The Disproportionate Impact of Fear of Negative Evaluation on First-Generation College Students, LGBTQ+ Students, and Students with Disabilities in College Science Courses

Carly A. Busch,[†§] Nicholas J. Wiesenthal,[†§] Tasneem F. Mohammed,[†] Shauna Anderson,[‡‖] Margaret Barstow,[‡‖] Cydney Custalow,[‡‖] Jas Gajewski,[‡‖] Kristin Garcia,[‡‖] Cynthia K. Gilabert,[‡‖] Joseph Hughes,[‡‖] Aliyah Jenkins,[‡‖] Miajah Johnson,[‡‖] Cait Kasper,[‡‖] Israel Perez,[‡‖] Brieana Robnett,[‡‖] Kaytlin Tillett,[‡‖] Lauren Tsefrekas,[‡‖] Emma C. Goodwin,[†] and Katelyn M. Cooper[†*]

[†]Research for Inclusive STEM Education Center and [‡]Biology Education Research Course, School of Life Sciences, Arizona State University, Tempe, AZ 85287

ABSTRACT

Fear of negative evaluation (FNE), defined as a sense of dread associated with being negatively judged in a social situation, has been identified as the primary factor underlying undergraduate anxiety in active-learning science courses. However, no quantitative studies have examined the extent to which science undergraduates experience FNE and how they are impacted by FNE in college science courses. To address this gap, we surveyed 566 undergraduates from one university in the U.S. Southwest who were enrolled in life sciences courses where they had opportunities to speak in front of the whole class. Participants were asked a suite of questions regarding their experiences with FNE in large-enrollment college science courses. We found that first-generation college students, LGBTQ+ students, and students with disabilities reported disproportionately high levels of FNE compared with their counterparts. Additionally, students reported that FNE can cause them to overthink their responses and participate less in class. Participants rated being cold called and presenting alone as forms of whole-class participation that elicit the highest levels of FNE. This research highlights the impact of FNE on undergraduates and provides student-generated recommendations to reduce FNE in active-learning science courses.

INTRODUCTION

More than one-third of undergraduates in the United States report that anxiety, commonly defined as an unpleasant emotional state characterized by feelings of worry (Spielberger, 2013), impedes their academic performance (American College Health Association, 2021). Anxiety is thought to be particularly common among undergraduates in the context of active-learning science courses (England *et al.*, 2017; Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020; Hood *et al.*, 2021), where students participate in their learning through activities and discussions in class (Freeman *et al.*, 2014; Driessen *et al.*, 2020). Specifically, the rigor and complexity of science content coupled with the notoriously competitive environments of science courses may increase anxiety among science students (Brainard and Carlin, 1998; Seymour *et al.*, 2004; Udo *et al.*, 2004; Mallow, 2006). Further, the inherently social and engaging aspects of active-learning courses have the potential to exacerbate undergraduate anxiety (England *et al.*, 2017; Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020; Hood *et al.*, 2021).

Stephanie Gardner, *Monitoring Editor*

Submitted Oct 4, 2022; Revised May 5, 2023; Accepted May 19, 2023

CBE Life Sci Educ September 1, 2023 22:ar31

DOI:10.1187/cbe.22-10-0195

[§]These authors contributed equally.

[‖]These authors contributed equally.

*Address correspondence to: Katelyn M. Cooper (katelyn.cooper@asu.edu).

Notably, national calls recommend that college science courses transition from traditional lecture to active learning (American Association for the Advancement of Science, 2011, 2015) because of the overwhelming evidence that students learn more and fail less in active learning compared with traditional lecture (Freeman *et al.*, 2014; Theobald *et al.*, 2020). However, fully engaging in active-learning practices is thought to be vital to reaping the benefits of taking an active-learning course (Levin, 2000; Freeman *et al.*, 2007; Brazeal *et al.*, 2016; Cavanagh *et al.*, 2016). Yet researchers have found that anxiety can inhibit student participation in active learning (Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020; Hood *et al.*, 2021; Novak *et al.*, 2022). As such, researchers and educators champion implementing active learning in ways that minimize student anxiety in the hopes of maximizing student gains (Hsu and Goldsmith, 2021; Yannier *et al.*, 2021).

Studies examining undergraduate anxiety in the context of both large- and small-enrollment active-learning courses have identified fear of negative evaluation (FNE) as a primary factor underlying student anxiety in active learning and a potential target for lessening student anxiety and maximizing performance (Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020). FNE is defined as the sense of dread associated with being unfavorably evaluated in a social situation (Watson and Friend, 1969; Weeks *et al.*, 2005) and can occur in both academic and nonacademic settings (Weeks *et al.*, 2005; Weeks and Howell, 2012). Importantly, to experience FNE, one must engage in or plan to engage in a social situation, because FNE is dependent on being judged by others. This distinguishes it from test anxiety or feeling tense, nervous, or fearful in evaluative situations (Cassady, 2010), due to the requisite social context of FNE. FNE is also distinct from social anxiety, which pertains to affective reactions in social situations regardless of whether evaluation from others occurs (Weeks *et al.*, 2005; Morrison and Heimberg, 2013).

As college science courses continue to transition from traditional lecture to active learning, where students often engage in more social situations in class, undergraduates encounter more social evaluative teaching practices (Stains *et al.*, 2018). Social evaluative teaching practices are defined as approaches to teaching that result in an opportunity for students to be judged by others in class (Covington, 1981; Stipek, 1993). Past research studies have highlighted that any situation in which a student's response is broadcast to others, such as when voluntarily asking and answering questions in class, contributing to group discussions, or being called on to speak in class without volunteering, can elicit FNE (Cooper *et al.*, 2018; Downing *et al.*, 2020; Nadile *et al.*, 2021a). Qualitative studies have suggested that being cold called, defined as being asked to answer a question in front of the whole class with no opportunity to discuss the answer with others, often elicits extremely high FNE among college science students (Broeckelman-Post *et al.*, 2016; England *et al.*, 2017; Cooper *et al.*, 2018; Hood *et al.*, 2021). When students are warm called, defined as having the opportunity to discuss the question with others before being involuntarily asked to share their answer in front of the class, undergraduate science students still report experiencing FNE, although they describe it as less extreme compared with when they are cold called (Downing *et al.*, 2020). In interviews with undergraduate science students, FNE is often described as a fear of being perceived as "stupid" by their science classmates (Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020). Students also describe fearing that a single negative social interaction may permanently harm their reputation in college.

Participants in these interview studies also highlighted an array of ways they were negatively impacted by FNE in active-learning courses. For example, undergraduate science students describe that FNE prevents them from thinking through science problems and articulating their thoughts to others during class (Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020). The psychology literature suggests that this response is likely a result of monitoring the classroom environment for threats of negative evaluation, which increases students' cognitive load and hinders their abilities to think and perform specific tasks (Sweller, 1994; Heimberg *et al.*, 2010). Additionally, if students are asked to contribute to a group or whole-class discussion, individuals with FNE may monitor their performance for potential flaws, such as blushing, sweating, shaking, or whether their voice is cracking (Rapee and Barlow, 1991; Eysenck and Calvo, 1992; Owens *et al.*, 2008; Heimberg *et al.*, 2010). Undergraduate science students also describe that FNE can cause them to second-guess their answers and doubt their abilities in science (Downing *et al.*, 2020). This is particularly concerning, given research that links low self-efficacy, defined as doubts in one's abilities within an academic learning environment, to lower academic performance (Bouffard *et al.*, 2005; Hsieh *et al.*, 2007; Liu *et al.*, 2015; Honicke and Broadbent, 2016). Finally, science undergraduates in qualitative interview studies describe that FNE can cause them to participate less in their courses (Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020). A recent survey study of more than 400 science undergraduates supported this finding; the higher a student's FNE, the less likely the student was to report voluntarily answering questions in the context of large-enrollment college science courses (Nadile *et al.*, 2021a). In sum, high FNE may have a remarkably negative impact on students in the context of college science.

Notably, low to moderate levels of FNE may have some positive effects on students. College science students in an interview study described that they are more likely to prepare for class if they perceive they will be put in a situation where they may be negatively evaluated by others (Downing *et al.*, 2020). This finding aligns with the Yerkes-Dodson law, which suggests that human performance on complex tasks can increase with a certain level of stress and anxiety, but only to a certain extent (Yerkes and Dodson, 1908). This helps explain why students can report both positive and negative impacts of FNE, although they are far more likely to mention consequences compared with benefits (Cooper *et al.*, 2018; Cooper and Brownell, 2020; Downing *et al.*, 2020).

There is some evidence to suggest that undergraduates may experience disproportionate levels of FNE relative to others depending on their demographics. While there has been little research examining demographic differences regarding FNE, demographics are often strong predictors of anxiety. For example, women are known to have higher anxiety than men (Misra and McKean, 2000; Bayram and Bilgel, 2008; Bryant *et al.*, 2013; Abdous, 2019; England *et al.*, 2019), and one study showed that women have higher anxiety than men specifically in the context of whole-class discussions (Eddy *et al.*, 2014).

Additionally, persons excluded because of their ethnicity or race (PEERs), members of the LGBTQ+ community, and first-generation college students report higher general anxiety compared with white students (Okazaki, 1997; Eckberg, 2015), non-LGBTQ+ students (Oswalt and Wyatt, 2011), and continuing-generation students (Grant *et al.*, 2014; Abdous, 2019), respectively. With regard to FNE specifically, students who do not speak English as their first language have been shown to have higher levels of FNE in the college classroom because their native language differs from the language they are expected to speak in class (Aida, 1994; Kitano, 2001; Tzoannopoulou, 2016). Additionally, disability resource center directors described that undergraduates with mental health and learning disabilities often report FNE in small-group and whole-class discussions (Gin *et al.*, 2020), and another study found that adults with speech disorders reported higher levels of FNE than their peers without speech disorders (Blood and Blood, 2016). Given the negative impact that FNE can have on undergraduates in active-learning college science courses and the disproportionate impact that FNE may be having on students who are underserved in science, lessening FNE in college science courses may be an important step to creating a more diverse and inclusive scientific community.

Current Study

To date, the majority of studies examining fear of negative evaluation in the context of science classrooms are qualitative interviews of students (Cooper *et al.*, 2018; Downing *et al.*, 2020). These studies have described FNE, the active-learning practices that can evoke FNE, and how FNE can affect undergraduates in college science courses. However, the extent to which these findings are generalizable to a larger population is not well understood. While one study found that students with higher levels of FNE are less likely to report voluntarily answering questions in college science courses (Nadile *et al.*, 2021a), the extent to which students experience FNE, the most common practices that evoke FNE, and the most common ways undergraduates are affected by FNE are largely unknown. Further, no studies have examined how FNE and its effects vary based on student identities. To address these gaps in the literature, we designed a quantitative survey study to examine to what extent students report experiencing FNE in the context of college science courses and whether FNE levels vary by student demographics. We also sought to identify what teaching practices are most likely to evoke FNE, what behaviors students are most worried could be negatively evaluated by peers, the extent to which students report judging others for exhibiting such behaviors, and what students perceive instructors can do to reduce FNE among undergraduates.

