, 2015; Murphy & Dweck, 2010) and demonstrate that students' perceptions of the classroom context (operationalized in this case by students' perceptions of their professors' mindset beliefs) powerfully predict their psychological experiences above and beyond their own personal mindset beliefs. Indeed, these findings emphasize the important role of *context* in mindset theory—that the perceived mindset beliefs of powerful people in the local context can predict students' experiences above and beyond their own personal mindset beliefs.

Although these results should be replicated in future experimental and field settings before moving to intervention, this research—conducted in four different university settings—suggests that it might not be enough to focus solely on changing students' personal mindset beliefs to create psychologically safe learning environments in which students are motivated and willing to take risks to advance their learning and development. It also may be necessary to change the learning environment itself by educating powerful institutional actors (such as faculty, staff, and administrators) about the power of their mindset beliefs for students' experiences, and helping them adopt and communicate growth mindset beliefs about students' ability through their policies, practices, and interactions with students. Through faculty-focused interventions such as these, it may be possible to create growth mindset classroom cultures that engage and motivate all students to reach their fullest potential.

Importantly, in Study 4, we were able to control for students' general perceptions of how warm or competent their professor was. These analyses largely demonstrate that the associations of perceived professor mindset on students' psychological experiences in class are not simply a function of how friendly or competent they perceive their professor to be. Students' perceptions of their professors' *mindset* beliefs (e.g., whether intelligence is fixed or changeable) uniquely predict students' belonging, evaluative concerns, and imposter feelings above and beyond these warmth and competence perceptions. However, it is quite possible that in the field, students' perceptions of their professor's mindset beliefs could covary with other more positive perceptions of the professor. If professors believe that students can learn and develop their skills, they might engage in more helpful pedagogical practices (providing lots of learning strategies, encouraging students to seek help and persist when struggling) than professors who believe students cannot learn and develop their skills. In fact, this would be expected. In the experimental context, it is ideal to isolate the role of faculty mindset beliefs from other perceptions; however, we speculate that future work examining how faculty mindset beliefs shape pedagogical practices are likely to find that growth mindset faculty are perceived as more warm, helpful, and empathetic by their students.

One might also wonder why we do not find evidence for moderation by students' demographic characteristics (e.g., their gender or race). Although the large bulk of literature on the effects of lay theory beliefs did not historically theorize or explore moderation by students' demographic characteristics (e.g., see Molden & Dweck, 2006; Yeager & Dweck, 2012, for reviews), some research suggests that students who are underrepresented, negatively stereotyped, or stigmatized in a particular academic do-

main—such as women or racial/ethnic minorities in STEM—can experience even stronger negative outcomes when they either personally endorse fixed mindset beliefs or when they perceive that others endorse fixed mindset beliefs (Aronson, Fried, & Good, 2002; Canning, Muenks, et al., 2019; Good, Aronson, & Inzlicht, 2003; Rattan et al., 2018). For example, although Canning, Muenks, and colleagues (2019) found a main effect such that all students performed more poorly in STEM classes when the professor self-reported more fixed (vs. growth) mindset beliefs, the racial achievement gap was twice as large in courses taught by professors who endorsed more fixed mindset beliefs. These moderation findings are consistent with other research on the effects of environmental cues on people's psychological experiences. In this literature, identity-relevant cues—such as the number of people in a setting who share a given identity—can affect people's cognitive, psychological, and physiological experiences (Cheryan et al., 2009; Ely & Thomas, 2001; Master et al., 2016; Murphy et al., 2007; Murphy & Taylor, 2012; Purdie-Vaughns et al., 2008; Stephens et al., 2012; Thoman, Smith, Brown, Chase, & Lee, 2013).

Although we found some evidence for moderation by student gender and race in Study 2 (see Table S11 in the online supplemental materials) that is consistent with a moderation story, the majority of evidence across our studies suggests that perceiving one's professor to endorse more fixed mindset beliefs leads to more negative psychological and behavioral experiences for *all* students. Perhaps we find these effects because it is important to almost all students that they are seen as smart, competent individuals (Covington, 2000; Ryan & Pintrich, 1997). Thus, this cue is identity-relevant to almost all students who care about being perceived in a favorable light by their professors. Indeed, this is consistent with most mindset research that often finds statistically significant main effects of lay theories on students' motivation and performance (e.g., see Molden & Dweck, 2006; Yeager & Dweck, 2012, for reviews). Given the somewhat inconsistent findings in this article and across this emerging literature, the question of whether, when, and for which groups moderation occurs is an important area of study that researchers should continue to theorize about and explore.

These studies are among the first to examine students' perceptions of professors' mindsets in naturally occurring classroom contexts. These results are consistent with other work demonstrating that perceptions of fixed mindset beliefs in organizations and institutions lead to lowered feelings of belonging (Aronson et al., 2002; Canning, Muenks, et al., 2019; Good et al., 2003; Rattan et al., 2018). However, these studies extend prior work by demonstrating that perceived mindset beliefs also shape students' evaluative concerns, imposter feelings, and negative affect, in both experimentally manipulated laboratory settings as well as actual college classroom contexts. Thus, these findings provide new and expanded external validity to the burgeoning literature on people's perceptions of powerful others' beliefs, and demonstrate that these perceptions predict a wider range of psychological experiences than was previously explored.