Our specific research questions were all contextualized in large-enrollment college science courses that provide opportunities for students to speak in front of the whole class:

1. To what extent do undergraduates report experiencing FNE?
   a. Do student demographics predict severity of FNE?
2. In what ways does FNE impact undergraduates?
3. To what extent do different social evaluative teaching practices evoke varying levels of FNE among undergraduates?
   a. Is there a relationship between whether a student has experienced a particular practice and the student's FNE?
4. To what extent do students worry about their peers negatively evaluating them when they exhibit certain behaviors during class and to what extent do they report negatively evaluating their peers when their peers exhibit such behaviors during class?
5. How do students perceive instructors can reduce FNE?

METHODS

This study was conducted with an approved Arizona State University Institutional Review Board protocol (no. 00015621).

This research project was carried out as part of an online course-based undergraduate research experience (CURE), in which 14 undergraduates who were enrolled in an online biology or biochemistry degree program engaged in a biology education research project in the context of a course (Auchincloss *et al.*, 2014). The biology education CURE was backward designed to develop students' process of science and quantitative reasoning skills (Cooper *et al.*, 2017; Cooper and Brownell, 2018). The students met synchronously for an hour and a half over 15 weeks, in addition to spending an additional ~5–10 hours on the project each week. Henceforth, these student researchers will be referred to as CURE researchers. In collaboration with the instructor (K.M.C.), three graduate research assistants (C.A.B., N.J.W., T.F.M.), and a postdoc research assistant (E.C.G.), the CURE researchers were responsible for carrying out the project from research question development through writing up the research findings.

Positionality Statement

The researchers on this project identify as women and men, with races or ethnicities that include Black, Asian, multiracial, and white. Some researchers are the first in their family to attend college. At the time the study was conducted, three researchers were graduate students, 14 were undergraduate students, one researcher was a postdoctoral scholar, and one was an assistant professor. Of the 14 CURE researchers, 13 have prior experience taking in-person courses with whole-class discussions. Some researchers identify as having extremely high FNE and others have low FNE. The diverse identities and experiences of the research team were leveraged to try and counteract biases in the way the data were collected, analyzed, and evaluated for this research (Intemann, 2009).

Study Context

We posited that student FNE likely varies across course contexts, such as between large-enrollment and small-enrollment courses, between major courses and nonmajor courses, and between active-learning and traditional lecture courses. Therefore, we chose to confine our study to examining FNE among science majors enrolled in large-enrollment science courses that provide opportunities for students to speak out in front of the whole class. We focused on large-enrollment courses, because we predicted they would elicit the greatest levels of FNE owing to the number of students who could potentially pass judgment on a particular student; we defined large-enrollment courses as those with 100 students or more to align with previous studies (Mohammed *et al.*, 2021; Nadile *et al.*, 2021a). We also asked participants to consider only science courses where there were opportunities to speak out in front of the whole class when

completing the survey so that we could explore the impact of a set of social evaluative practices that are specific to whole-class discussion. On the survey, we described what we meant by courses that included whole-class discussion by providing examples such as opportunities to voluntarily ask and answer questions in front of the whole class or instances when the instructor calls on students who do not volunteer to speak in front of the whole class.

Survey Development

We developed a survey to answer our research questions. The survey first asked participants to confirm that they had been enrolled in at least one large-enrollment course of 100 students or more that included whole-class discussions. Students who confirmed that they had advanced to the remaining survey questions.

RQ 1: To What Extent Do Undergraduates Report Experiencing FNE in Large-Enrollment College Science Courses? On the survey, we included a modified version of the 12-item Brief Fear of Negative Evaluation (BFNE) scale, a widely used instrument in social anxiety research (Leary, 1983; Rodebaugh *et al.*, 2004; Weeks *et al.*, 2005). Several studies have previously assessed the validity of the latent structure of the original BFNE scale in student and non-student populations, as well as in clinical and nonclinical settings (Rodebaugh *et al.*, 2004; Weeks *et al.*, 2005; Duke *et al.*, 2006). Evidence from these studies support a correlated two-factor model, with eight positively framed items comprising one factor and four negatively framed items comprising a second factor (Rodebaugh *et al.*, 2004; Weeks *et al.*, 2005; Duke *et al.*, 2006). However, the negatively framed items have lower evidence for convergent validity with other theoretically related constructs and greater potential for confusion and misinterpretation by study participants, suggesting that only the eight positively framed items should be used to measure FNE (Rodebaugh *et al.*, 2004; Weeks *et al.*, 2005; Duke *et al.*, 2006). We therefore modified the eight positively framed items for use in the context of college science courses, changing the wording of each item only to prompt participants to consider their classmates and experiences in a large-enrollment college science course. Students answered the eight items about the extent to which they worry about others evaluating them (e.g., "I worry about what my classmates in large-enrollment college science courses will think of me even when I know it doesn't make any difference," "I am frequently afraid of my classmates in my large-enrollment college science courses noticing my shortcomings"), using five Likert response options ranging from 1, not at all characteristic of me, to 5, extremely characteristic of me. For this study, we label total scores ranging from 8 to 16 as mild FNE, 17 to 31 as moderate FNE, and 32+ as severe FNE. We adopted these ranges based on the ranges for mild, moderate, and severe anxiety on the generalized anxiety seven-item scale (GAD-7; Spitzer *et al.*, 2006), as the positively framed FNE items do not have established thresholds to determine mild, moderate, or severe FNE.

RQ 2: In What Ways Does FNE Impact Undergraduates? We examined the extant literature to generate a list of ways in which FNE may positively and negatively affect students. Survey participants were asked to report how likely they were to respond to FNE by: 1) preparing more, 2) struggling to think through science problems in class, 3) struggling to articulate their thoughts when contributing to discussions, 4) participating less, 5) overthinking their responses in discussions, 6) considering dropping the course, and 7) intentionally making an effort to bolster their reputation with the individual(s) they perceived are judging them. Participants answered how likely they were to respond to feelings of judgment on a continuous sliding scale ranging from 0, never, to 4, always. For RQ2 (as well as RQ3 and RQ4), the outcomes were measured with single items with responses recorded to the tenths place, so we treated our outcome as linear rather than ordinal because participants could select non-integer values in their response. Further exploration of the data confirmed that the responses for these questions illustrate the continuous nature of these data and participants did not limit their selections to integer values. Additionally, given the sample size of the study and the robustness of parametric tests, these data can be considered to be linear and treated as such in the analyses (Sullivan and Artino, 2013).

RQ 3: To What Extent Do Different Social Evaluative Teaching Practices Evoke Different Levels of FNE among Undergraduates? To assess how students' FNE may vary based on social evaluative teaching practices, students were first asked a series of *yes* or *no* questions about whether they had at least one opportunity to participate in seven practices that prior studies suggest could elicit FNE (Broeckelman-Post *et al.*, 2016; England *et al.*, 2017; Cooper *et al.*, 2018; Downing *et al.*, 2020; Hood *et al.*, 2021): 1) cold call, defined as involuntarily answering a question in front of the whole class without having the opportunity to talk to a neighbor; 2) warm call, defined as involuntarily answering questions in front of the whole class after having the opportunity to talk to a neighbor; 3) group call, defined as involuntarily answering a question in front of the whole class on behalf of a small group; 4) voluntarily answering a question in front of the whole class; 5) voluntarily asking a question in front of the whole class; 6) presenting in front of the whole class alone; and 7) presenting in front of the whole class in a group. For each social evaluative teaching practice, all students answered a question about the extent to which they would worry about being judged by other students in a context where they would need to participate in each practice, which they answered on a continuous sliding scale ranging from 0, not at all, to 4, extremely. We used a single item to assess FNE for each of the seven practices, as opposed to adapting the eight-item FNE scale for each practice, to limit the length of the survey while allowing us to examine participants' perceptions of all seven practices. We chose to ask all students about FNE as it relates to each practice because prior work has suggested that students often fear or make judgments about active-learning practices that they have not yet engaged in (Cavanagh *et al.*, 2016, 2018; Tharayil *et al.*, 2018), and we were interested in examining how FNE differed, if at all, between students who had previous experience engaging in a particular practice and those who had not.

RQ 4: What Behaviors Evoke FNE among Undergraduates and What Behaviors Cause Students to Negatively Evaluate Others? To assess what behaviors students perceive to commonly elicit FNE in large-enrollment college science courses,

we asked students to consider a list of behaviors generated from the literature and report how likely it was that others would judge them negatively if they exhibited each behavior. Students responded to the question about each behavior on a continuous sliding scale from 0, extremely unlikely, to 5, extremely likely. The behaviors were identified based on prior literature (Rapee and Barlow, 1991; Eysenck and Calvo, 1992; Owens *et al.*, 2008; Heimberg *et al.*, 2010; Cooper *et al.*, 2018; Downing *et al.*, 2020; Nadile *et al.*, 2021a); the behaviors were: 1) asking too many questions, 2) answering too many questions, 3) making too many comments (e.g., debating with the instructor), 4) not contributing in class, 5) not appearing engaged, 6) falling asleep in class, 7) coming to class late or leaving early, 8) talking while the instructor is talking, 9) providing the correct answer, 10) providing the incorrect answer, 11) how I look (e.g., If I blush, I sweat, I have a visible disability, I'm insecure about my appearance), and 12) how I speak (e.g., I stutter, I don't use big words, I have an accent, English is my second language, I don't know the vocabulary).

Because there is sometimes a disconnect between the extent to which students worry about others judging them and the likelihood that others will in fact pass judgment on them (Üztemur, 2020), we also asked participants how likely they were to negatively judge another student based on each of the 12 behaviors, which they answered on a continuous sliding scale from 0, extremely unlikely, to 5, extremely likely.

RQ 5: How Can Instructors Decrease FNE in Large-Enrollment Science Courses? The literature (Cooper *et al.*, 2018, 2021; Cooper and Brownell, 2020; Downing *et al.*, 2020; Hsu and Goldsmith, 2021) informed a list of 18 ways that instructors could potentially decrease student FNE in the context of large-enrollment college science courses (e.g., constructively respond to students, be open to student questions). The list was presented to survey participants and they were asked to select each way they perceived an instructor could lessen their FNE in the context of large-enrollment college science courses.

Participant Demographics. Students answered a suite of demographic questions, including questions about gender, race/ethnicity, college generation status, LGBTQ+ status, disability status, and being an international student at the end of the survey. A copy of the survey questions analyzed in this study can be found in the Supplemental Material. All participants received the survey questions in a fixed order as represented in the Supplemental Material.

Validity and Reliability of Survey Questions. To establish cognitive validity of the survey questions, we conducted three rounds of think-aloud interviews with a total of 14 undergraduates (seven in round 1, six in round 2, one in round 3) who had been enrolled in large-enrollment college science courses (Trenor *et al.*, 2011). The survey was revised after each round and finalized after round 3, when we were confident that each question was being interpreted correctly. To evaluate the internal consistency of the modified FBNE scale, we calculated McDonald's omega total, an alternative reliability measure to Cronbach's alpha that does not assume equivalence of factor loadings in the model (Hancock *et al.*, 2010). The BFNE items displayed excellent internal consistency in our study population. To assess the construct validity of our modified BFNE and establish that the instrument functions as expected to measure the latent construct of FNE in the context of large-enrollment undergraduate science courses at our institution, we used confirmatory factor analyses (CFAs) to evaluate a one-factor model (Hancock *et al.*, 2010). Though evaluation of descriptive statistics for the BFNE items revealed no deviation from normality, a robust maximum likelihood estimator with the Satorra-Bentler correction was used in the CFAs to account for potential nonnormality in item responses (Hancock *et al.*, 2010). Evaluation of initial CFAs indicated two instances of high correlation between a pair of similarly worded items. We repeated a CFA allowing these item pairs to correlate within the model, and the revised BFNE model displayed good model fit. This revised model was used to calculate individual factor scores weighted to reflect model factor loadings for each study participant, using Bartlett's method (DiStefano *et al.*, 2009). The full results of the CFA can be found in Supplemental Tables S1 and S2. All analyses were conducted in R v. 4.2.0, using the base, psych, and lavaan packages (R Core Team, 2019; Rosseel, 2012; RStudio Team, 2019; Revelle, 2022).

Participant Recruitment

We sent an email to all instructors teaching biology, chemistry, geosciences, and physics courses at a large research-intensive institution in the U.S. Southwest, asking them to send our survey out to their students in exchange for a small amount of extra credit or for being entered into a raffle for the chance to win one of two $100 gift cards. Of the 304 instructors who were contacted, 37 (12.17%) agreed to send our survey to their students.

Data Cleaning and Analysis

A total of 979 science majors who had taken at least one large-enrollment in-person college science course began the survey. After removing students who did not complete the survey and students who completed the survey in under 3 minutes, a total of 566 students were included in the final data set (57.8%).

RQ 1: To What Extent Do Undergraduates Report Experiencing FNE in Large-Enrollment College Science Courses? The data were analyzed using a linear regression model that examined how general FNE scores differed among demographics that included gender, race, college generation status, LGBTQ+ status, disability status, and whether the student was an international student. Our output was students' weighted BFNE factor scores. Notably, we grouped individuals who identify as women, gender-queer, or nonbinary into one group: woman/nonbinary. We chose to do this because excluding the small number of nonbinary and gender-queer individuals would decrease the number of LGBTQ+ individuals represented in the study, and considering the historic and current privilege that men experience in the context of science, which is neither afforded to women nor gender nonbinary individuals, the grouping was logical (Cooper *et al.*, 2020; Cech, 2022). Owing to low sample sizes, we also combined Black or African American, Latin*, Pacific Islander, and American Indian or Alaska Native individuals into one group: persons excluded because of their ethnicity or race (PEERs). While Asian individuals are not typically

considered historically underrepresented in science (National Science Foundation, 2021), we acknowledge that these individuals do still face acts of discrimination and prejudice that white students do not (Singer *et al.*, 2003; Ruiz *et al.*, 2020). As such, Asian individuals were included in the analyses as a separate group, as were white individuals. Participants responded to a single item to report whether they identified as having a disability; participants who selected "yes" were considered to have a disability. On a follow-up question, participants selected the disability(ies) they identified as having, including depression or anxiety. Importantly, participants who reported that they had depression and/or anxiety without self-reporting having a disability were not considered to have a disability. Regrettably, we did not collect data on whether students were native English speakers; however, we used whether students were international students as a proxy for this identity (Bartram and Bailey, 2009; Marrone *et al.*, 2018). Identity groups that are neither underrepresented nor underserved in science served as the reference group in all regression analyses, which include men, white, not LGBTQ+, not disabled, continuing generation, and not an international student. Although students were asked on the survey whether they self-identify as having anxiety and/or depression, we chose not to include this in our model. Fear of negative evaluation is a known underlying cause of anxiety and has been shown to be positively correlated with scaled measures of anxiety (Ganesh Kumar *et al.*, 2015; Iqbal and Ajmal, 2018). Because depression and anxiety are often comorbid and highly related (Boyer, 2000; Clark and Beck, 2010; Kalin, 2020; McTeague *et al.*, 2020), we did not want to mask potential demographic differences in FNE levels by including these variables in our model. The model used to answer this research question is: FNE factor score ~ gender + race/ethnicity + college generation status + LGBTQ+ status + disability + international status.

RQ2–RQ5: (RQ2) How Does FNE Impact Students? (RQ3) Does FNE Vary by Social Evaluative Teaching Practice? (RQ4) What Behaviors Evoke FNE and Cause Students to Negatively Evaluate Others? (RQ5) How Can Instructors Decrease FNE in Large-Enrollment Science Courses? We used descriptive statistics to assess the most common ways that FNE affects students, which social evaluative teaching practices cause FNE, the most common behaviors to evoke FNE among students, which behaviors are most likely to cause students to pass judgment on others, and ways that students perceive instructors can decrease FNE in large-enrollment college science courses.

For RQ2, we assessed demographic differences in how FNE impacts students using linear regression analyses. We included gender in our models, because it approached significance for predicting FNE ($p = 0.08$) and because it is known to be associated with anxiety (Bayram and Bilgel, 2008; Eddy *et al.*, 2014), and the predictors we found to be significant for FNE: college generation status, LGBTQ+ status, and disability status (model: Impact score ~ gender + college generation status + LGBTQ+ status + disability status).

For RQ3, we further examined whether students' FNE regarding particular social evaluative practices differed based on whether they had previously engaged in the practice. We regressed students' FNE scores on whether they had participated in the practice and controlled for the demographics described for RQ2. The results of all regressions are reported in the Supplemental Material.

For RQ4, we conducted paired *t* tests to assess whether there were differences in the extent to which students expected to be negatively evaluated when behaving a particular way in class and their rating of the extent to which they were likely to pass judgment on others for exhibiting the same behavior. The results of the *t* tests are reported in the Supplemental Material. Additionally, we calculated the mean and SD of FNE scores for behaviors that influence whose perspectives are heard during class (e.g., answering too many questions) disaggregated by demographic characteristics to descriptively assess whether students from non-minoritized groups report lower FNE for these practices. We conducted linear regressions to assess demographic differences using the same predictors as before. All means and SDs, as well as results from the linear regressions, can be found in the Supplemental Material. For RQ2–RQ4, we used Bonferroni corrections for multiple hypothesis testing based on the number of related tests performed. All significant results reported in the text passed their respective adjusted thresholds. The Supplemental Material contains the full results from all statistical tests and notes the Bonferroni correction used for each.

RESULTS

Participants

A total of 566 student participants were included in the analyses. Most participants identified as being women, white, and continuing-generation college students. Participants primarily identified as not being LGBTQ+, not having a disability, and not being an international student. Participant demographics are summarized in Table 1.

Finding 1: Most Students Report Mild or Moderate FNE

In the context of large-enrollment science courses that incorporate whole-class discussion, we found that 47.4% of students reported mild FNE, 41.9% of students reported moderate FNE, and 10.6% of students reported severe FNE. First-generation college students, ($p = 0.02$), LGBTQ+ students ($p < 0.001$), and students with disabilities ($p = 0.03$) reported significantly higher FNE than continuing-generation college students, non-LGBTQ+ students, and students who do not identify with having a disability, respectively (Figure 1). The difference between the higher levels of FNE reported by women, gender-queer, and gender nonbinary individuals compared with men approached significance ($p = 0.08$). The full results of the regression are provided in the Supplemental Table S3.

Finding 2: FNE Causes Students to Overthink Their Responses to Questions and to Participate Less in Class

In response to experiencing FNE, students reported they most frequently overthought their responses to questions and participated less in course interactions in an effort to avoid being negatively evaluated. The next most common way students reported being impacted by FNE was preparing more for class, followed by experiencing difficulty speaking and thinking in class. Notably, students rarely consider dropping a course in response to FNE. Students' likelihood of exhibiting certain behaviors in response to FNE is summarized in Figure 2; full summary statistics are available in Supplemental Table S4.

TABLE 1. Summary of participant demographics

Participant demographics (N = 566) n (%)			
Gender		**College generation status**	
Woman	392 (69%)	First-generation	220 (39%)
Man	155 (27%)	Non-first generation	323 (57%)
Gender-queer or nonbinary	10 (2%)	Decline to state	23 (4%)
A gender not listed	1 (0.2%)	**LGBTQ+ status**	
Decline to state	8 (1%)	LGBTQ+	85 (15%)
Race/ethnicity		Not LGBTQ+	455 (80%)
Pacific Islander	5 (0.9%)	Decline to state	26 (5%)
Black/African American	30 (5%)	**International student**	
Hispanic/Latin*	96 (17%)	Yes	27 (5%)
White/Caucasian	261 (46%)	No	522 (92%)
Asian or Asian American	123 (22%)	Decline to state	17 (3%)
American Indian or Alaska Native	5 (0.9%)	**Disability status**	
Other	25 (4%)	Yes	29 (5%)
Decline to state	21 (4%)	No	521 (94%)
		Decline to state	16 (3%)

Based on our regression analyses, women/nonbinary students reported struggling to think (β = 0.46, $p < 0.001$), struggling to speak (β = 0.49, $p < 0.001$), participating less (β = 0.43, $p = 0.002$), and overthinking (β = 0.70, $p < 0.001$) in response to experiencing FNE more often than men. LGBTQ+ students reported struggling to speak (β = 0.51, $p = 0.001$) and participating less (β = 0.72, $p < 0.001$) in response to FNE more often than non-LGBTQ+ students. Finally, first-generation college students reported struggling to think (β = 0.32, $p = 0.004$) and considering dropping a course (β = 0.27, $p = 0.004$) more than continuing-generation students. There were no significant differences based on disability status. Full results from the linear regressions are available in Supplemental Table S5.

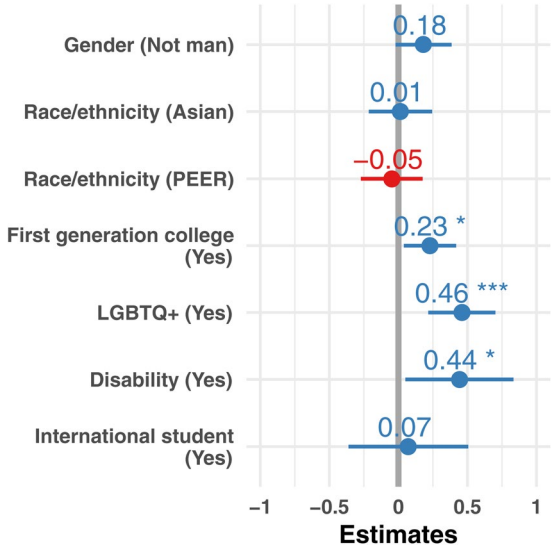

FIGURE 1. FNE factor scores regressed on gender, race/ethnicity, college generation status, LGBTQ+ status, disability status, and international student status. Groups of interest are listed in parentheses. Reference groups are men, white students, continuing-generation college students, non-LGBTQ+ students, and students who do not identify as having a disability. Blue numbers (and those to the right of the vertical gray line) indicate a positive estimate, or a higher FNE score, whereas red (left of the vertical gray line) indicates a negative estimate, or a lower FNE score. Confidence intervals that do not cross the vertical gray line at $x = 0$ are statistically significant, which is also indicated by the asterisks. Significance: *$p < 0.05$; ***$p < 0.001$ (model: FNE factor score ~ gender + race/ethnicity + college generation status + LGBTQ+ status + disability + international status).