One of the unique methodological contributions of the two field studies (Studies 3 and 4) is that we examine students' psychological experiences immediately following their STEM classes using ESM (Zirkel et al., 2015). This innovative method allows students to report how they feel immediately following class, rather than waiting hours, days, or weeks in the future to report their experiences. We know from prior research that virtually all self-report data suffers from retrospective bias (e.g., Kahneman & Krueger, 2006); however, experience-sampling methods help minimize this bias. Thus, these studies are the first, to our knowledge, to capture students' in-the-moment psychological experiences—with more than 6,000 ESM surveys—and to examine students' psychological experiences as a function of students' authentically perceived faculty mindset beliefs in their actual STEM learning environments.

These studies are only the beginning of what we hope will be new directions in exploring how mindset is perceived in educational settings. Indeed, many more questions remain. For example, the present research documents the psychological, motivational, and academic consequences of perceiving that one's professor endorses fixed (vs. growth) mindset beliefs. However, future work should explore, in both the lab and the field, how perceived (and self-reported) faculty mindset beliefs are communicated to students. That is, what are teachers and professors saying or doing that leads students to perceive that they endorse more fixed or growth mindset beliefs? For example, researchers could examine whether certain behaviors such as how faculty respond to student struggles or failures, how they praise student success, or how much they emphasize learning versus performance (e.g., Barger, 2019; Canning, Muenks, et al., 2019; Schmidt et al., 2015; Sun, 2018) contributes to students' perceptions of their professors' beliefs. Further, to what extent do these perceived beliefs on the part of students align with faculty's self-reported beliefs—that is, to what extent are students' perceptions accurate, and are students' perceptions as equally powerful as faculty's self-reported beliefs? To examine this, researchers could use alternative experimental paradigms that hold constant professor's beliefs, but bias students' perceptions by employing biased response scales. Future longitudinal studies could also extend the present research by examining whether students' perceptions of their professors' mindset beliefs predict even longer-term outcomes that what is explored here, including students' retention in STEM fields, their choice of major, or their entrance into STEM careers upon graduation.

Another area for future work is in the theorizing and measurement of psychological vulnerability. We theorize psychological vulnerability as a multifaceted measure of self-threat—that is, a psychological threat to one's self-concept in evaluative settings. Because professors' fixed mindset beliefs may threaten students' self-concepts as smart and competent (i.e., Am I the kind of student who "has" the fixed, natural talent valued by this fixed mindset professor?), students may experience psychological threat in fixed mindset classrooms. Psychological threat is a complex, multifaceted construct that may consist of different psychological concerns in different contexts (e.g., Branscombe, Ellemers, Spears, & Doosje, 1999). Indeed, there is no agreed upon measure of psychological threat. Based on the findings presented here, we suggest that students' evaluative concerns, belonging, imposter feelings, and negative affect are important facets of students' psychological experiences that should be captured. Future research could use our measure to further examine the predictive validity of psychological vulnerability in other evaluative contexts.

Conclusion

If the United States is to remain globally competitive, we need more students to pursue and persist in STEM fields. Thus, it is critical to understand the factors that shape students' engagement and performance in STEM classroom contexts. The current work demonstrates that students' perceptions of what their professor believes about the malleability of intelligence (Dweck, 1999) can predict how students anticipate and experience their STEM classrooms—the extent to which they feel comfortable and supported, versus afraid to take risks and make mistakes. Further, how students experience their classrooms contributes to students' downstream behavioral and performance outcomes in STEM—their behavioral engagement, interest, and grades in STEM. Future experimental and longitudinal work should continue to investigate how mindset beliefs are communicated to students and how these beliefs influence and shape students' psychological, motivational, and performance outcomes. Ultimately, researchers and practitioners could use this (and future) work to educate college faculty about the ways in which their mindset beliefs and behaviors affect students' psychological experiences in class, their motivation, and their performance. Understanding how to help faculty communicate more of a growth mindset by creating a growth mindset culture in their classrooms seems critical to motivating and sustaining college students' performance and retention in STEM.

Context of the Research

The large majority of mindset research examines how the mindset beliefs of individuals (e.g., students) influences those individuals' personal outcomes (e.g., their motivation, engagement, performance). Our research takes a different approach by examining how perceiving the mindset of powerful others can shape our psychological experiences, motivation, and performance. The studies reported here are part of an ongoing program of research in our lab examining how situational cues such as the perceived beliefs of powerful individuals in a setting—such as the beliefs of teachers or supervisors—influence others' psychological experiences, motivation, and engagement in educational and workplace settings. Previous work has found that college STEM professors' self-reported mindset beliefs (i.e., about the malleability of intellectual ability) predict students' performance in those professors' classes (Canning, Muenks, et al., 2019). This project extends that work by examining how students' *perceptions* of their STEM professors' mindset beliefs act a situational cue that signals what (e.g., flawless performance) and who (e.g., the talented students) is valued by the professor. Here, we take a multimethod approach by examining these questions in the lab (where, due to random assignment, we have greater confidence in causal inference) and in the field (to examine external validity and generalizability). Moreover, we use ESM to examine students' psychological experiences in their actual college classrooms as a function of students' perceived faculty mindset. This allows us to examine students' psychological experiences in real time without concern for retrospective bias. Our results reveal that students' perceptions of their STEM professors' mindset beliefs influence students' anticipated and in-the-moment psychological experiences in the classroom, as well as their downstream motivation and performance over time (longitudinally). Future directions of this work include further understanding the psychological processes underlying these effects, as well as the specific professor practices that shape students' perceptions of their professors' beliefs.

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