Finding 3: Being Cold Called and Presenting Alone Evoke Highest FNE among Students

Combining ratings from students who had and had not participated in particular evaluative practices, we found that being cold called and presenting alone evoked the highest levels of FNE (cold call M = 1.8, SD = 1.3; presenting alone M = 2.0, SD = 1.4). The means and SDs of FNE ratings for each evaluative practice can be found in Supplemental Table S6. When analyzing student FNE ratings by whether they had actually participated in a particular evaluative situation, we found that FNE levels were significantly higher among students who had not voluntarily asked a question (β = 0.82, $p < 0.001$) and students who had not voluntarily answered a question (β = 0.80, $p < 0.001$; full results in Supplemental Table S7). Students' FNE scores for each active-learning practice separated by whether or not they have engaged in each practice are reported in Figure 3.

Finding 4: Students Worry That They Will Be Judged by Others and Admit to Judging Others for Similar Behaviors

Participants reported that, on average, the practices that would elicit the highest likelihood of negative evaluation from other students were making too many comments in class (M = 2.9, SD = 1.7), talking while the instructor is speaking (M = 2.6, SD = 1.6), and asking too many questions during class (M = 2.5, SD = 1.5), which indicates moderate concern for being judged (i.e., a 3 indicates "somewhat likely," and a 2 indicates "somewhat unlikely"). On the contrary, students felt that not contributing to classroom discussions or activities (M = 1.2, SD = 1.4), being disengaged during class (M = 1.2, SD = 1.3), or providing the

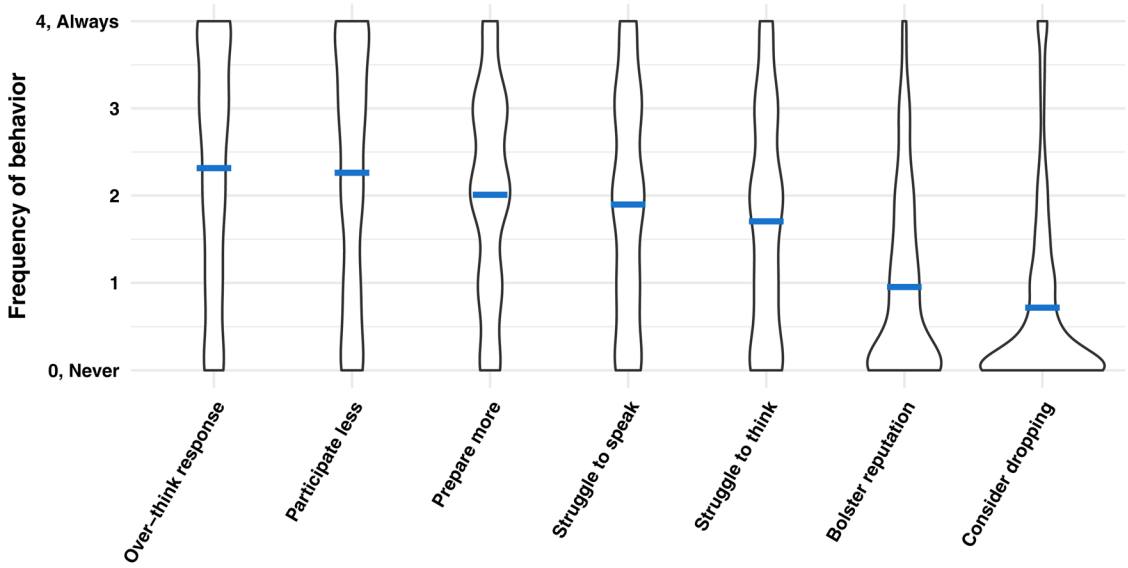

FIGURE 2. Students' self-reported frequency of performing a certain behavior in response to FNE in the context of college science courses. The middle blue line within each violin represents the mean value of likeliness of performing each indicated behavior.

correct answer during classroom discussions (M = 2.2, SD = 1.6) were least likely to evoke negative evaluation from other students (1 indicates "unlikely").

Because individuals can fear negative evaluation even when the likelihood of being judged by others is low (Shafique *et al.*, 2017), we were interested in understanding how likely participants in the study would be to judge others for exhibiting the same behaviors. Notably, students expressed the highest FNE about behaviors that they were also most likely to admit judging others for, such as making too many comments in class (M = 2.3, SD = 1.7) and talking while the instructor is talking (M = 2.5, SD = 1.7). They also expressed lowest FNE about behaviors they were unlikely to report judging others for, such as giving a correct answer (M = 0.5, SD = 0.9) and not contributing to class (M = 0.9, SD = 1.2). Means and SDs for students' ratings of all behaviors in both contexts can be found in Supplemental Table S8.

We compared students' ratings of their FNE from peers when exhibiting a behavior and their likelihood of judging their peers exhibiting the behavior using paired *t* tests and found

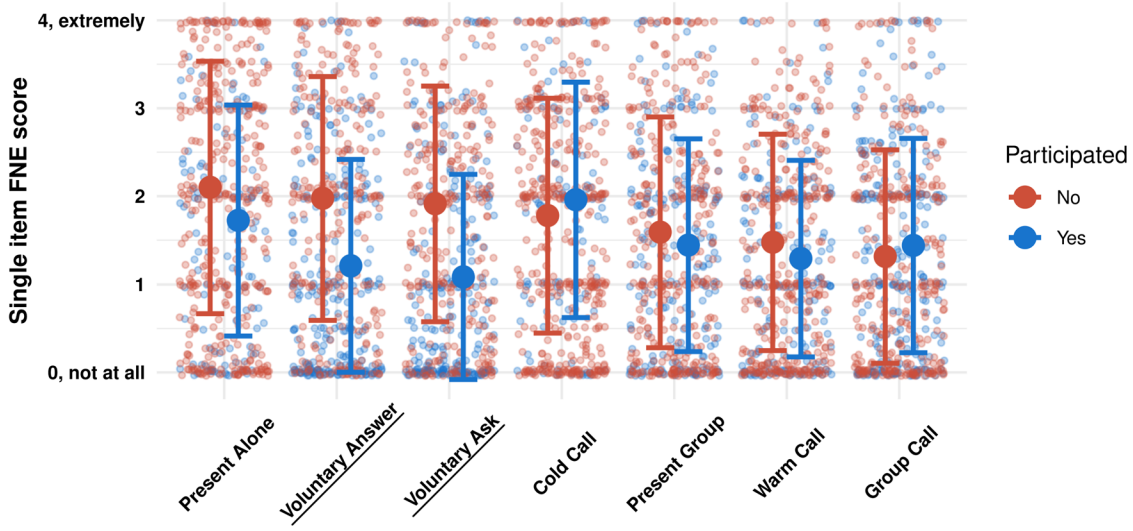

FIGURE 3. Students' FNE scores by whether they participated in each social evaluative practice. For each practice, students were asked to rate the extent to which they worry about being judged by other students in a context where they would need to participate in each practice, ranging from 0, not at all, to 4, extremely. Underlined practices indicate that prior experience with the social evaluative practice was a significant predictor ($p < 0.001$) in the linear regression of the student FNE for the practice (model: practice FNE score ~ practice experience + gender + first-gen + LGBTQ+ + disability). The fully shaded point represents the mean with SD, with individual responses lightly shaded behind.

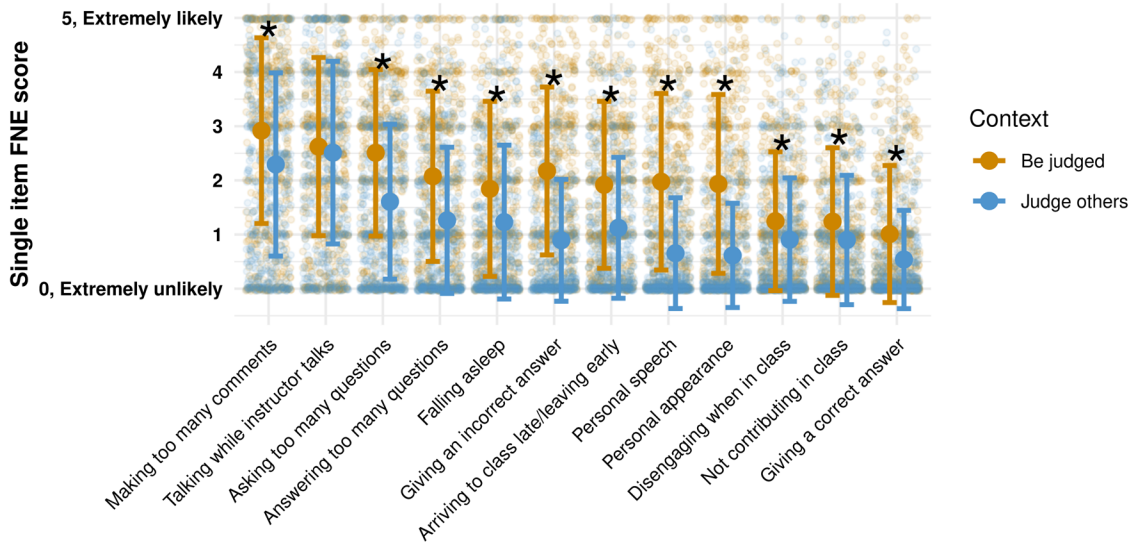

FIGURE 4. Students' perceptions of a behavior's likelihood of causing them to be negatively evaluated by their peers (orange) and how likely participants said they were to evaluate their peers for exhibiting each behavior (blue). For each behavior, students were asked to rate how likely they would be to worry about being judged by other students if they exhibited the behavior and the likelihood of judging others for exhibiting the behavior, ranging from 0, extremely unlikely, to 5, extremely likely. Asterisks indicate that the difference of the means is significant based on paired *t* tests (all $p < 0.001$). The fully shaded point represents the mean with SD, with individual responses lightly shaded behind.

that, for 11 of the 12 behaviors, students rated the likelihood that they would be judged by others higher than the likelihood that they would judge others for the same behavior (all $p < 0.001$). The full results from the paired *t* tests can be found in Supplemental Table S9. The only behavior for which there was not a significant difference was in judging others or being judged for talking while the instructor talks ($p = 0.07$). Students' perceptions as to what extent it is likely they would be judged for exhibiting specific behaviors in the classroom and to what extent they pass judgment on others for exhibiting the specific behaviors are depicted in Figure 4.

Based on linear regression analyses comparing FNE scores across demographic groups for behaviors that affect whose perspectives are heard during class (i.e., answering too many questions, asking too many questions, making too many comments, giving a correct answer, giving an incorrect answer), LGBTQ+ students reported higher FNE associated with asking too many questions ($\beta = 0.51$, $p = 0.005$), making too many comments ($\beta = 0.65$, $p = 0.002$), and providing an incorrect answer ($\beta = 0.78$, $p < 0.001$) compared with those who do not identify as LGBTQ+. There were no significant differences among demographic groups based on gender, college generation status, or disability status. Means and SDs for students' FNE ratings disaggregated by demographic groups as well as full results from the linear regression analyses for these five behaviors can be found in Supplemental Tables S10 and S11.

Finding 5: To Reduce FNE, Students Recommend That Instructors Allow Students to Work Alone and Choose Their Own Seats, Respond Constructively to Comments, and Be Open to Questions

Students were asked to choose from a list of potential ways to lessen FNE in large-enrollment college science courses. From this list, all students selected that instructors allowing students to work alone and choose their own seats in the classroom, responding constructively to student answers, and being open to questions from students in the class were ways to lessen FNE in the classroom. Instructors avoiding harsh criticism, taking volunteers, and building relationships with students were also commonly selected recommendations. The percent of students who selected each recommendation for reducing FNE is illustrated in Figure 5.

DISCUSSION

The Disproportionate Impact of FNE on LGBTQ+ Students, Students with Disabilities, and First-Generation Students and Its Negative Effects

This study revealed that FNE disproportionately impacts students who are already underrepresented and underserved in science. Specifically, LGBTQ+ students were more likely to report higher levels of FNE than their non-LGBTQ+ counterparts. An in-depth interview study of LGBTQ+ undergraduates enrolled in an active-learning biology course established that LGBTQ+ students report that their LGBTQ+ identities are more apparent in active-learning courses compared with traditional lecture courses because of the increased interactions between students and instructors (Cooper and Brownell, 2016). These LGBTQ+ students reported that although their identities are often concealable, there are more opportunities for them to be outed and potentially negatively evaluated by other students. Further, transgender students described that speaking out in class can be particularly fear-inducing if they perceive that their voice does not match their gender identity. In addition to finding that LGBTQ+ students have higher FNE than their peers, the current study also revealed that students who identify as having a disability reported higher levels of FNE than students without disabilities. Notably, students who identify their anxiety or depression as a disability were included in the model. This

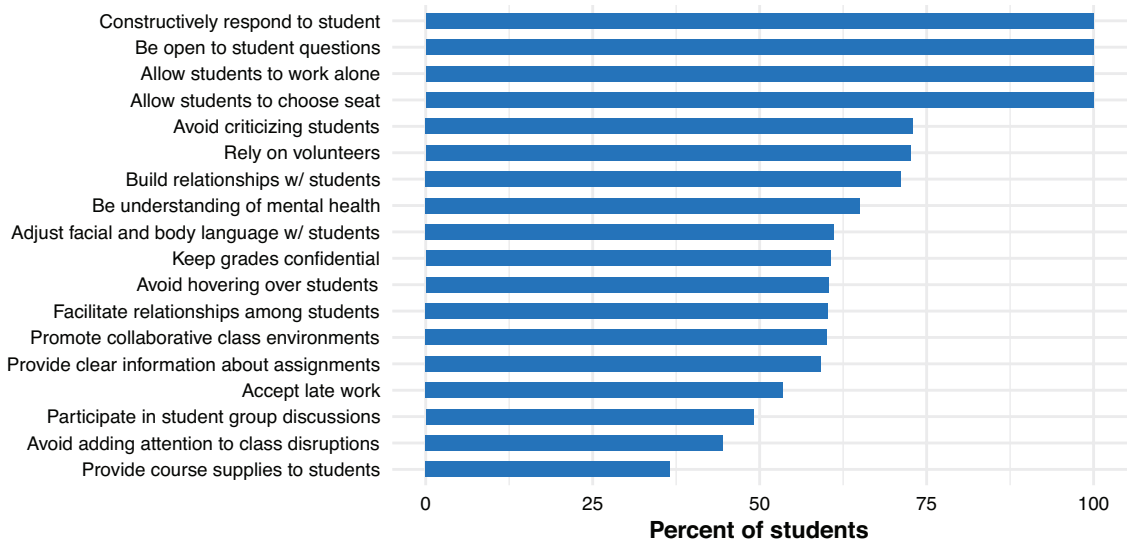

FIGURE 5. Percentage of students who selected a factor related to how instructors can decrease FNE in large-enrollment college science courses.

finding aligns with those of an interview study of disability resource center directors about how students with disabilities navigate active-learning classrooms; disability resource center directors reported that students with mental health disabilities often struggle with participating when cold called because of their FNE (Gin *et al.*, 2020). Additionally, studies have shown that students with learning disabilities report higher levels of social anxiety in college classrooms than their undergraduate peers (Carroll and Iles, 2006; Gin *et al.*, 2020). If students' learning disabilities cause them to take more time to think through a question or affect their ability to articulate their thoughts, this may also explain increased levels of FNE among students with disabilities in whole-class discussions (Rapee and Barlow, 1991; Heimberg *et al.*, 2010). Additionally, students with disabilities report experiencing stigma in college science (Moon *et al.*, 2012; Braun *et al.*, 2018). Therefore, any social evaluative situation may be fear-inducing if students perceive it would result in discrimination. Our study also found that first-generation college-going students reported higher FNE than their peers, which aligns with past studies citing that first-generation status could lead to higher levels of generalized anxiety and stress in college classroom environments (Gaudier-Diaz *et al.*, 2019; Hood *et al.*, 2020; Noel *et al.*, 2021). Notably, first-generation college students were the only group to report being more likely to drop a course in response to experiencing FNE. A lack of exposure to advanced course work leading up to college may be partially responsible for these increased levels of FNE among these students and likelihood of dropping a course when faced with high levels of FNE (Riehl, 1994; Engle, 2007). Further, first-generation college students report lower feelings of belonging at their universities, which may exacerbate their FNE (Stephens *et al.*, 2012; Stebleton *et al.*, 2014).

The disproportionate impact that FNE has on students who are already underrepresented and underserved in science is particularly concerning in light of the negative impact that FNE has on students. Students reported it was most common for FNE to cause them to overthink their responses and not participate in class. Indeed, social anxiety has been found to be linked to excessive deliberation (Hunter *et al.*, 2022), and the qualitative study of community college students in active-learning classrooms found that students' FNE causes them to second-guess their responses, as well as their intelligence (Downing *et al.*, 2020). While carefully considering one's response is an important step to answering a question (Liu *et al.*, 2014), excessive deliberation often leads to selecting an incorrect response (Mallinson and Miller, 1956; Bennett and Lafser, 2005). Concerningly, undergraduates in the current study also reported that FNE can reduce their participation in class. Decades of research highlights the link between participation in the classroom and student success (Lyons, 1989; Junn, 1994; Garside, 1996; Dancer and Kamvounias, 2005). Specifically, participation has been found to increase communication skills (Dancer and Kamvounias, 2005) and motivation (Junn, 1994) and help students become critical thinkers in learning environments (Garside, 1996). As such, lowering student FNE may be an effective approach to increasing student participation and performance among students who are already underrepresented and underserved in science. Notably, FNE also commonly caused students to prepare more for class. However, given the potential consequences of increasing student FNE, we argue that other approaches, such as providing preclass chapter quizzes (Dobson, 2008; Johnson and Kiviniemi, 2009) or other preclass online activities (Moravec *et al.*, 2010; Jensen *et al.*, 2018) that promote student learning before a class lecture would be more appropriate ways to encourage student preparedness.

FNE with Respect to Social Evaluative Teaching Practices

Students were asked a series of questions that evaluated their FNE with respect to social evaluative teaching practices found within large-enrollment college science courses that invite whole-class discussion. Prior literature has found that cold call elicits severe FNE from students (Cooper *et al.*, 2018; Downing *et al.*, 2020); as such, it is unsurprising that cold call emerged

as the practice most likely to induce FNE among students who had experienced it in this study. Cold call has been critiqued by the science education community, largely for omitting the opportunity for students to discuss their answers with each other, which instructors predict would lessen students' FNE (Auerbach and Andrews, 2018; Cooper *et al.*, 2021). Indeed, students report notably lower FNE associated with warm call, when students are able to discuss their responses before being asked to respond to a question in front of the whole class, and with group call, when students work together on a question in a group and one student responds to the whole class on the group's behalf.

Students who had not experienced voluntary social evaluative situations, namely answering and asking questions, reported markedly higher FNE compared with those who had experienced them. However, there was little difference in FNE between students who had and who had not participated in involuntary whole-class social evaluative situations such as cold call and group call. As such, the difference in FNE scores between students who had and had not participated in voluntary evaluative situations may be explained by students who have less FNE being more willing to participate, as opposed to increased exposure to a practice decreasing FNE over time. However, the design of our study prevents us from offering a conclusion about why these differences exist.

Behaviors That Evoke FNE

Prior studies tend to focus on the teaching practices that evoke FNE (England *et al.*, 2017; Cooper *et al.*, 2018; Cooper and Brownell, 2020; Hood *et al.*, 2021), and little research has examined what student-specific behaviors undergraduates worry about being judged for. Encouragingly, the current study revealed that undergraduates worry they will be judged for behaviors that may limit the diversity of voices heard in the classroom, such as commenting too much in class, asking too many questions, and answering too many questions. Prior studies have shown the voices that are heard within science courses are likely not representative of the class makeup. For example, despite women making up 60% of undergraduate biology students, their voices are only heard 40% of the time (Eddy *et al.*, 2014), and a study across the sciences found that men were more likely than women to report asking questions (Nadile *et al.*, 2021b). Additionally, research has found that students prefer when others avoid taking too much time for themselves in the class and allow others to speak (Fassinger, 1995; Glock, 2016). However, given that FNE disproportionately affects students who are already underrepresented and underserved in science, students in majority groups may be less concerned about being judged for overcontributing. Indeed, non-LGBTQ+ students reported lower FNE associated with many behaviors that affect whose perspectives are heard during class (e.g., answering too many questions) compared with LGBTQ+ students. Therefore, instructors may want to consider alternatives to asking students to speak out in front of the whole class in order to create a more equitable environment (Cooper *et al.*, 2021).

Given that students often describe fearing negative evaluation even in situations where they can recognize that the chances of being judged by others is low (Heimberg *et al.*, 2010; Shafique *et al.*, 2017; Cooper *et al.*, 2018), we were interested to see whether this was the case in the context of courses that invite students to speak in front of the whole class. Students, for the most part, ranked behaviors they were most likely to judge others for as the ones they were most likely to perceive would elicit judgment from others. Past research has found that students generally have an agreed upon set of expectations for participation in college courses (Fassinger, 1995) and seem to be aware of what behaviors elicit judgment and what behaviors do not. However, while students worried that their speech or appearance would elicit judgment from others, they reported that they were very unlikely to pass judgment on others based on these metrics. This may be a result of social desirability bias (Paulhus, 1984); students may be unwilling to admit judging others on speech or appearance, because this is considered to be socially inappropriate (Blood *et al.*, 1979; Kwan and Trautner, 2011; Klein and Shtudiner, 2021). Conversely, students may be especially likely to fear negative evaluation based on their looks or speech owing to high levels of self-consciousness (Turk *et al.*, 2001; Brown and Stopa, 2007). In general, students were more likely to worry about being judged by others than to admit judging others for the same behavior. While this is likely partially due to social desirability bias (Paulhus, 1984), it could also be due to the spotlight effect, defined as the over-analyzation or overestimation of one's actions in a learning space (Gilovich *et al.*, 2000).

Why Decreasing FNE Is Important and How Students Think Instructors Can Help

Importantly, students' experiences with and reactions to FNE may affect their science identity development. Carlone and Johnson (2007) proposed that science identity development is influenced by students' perceived competence, performance, and recognition, all of which may be negatively affected by higher levels of FNE. Specifically, competence refers to the knowledge and understanding of science content; performance encompasses the ways of talking and using scientific tools to socially demonstrate competence; recognition encapsulates both seeing the self and being seen by meaningful others as a "science person" (Carlone and Johnson, 2007). FNE may dampen students' competence, because it can not only hinder their ability to think through science problems but may also prevent them from engaging in active-learning activities that are known to bolster student learning (Cooper *et al.*, 2018; Downing *et al.*, 2020). Further, because FNE can interfere with both students' ability to think through science problems and articulate their thoughts about science, it likely hinders their performance in science courses. Finally, FNE may impede students' ability to recognize themselves as "science people," because they are not meeting the expectation of what a science student should do (i.e., clearly articulate their reasoning when answering questions during class). A student's lack of participation or a suboptimal performance likely affects the extent to which meaningful others, such as peers and instructors, view the student as a "science person." Therefore, one potential mechanism for instructors to enhance students' science identity and ultimately their academic achievement and retention (Merolla and Serpe, 2013; Perez *et al.*, 2014; Seyranian *et al.*, 2018; Hughes *et al.*, 2019; Oseguera *et al.*, 2019) is to structure courses to decrease students' FNE.

When we asked students which instructor recommendations they agreed would help reduce student FNE, four were selected by every participant in the study; students recommended that instructors allow students to work alone, allow students to choose their own seats in the classroom, constructively respond to student questions and answers, and be open to questions from the students during class meetings. Studies have shown that, on days when a student's anxiety, and consequently FNE, is unusually high, it can be helpful for the student to work alone in a classroom (Hood *et al.*, 2021; Novak *et al.*, 2022). As such, giving students the option to opt out of group work on days when they need to may help curb extreme feelings of FNE. Allowing students to choose their seats may also be helpful in reducing FNE, because studies show that being able to choose one's seat in class can allow students to work better or feel more comfortable in certain seats within the classroom (Levine *et al.*, 1980; Hillmann *et al.*, 1991; Schussler *et al.*, 2021). Being able to choose their own seats may also decrease students' FNE, because it gives them the opportunity to select which classmates they sit near, and therefore their partners for in-class assignments. Specifically, studies have shown that choosing one's own seat can reduce anxiety for LGBTQ+ undergraduates, because they can be more selective in their in-class assignment partners and choose partners who they anticipate or know will be accepting of their LGBTQ+ identities (Cooper and Brownell, 2016). Students' request for constructive responses from instructors can be addressed by having instructors learn how to error frame (Bell and Kozlowski, 2008; Steele-Johnson and Kalinoski, 2014), defined as redefining student errors or mistakes as useful tools of development or refinement. Emphasizing positive aspects of students' incorrect responses, instead of only highlighting what is wrong with them, may boost student confidence and decrease the extent to which they worry about being negatively evaluated. Finally, setting aside time for students to ask questions can reduce student discomfort about posing a question to the instructor and increase their willingness to participate (Nadile *et al.*, 2021a,b). Specifically, research has shown that when instructors are less critical or harsh and more constructive or immediate in their responses during class meetings, students are more willing to participate in classroom discussions and activities (Rocca, 2008). We argue that these four recommendations are relatively easy to implement and have the potential to have a significant impact on lessening FNE and increasing student participation in large-enrollment active-learning science courses.

Limitations

This quantitative study was conducted at one institution in the southwestern U.S. and focused on the context of large-enrollment science courses for majors that offered opportunities for whole-class participation. We hope future studies will examine FNE in different contexts, including at different institution types, in smaller classrooms, in nonmajor courses, and with other active-learning practices. We recognize that a validated scale would have been preferable to the single items used to measure student FNE with regard to specific social evaluative situations. However, we chose to use the single items to allow us to explore more practices. Additionally, students were asked to consider their experiences across all large-enrollment college science courses with opportunities to speak out in front of the whole class. As such, we were unable to assess whether FNE varied by science course discipline. We acknowledge that students may not accurately report their behaviors (Brown *et al.*, 2015). Therefore, we encourage future experimental studies to test whether students indeed demonstrate particular behaviors in moments when they are experiencing FNE. It is also important to note that there were not enough students who identified as having a disability to disaggregate the results by specific types of disabilities (e.g., mental health/learning disability, physical disability). However, future studies should examine whether FNE differs by disability type.

CONCLUSION

In this quantitative survey study, we asked students about their experiences in large-enrollment college science courses and their associated fear of negative evaluation (FNE) or the extent to which they worry they will be negatively judged by others in class. We found that undergraduate students who identify as LGBTQ+, as first-generation college students, or as having a disability reported higher levels of FNE than their respective counterparts. Students reported that FNE caused them to overthink their responses and participate less in class. Presenting in front of the whole class and being randomly called on to speak in front of the class without having the opportunity to discuss the question with others elicited the highest levels of FNE among undergraduates. Students were most concerned that they would be judged if they made too many comments in class, asked too many questions, or answered too many questions. Participants recommended that instructors lessen FNE in large-enrollment college science courses by allowing students to work alone, being open to questions during class meetings, constructively responding to student questions and answers, and allowing students to select their own seats in class. The findings from this study highlight how instructors can modify their instruction to be more equitable for students with anxiety in large-enrollment college science courses.

ACKNOWLEDGMENTS

We thank Dr. Yi Zheng for her feedback on the statistical approaches to this study. We thank the instructors who were willing to share our survey with their students and the undergraduates who were willing to participate in our study. We are extremely grateful to Dr. Ara Austin and the College of Liberal Arts and Sciences at Arizona State University for the development of the Online Undergraduate Research Scholars (OURS) program, which partially funded this course-based undergraduate research experience for ASU undergraduates enrolled in the online bachelor of science degree programs. C.A.B., N.J.W., and T.F.M. are supported by National Science Foundation (NSF) Graduate Fellowships (grant no. 026257-001). This project built upon conclusions from a meeting that brought together psychologists, psychiatrists, student support specialists, and biology education researchers. This meeting identified FNE as the most pressing factor underlying student anxiety in active learning and was supported by an NSF RCN-UBE Incubator award (no. 2018902). Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF.

REFERENCES

Abdous, M. (2019). Influence of satisfaction and preparedness on online students' feelings of anxiety. *The Internet and Higher Education*, *41*, 34–44. https://doi.org/10.1016/j.iheduc.2019.01.001

Aida, Y. (1994). Examination of Horwitz, Horwitz, and Cope's construct of foreign language anxiety: The case of students of Japanese. *Modern Language Journal*, *78*(2), 155–168. https://doi.org/10.2307/329005

American Association for the Advancement of Science. (2011). *Vision and change in undergraduate biology education: A call to action*. Washington, DC. Retrieved May 23, 2022, from https://live-visionandchange.pantheonsite.io/wp-content/uploads/2011/03/Revised-Vision-and-Change-Final-Report.pdf

American Association for the Advancement of Science. (2015). *Vision and change in undergraduate biology education: Chronicling change, inspiring the future*. Washington, DC. Retrieved May 23, 2022, from http://Visionandchange.Org.

American College Health Association. (2021). *Undergraduate student reference group data report, Fall 2021 (National College Health Assessment III)*. Retrieved April 29, 2021, from www.acha.org/documents/ncha/NCHA-III_FALL_2021_UNDERGRADUATE_REFERENCE_GROUP_EXECUTIVE_SUMMARY.pdf

Auchincloss, L. C., Laursen, S. L., Branchaw, J. L., Eagan, K., Graham, M., Hanauer, D. I., … & Rowland, S. (2014). Assessment of course-based undergraduate research experiences: A meeting report. *CBE—Life Sciences Education, 13*(1), 29–40.

Auerbach, A. J. J., & Andrews, T. C. (2018). Pedagogical knowledge for active-learning instruction in large undergraduate biology courses: A large-scale qualitative investigation of instructor thinking. *International Journal of STEM Education*, *5*(1), 19. https://doi.org/10.1186/s40594-018-0112-9

Bartram, B., & Bailey, C. (2009). Different students, same difference? A comparison of UK and international students' understandings of "effective teaching." *Active Learning in Higher Education*, *10*(2), 172–184. https://doi.org/10.1177/1469787409104903

Bayram, N., & Bilgel, N. (2008). The prevalence and socio-demographic correlations of depression, anxiety and stress among a group of university students. *Social Psychiatry and Psychiatric Epidemiology*, *43*(8), 667–672. https://doi.org/10.1007/s00127-008-0345-x

Bell, B. S., & Kozlowski, S. W. J. (2008). Active learning: Effects of core training design elements on self-regulatory processes, learning, and adaptability. *Journal of Applied Psychology*, *93*(2), 296–316. https://doi.org/10.1037/0021-9010.93.2.296

Bennett, B., & Lafser, N. (2005). Instinct and second-guessing oneself on Tests. *Undergraduate Psychology Research Methods Journal*, *1*(3). Retrieved May 23, 2022, from https://digitalcommons.lindenwood.edu/psych_journals/vol1/iss3/10

Blood, G. W., & Blood, I. M. (2016). Long-term consequences of childhood bullying in adults who stutter: Social anxiety, fear of negative evaluation, self-esteem, and satisfaction with life. *Journal of Fluency Disorders*, *50*, 72–84. https://doi.org/10.1016/j.jfludis.2016.10.002

Blood, G. W., Mahan, B. W., & Hyman, M. (1979). Judging personality and appearance from voice disorders. *Journal of Communication Disorders*, *12*(1), 63–67. https://doi.org/10.1016/0021-9924(79)90022-4

Bouffard, T., Bouchard, M., Goulet, G., Denoncourt, I., & Couture, N. (2005). Influence of achievement goals and self-efficacy on students' self-regulation and performance. *International Journal of Psychology*, *40*(6), 373–384. https://doi.org/10.1080/00207590444000302

Boyer, P. (2000). Do anxiety and depression have a common pathophysiological mechanism? *Acta Psychiatrica Scandinavica*, *102*, 24–29.

Brainard, S. G., & Carlin, L. (1998). A six-year longitudinal study of undergraduate women in engineering and science. *Journal of Engineering Education*, *87*(4), 369–375.

Braun, D. C., Clark, M. D., Marchut, A. E., Solomon, C. M., Majocha, M., Davenport, Z., … & Gormally, C. (2018). Welcoming Deaf students into STEM: Recommendations for university science education. *CBE—Life Sciences Education*, *17*(3), es10. https://doi.org/10.1187/cbe.17-05-0081

Brazeal, K. R., Brown, T. L., & Couch, B. A. (2016). Characterizing student perceptions of and buy-in toward common formative assessment techniques. *CBE—Life Sciences Education*, *15*(4), ar73. https://doi.org/10.1187/cbe.16-03-0133

Broeckelman-Post, M., Johnson, A., & Reid Schwebach, J. (2016). Calling on students using notecards: Engagement and countering communication anxiety in large lecture. *Journal of College Science Teaching*, *45*(5), 27–33. https://doi.org/10.2505/4/jcst16_045_05_27

Brown, G. T. L., Andrade, H. L., & Chen, F. (2015). Accuracy in student self-assessment: Directions and cautions for research. *Assessment in Education: Principles, Policy & Practice*, *22*(4), 444–457. https://doi.org/10.1080/0969594X.2014.996523

Brown, M. A., & Stopa, L. (2007). The spotlight effect and the illusion of transparency in social anxiety. *Journal of Anxiety Disorders*, *21*(6), 804–819. https://doi.org/10.1016/j.janxdis.2006.11.006

Bryant, F. B., Kastrup, H., Udo, M., Hislop, N., Shefner, R., & Mallow, J. (2013). Science anxiety, science attitudes, and constructivism: A binational study. *Journal of Science Education and Technology*, *22*(4), 432–448. https://doi.org/10.1007/s10956-012-9404-x

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching*, *44*(8), 1187–1218.

Carroll, J. M., & Iles, J. E. (2006). An assessment of anxiety levels in dyslexic students in higher education. *British Psychological Society*, *76*, 651–682.

Cassady, J. C. (2010). Test anxiety: Contemporary theories and implications. In *Anxiety in schools* (pp. 7–26). New York, NY: Peter Lang.

Cavanagh, A. J., Aragón, O. R., Chen, X., Couch, B., Durham, M., Bobrownicki, A., … & Graham, M. J. (2016). Student buy-in to active learning in a college science course. *CBE—Life Sciences Education*, *15*(4), ar76. https://doi.org/10.1187/cbe.16-07-0212

Cavanagh, A. J., Chen, X., Bathgate, M., Frederick, J., Hanauer, D. I., & Graham, M. J. (2018). Trust, growth mindset, and student commitment to active learning in a college science course. *CBE—Life Sciences Education*, *17*(1), ar10. https://doi.org/10.1187/cbe.17-06-0107

Cech, E. A. (2022). The intersectional privilege of white able-bodied heterosexual men in STEM. *Science Advances*, *8*(24), eabo1558. https://doi.org/10.1126/sciadv.abo1558

Clark, D. A., & Beck, A. T. (2010). Cognitive theory and therapy of anxiety and depression: Convergence with neurobiological findings. *Trends in Cognitive Sciences*, *14*(9), 418–424.

Cooper, K. M., Auerbach, A. J. J., Bader, J. D., Beadles-Bohling, A. S., Brashears, J. A., Cline, E., … & Brownell, S. E. (2020). Fourteen recommendations to create a more inclusive environment for LGBTQ+ individuals in academic biology. *CBE—Life Sciences Education*, *19*(3), es6. https://doi.org/10.1187/cbe.20-04-0062

Cooper, K. M., & Brownell, S. E. (2016). Coming out in class: Challenges and benefits of active learning in a biology classroom for LGBTQIA students. *CBE—Life Sciences Education*, *15*(3), ar37. https://doi.org/10.1187/cbe.16-01-0074

Cooper, K. M., & Brownell, S. E. (2018). Developing course-based research experiences in discipline-based education research: Lessons learned and recommendations. *Journal of Microbiology & Biology Education*, *19*(2), 1–5.

Cooper, K. M., & Brownell, S. E. (2020). Student anxiety and fear of negative evaluation in active learning science classrooms. In Mintzes, J. J. & Walter, E. M. (Eds.), *Active learning in college science: The case for evidence-based practice* (pp. 909–925). Cham, Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-030-33600-4_56

Cooper, K. M., Downing, V. R., & Brownell, S. E. (2018). The influence of active learning practices on student anxiety in large-enrollment college science classrooms. *International Journal of STEM Education*, *5*(1), 23. https://doi.org/10.1186/s40594-018-0123-6

Cooper, K. M., Schinske, J. N., & Tanner, K. D. (2021). Reconsidering the share of a think–pair–share: Emerging limitations, alternatives, and opportunities for research. *CBE—Life Sciences Education*, *20*(1), fe1. https://doi.org/10.1187/cbe.20-08-0200

Cooper, K. M., Soneral, P. A., & Brownell, S. E. (2017). Define your goals before you design a CURE: A call to use backward design in planning course-based undergraduate research experiences. *Journal of Microbiology & Biology Education*, *18*(2), 1–7.

Covington, M. V. (1981). Strategies for smoking prevention and resistance among young adolescents. *Journal of Early Adolescence*, *1*(4), 349–356.

Dancer, D., & Kamvounias, P. (2005). Student involvement in assessment: A project designed to assess class participation fairly and reliably.

Assessment & Evaluation in Higher Education, *30*(4), 445–454. https://doi.org/10.1080/02602930500099235

DiStefano, C., Zhu, M., & Mîndrilã, D. (2009). Understanding and using factor scores: Considerations for the applied researcher. *Practical Assessment, Research, and Evaluation*, *14*(20). https://doi.org/10.7275/DA8T-4G52

Dobson, J. L. (2008). The use of formative online quizzes to enhance class preparation and scores on summative exams. *Advances in Physiology Education*, *32*(4), 297–302. https://doi.org/10.1152/advan.90162.2008

Downing, V. R., Cooper, K. M., Cala, J. M., Gin, L. E., & Brownell, S. E. (2020). Fear of negative evaluation and student anxiety in community college active-learning science courses. *CBE—Life Sciences Education*, *19*(2), ar20. https://doi.org/10.1187/cbe.19-09-0186

Driessen, E. P., Knight, J. K., Smith, M. K., & Ballen, C. J. (2020). Demystifying the meaning of active learning in postsecondary biology education. *CBE—Life Sciences Education*, *19*(4), ar52.

Duke, D., Krishnan, M., Faith, M., & Storch, E. A. (2006). The psychometric properties of the Brief Fear of Negative Evaluation Scale. *Journal of Anxiety Disorders*, *20*(6), 807–817. https://doi.org/10.1016/j.janxdis.2005.11.002

Eckberg, D. A. (2015). Race and research methods anxiety in an undergraduate sample: The potential effects of self-perception. *Journal of Classroom Interaction*, *50*(2), 145–155.

Eddy, S. L., Brownell, S. E., & Wenderoth, M. P. (2014). Gender gaps in achievement and participation in multiple introductory biology classrooms. *CBE—Life Sciences Education*, *13*(3), 478–492. https://doi.org/10.1187/cbe.13-10-0204

England, B. J., Brigati, J. R., & Schussler, E. E. (2017). Student anxiety in introductory biology classrooms: Perceptions about active learning and persistence in the major. *PLoS ONE*, *12*(8), e0182506.

England, B. J., Brigati, J. R., Schussler, E. E., & Chen, M. M. (2019). Student anxiety and perception of difficulty impact performance and persistence in introductory biology courses. *CBE—Life Sciences Education*, *18*(2), ar21. https://doi.org/10.1187/cbe.17-12-0284

Engle, J. (2007). Postsecondary access and success for first-generation college students. *American Academic*, *3*(1), 25–48.

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition and Emotion*, *6*(6), 409–434. https://doi.org/10.1080/02699939208409696

Fassinger, P. A. (1995). Understanding classroom interaction. *Journal of Higher Education*, *66*(1), 82–96. https://doi.org/10.1080/00221546.1995.11774758

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences USA*, *111*(23), 8410–8415.

Freeman, S., O'Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., … & Wenderoth, M. P. (2007). Prescribed active learning increases performance in introductory biology. *CBE—Life Sciences Education*, *6*(2), 132–139. https://doi.org/10.1187/cbe.06-09-0194

Ganesh Kumar, J., Athilakshmi, R., Maharishi, R., & Maya, R. (2015). Relationship between fear of negative evaluation and anxiety. *International Journal of Indian Psychology*, *3*(1), 74–80.

Garside, C. (1996). Look who's talking: A comparison of lecture and group discussion teaching strategies in developing critical thinking skills. *Communication Education*, *45*(3), 212–227. https://doi.org/10.1080/03634529609379050

Gaudier-Diaz, M. M., Sinisterra, M., & Muscatell, K. A. (2019). Motivation, belongingness, and anxiety in neuroscience undergraduates: Emphasizing first-generation college students. *Journal of Undergraduate Neuroscience Education*, *17*(2), A145–A152.

Gilovich, T., Medvec, V. H., & Savitsky, K. (2000). The spotlight effect in social judgment: An egocentric bias in estimates of the salience of one's own actions and appearance. *Journal of Personality and Social Psychology*, *78*(2), 211–222.

Gin, L. E., Guerrero, F. A., Cooper, K. M., & Brownell, S. E. (2020). Is active learning accessible? Exploring the process of providing accommodations to students with disabilities. *CBE—Life Sciences Education*, *19*(4), es12. https://doi.org/10.1187/cbe.20-03-0049

Glock, S. (2016). Stop talking out of turn: The influence of students' gender and ethnicity on preservice teachers' intervention strategies for student misbehavior. *Teaching and Teacher Education*, *56*, 106–114. https://doi.org/10.1016/j.tate.2016.02.012

Grant, J. E., Odlaug, B. L., Derbyshire, K., Schreiber, L. R. N., Lust, K., & Christenson, G. (2014). Mental health and clinical correlates in lesbian, gay, bisexual, and queer young adults. *Journal of American College Health*, *62*(1), 75–78. https://doi.org/10.1080/07448481.2013.844697

Hancock, G. R., Hancock, G. R., Mueller, R. O., Stapleton, L. M., & Mueller, R. O. (Eds.) (2010). *The reviewer's guide to quantitative methods in the social sciences*. New York, NY: Routledge. https://doi.org/10.4324/9780203861554

Heimberg, R. G., Brozovich, F. A., & Rapee, R. M. (2010). A cognitive behavioral model of social anxiety disorder: Update and extension. In Hofmann, S. G. & DiBartolo, P. M. (Eds.), *Social anxiety* (2nd ed., pp. 395–422). San Diego, CA: Academic Press. https://doi.org/10.1016/B978-0-12-375096-9.00015-8

Hillmann, R. B., Brooks, C. I., & O'Brien, J. P. (1991). Differences in self-esteem of college freshmen as a function of classroom seating-row preference. *Psychological Record*, *41*(3), 315–320. https://doi.org/10.1007/BF03395113

Honicke, T., & Broadbent, J. (2016). The influence of academic self-efficacy on academic performance: A systematic review. *Educational Research Review*, *17*, 63–84. https://doi.org/10.1016/j.edurev.2015.11.002

Hood, S., Barrickman, N., Djerdjian, N., Farr, M., Gerrits, R. J., Lawford, H., … & Hull, K. (2020). Some believe, not all achieve: The role of active learning practices in anxiety and academic self-efficacy in first-generation college students. *Journal of Microbiology & Biology Education*, *21*(1), 10. https://doi.org/10.1128/jmbe.v21i1.2075

Hood, S., Barrickman, N., Djerdjian, N., Farr, M., Magner, S., Roychowdhury, H., … & Ross, K. (2021). "I like and prefer to work alone": Social anxiety, academic self-efficacy, and students' perceptions of active learning. *CBE—Life Sciences Education*, *20*(1), ar12.

Hsieh, P. Pei-H., Sullivan, J. R., & Guerra, N. S. (2007). A closer look at college students: Self-efficacy and goal orientation. *Journal of Advanced Academics*, *18*(3), 454–476. https://doi.org/10.4219/jaa-2007-500

Hsu, J. L., & Goldsmith, G. R. (2021). Instructor strategies to alleviate stress and anxiety among college and university STEM students. *CBE—Life Sciences Education*, *20*(1), es1. https://doi.org/10.1187/cbe.20-08-0189

Hughes, B. E., Schell, W. J., Annand, E., Beigel, R., Kwapisz, M. B., & Tallman, B. (2019). Do I think I'm an engineer? Understanding the impact of engineering identity on retention. *ASEE Annual Conference & Exposition held from June 15–October 19, 2019 at Tampa, FL*. https://doi.org/10.18260/1-2--32674

Hunter, L. E., Meer, E. A., Gillan, C. M., Hsu, M., & Daw, N. D. (2022). Increased and biased deliberation in social anxiety. *Nature Human Behaviour*, *6*(1), 146–154.

Intemann, K. (2009). Why diversity matters: Understanding and applying the diversity component of the national science foundation's broader impacts criterion. *Social Epistemology*, *23*(3–4), 249–266. https://doi.org/10.1080/02691720903364134

Iqbal, A., & Ajmal, A. (2018). Fear of negative evaluation and social anxiety in young adults. *Peshawar Journal of Psychology and Behavioral Sciences*, *4*(1), article 1. https://doi.org/10.32879/picp.2018.4.1.45

Jensen, J. L., Holt, E. A., Sowards, J. B., Heath Ogden, T., & West, R. E. (2018). Investigating strategies for pre-class content learning in a flipped classroom. *Journal of Science Education and Technology*, *27*(6), 523–535. https://doi.org/10.1007/s10956-018-9740-6

Johnson, B. C., & Kiviniemi, M. T. (2009). The effect of online chapter quizzes on exam performance in an undergraduate social psychology course. *Teaching of Psychology*, *36*(1), 33–37. https://doi.org/10.1080/00986280802528972

Junn, E. (1994). "Pearls of wisdom": Enhancing student class participation with an innovative exercise. *Journal of Instructional Psychology*. Retrieved May 23, 2022, from www.proquest.com/openview/359d801005695f249fb59e6573a5b27c/1?cbl=2029838&pq-origsite=gscholar

Kalin, N. H. (2020). The critical relationship between anxiety and depression. *American Journal of Psychiatry*, *177*(5), 365–367.

Kitano, K. (2001). Anxiety in the college Japanese language classroom. *Modern Language Journal*, *85*(4), 549–566. https://doi.org/10.1111/0026-7902.00125

Klein, G., & Shtudiner, Z. (2021). Judging severity of unethical workplace behavior: Attractiveness and gender as status characteristics. *BRQ*

Business Research Quarterly, *24*(1), 19–33. https://doi.org/10.1177/2340944420916100

Kwan, S., & Trautner, M. N. (2011). Judging books by their covers: Teaching about physical attractiveness biases. *Teaching Sociology*, *39*(1), 16–26. https://doi.org/10.1177/0092055X10390655

Leary, M. R. (1983). A brief version of the Fear of Negative Evaluation Scale. *Personality and Social Psychology Bulletin*, *9*(3), 371–375. https://doi.org/10.1177/0146167283093007

Levin, B. (2000). Putting students at the centre in education reform. *Journal of Educational Change*, *1*(2), 155–172. https://doi.org/10.1023/A:1010024225888

Levine, D. W., O'Neal, E. C., Garwood, S. G., & McDonald, P. J. (1980). Classroom ecology: The effects of seating position on grades and participation. *Personality and Social Psychology Bulletin*, *6*(3), 409–412. https://doi.org/10.1177/014616728063012

Liu, O. L., Frankel, L., & Roohr, K. C. (2014). Assessing critical thinking in higher education: Current state and directions for Next-Generation assessment. *ETS Research Report Series*, *2014*(1), 1–23. https://doi.org/10.1002/ets2.12009

Liu, R., Carrese, J., Colbert-Getz, J., Geller, G., & Shochet, R. (2015). "Am I cut out for this?" Understanding the experience of doubt among first-year medical students. *Medical Teacher*, *37*(12), 1083–1089. https://doi.org/10.3109/0142159X.2014.970987

Lyons, P. R. (1989). Assessing classroom participation. *College Teaching*, *37*(1), 36–38. https://doi.org/10.1080/87567555.1989.10532154

Mallinson, G. G., & Miller, D. J. (1956). The effect of second guessing on achievement scores of college tests. *Yearbook of the National Council on Measurements Used in Education*, *13*, 24–26.

Mallow, J. V. (2006). Science anxiety: Research and action. In Mintzes, J. J.. & Leonard, W. H. (Eds.), *Handbook of College Science Teaching* (pp. 3–14). Arlington, VA: National Library of Medicine..

Marrone, M., Taylor, M., & Hammerle, M. (2018). Do international students appreciate active learning in lectures? *Australasian Journal of Information Systems*, *22*, https://doi.org/10.3127/ajis.v22i0.1334

McTeague, L. M., Rosenberg, B. M., Lopez, J. W., Carreon, D. M., Huemer, J., Jiang, Y., ... & Etkin, A. (2020). Identification of common neural circuit disruptions in emotional processing across psychiatric disorders. *American Journal of Psychiatry*, *177*(5), 411–421.

Merolla, D. M., & Serpe, R. T. (2013). STEM enrichment programs and graduate school matriculation: The role of science identity salience. *Social Psychology of Education*, *16*(4), 575–597. https://doi.org/10.1007/s11218-013-9233-7

Misra, R., & McKean, M. (2000). College students' academic stress and its relation to their anxiety, time management, and leisure satisfaction. *American Journal of Health Studies*, *16*(1), 41–51.

Mohammed, T. F., Nadile, E. M., Busch, C. A., Brister, D., Brownell, S. E., Claiborne, C. T., ... & Cooper, K. M. (2021). Aspects of large-enrollment online college science courses that exacerbate and alleviate student anxiety. *CBE—Life Sciences Education*, *20*(4), ar69. https://doi.org/10.1187/cbe.21-05-0132

Moon, N. W., Todd, R. L., Morton, D. L., & Ivey, E. (2012). Accommodating students with disabilities in science, technology, engineering, and mathematics (STEM). *SciTrain: Science and Math for All*, (pp. 1–224). Atlanta, GA: Center for Assistive Technology and Environmental Access.

Moravec, M., Williams, A., Aguilar-Roca, N., & O'Dowd, D. K. (2010). Learn before lecture: A strategy that improves learning outcomes in a large introductory biology class. *CBE—Life Sciences Education*, *9*(4), 473–481. https://doi.org/10.1187/cbe.10-04-0063

Morrison, A., & Heimberg, R. (2013). Social anxiety and social anxiety disorder. *Annual Review of Clinical Psychology*, *9*, 249–274. https://doi.org/10.1146/annurev-clinpsy-050212-185631

Nadile, E. M., Alfonso, E., Barreiros, B. M., Bevan-Thomas, W. D., Brownell, S. E., Chin, M. R., ... & Gomez-Rosado, J. O. (2021a). Call on me! Undergraduates' perceptions of voluntarily asking and answering questions in front of large-enrollment science classes. *PLoS ONE*, *16*(1), e0243731.

Nadile, E. M., Williams, K. D., Wiesenthal, N. J., Stahlhut, K. N., Sinda, K. A., Sellas, C. F., ... & King, M. L. (2021b). Gender differences in student comfort voluntarily asking and answering questions in large-enrollment college science courses. *Journal of Microbiology & Biology Education*, *22*(2), e00100–21.

National Science Foundation. (2021). *Women, Minorities, and Persons with Disabilities in Science and Engineering 2021 Report*. Retrieved April 29, 2022, from https://ncses.nsf.gov/pubs/nsf21321/downloads

Noel, J. K., Lakhan, H. A., Sammartino, C. J., & Rosenthal, S. R. (2021). Depressive and anxiety symptoms in first generation college students. *Journal of American College Health*, Advance online publication, 1–10. https://doi.org/10.1080/07448481.2021.1950727

Novak, R. T., Bailey, E. G., Blinsky, B. D., Soffe, B. W., Patterson, D., Ockey, J., & Jensen, J. L. (2022). Verbalized studying and elaborative interrogation in the virtual classroom: Students with social anxiety prefer working alone, but working with a peer does not hurt their learning. *Journal of Microbiology & Biology Education*, *23*(1), e00232–21. https://doi.org/10.1128/jmbe.00232-21

Okazaki, S. (1997). Sources of ethnic differences between Asian American and White American college students on measures of depression and social anxiety. *Journal of Abnormal Psychology*, *106*, 52–60. https://doi.org/10.1037/0021-843X.106.1.52

Oseguera, L., Park, H. J., De Los Rios, M. J., Aparicio, E. M., & Johnson, R. (2019). Examining the role of scientific identity in Black student retention in a STEM scholar program. *Journal of Negro Education*, *88*(3), 229–248.

Oswalt, S. B., & Wyatt, T. J. (2011). Sexual orientation and differences in mental health, stress, and academic performance in a national sample of U.S. college students. *Journal of Homosexuality*, *58*(9), 1255–1280. https://doi.org/10.1080/00918369.2011.605738

Owens, M., Stevenson, J., Norgate, R., & Hadwin, J. A. (2008). Processing efficiency theory in children: Working memory as a mediator between trait anxiety and academic performance. *Anxiety, Stress & Coping*, *21*(4), 417–430. https://doi.org/10.1080/10615800701847823

Paulhus, D. L. (1984). Two-component models of socially desirable responding. *Journal of Personality and Social Psychology*, *46*(3), 598–609. https://doi.org/10.1037/0022-3514.46.3.598

Perez, T., Cromley, J. G., & Kaplan, A. (2014). The role of identity development, values, and costs in college STEM retention. *Journal of Educational Psychology*, *106*(1), 315–329. https://doi.org/10.1037/a0034027

Rapee, R. M., & Barlow, D. H. (1991). *Chronic anxiety: Generalized anxiety disorder and mixed anxiety-depression* (pp. x, 214). New York, NY: Guilford Press.

R Core Team. (2019). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved November 3, 2021, from www.R-project.org

Revelle, W. (2022). *psych: Procedures for Psychological, Psychometric, and Personality Research (2.2.5)*. Retrieved April 29, 2022, from https://CRAN.R-project.org/package=psych

Riehl, R. J. (1994). The academic preparation, aspirations, and first-year performance of first-generation students. *College and University*, *70*(1), 14–19.

Rocca, K. A. (2008). Participation in the college classroom: The impact of instructor immediacy and verbal aggression. *Journal of Classroom Interaction*, *43*(2), 22–33.

Rodebaugh, T. L., Woods, C. M., Thissen, D. M., Heimberg, R. G., Chambless, D. L., & Rapee, R. M. (2004). More information from fewer questions: The factor structure and item properties of the original and brief fear of negative evaluation scale. *Psychological Assessment*, *16*(2), 169.

Rosseel, Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software*, *48*, 1–36. https://doi.org/10.18637/jss.v048.i02

RStudio Team. (2019). *RStudio: Integrated development for R*. Boston, MA: RStudio, Inc. Retrieved April 22, 2022, from www.rstudio.com/

Ruiz, N. G., Horowitz, J. M., & Tamir, C. (2020, July 1). Many Black and Asian Americans say they have experienced discrimination amid the COVID-19 outbreak. *Pew Research Center's Social & Demographic Trends Project*. Retrieved April 29, 2022, from https://www.pewresearch.org/social-trends/2020/07/01/many-black-and-asian-americans-say-they-have-experienced-discrimination-amid-the-covid-19-outbreak/

Schussler, E. E., Reynolds, B., England, B. J., & Jennifer, B. R. (2021). Student active learning anxieties differ by preferred seating location in introductory biology classes. *Journal of College Science Teaching*, *51*(2). Retrieved April 29, 2022, from www.nsta.org/journal-college-science-teaching/journal-college-science-teaching-novemberdecember-2021/student-0

Seymour, E., Hunter, A.-B., Laursen, S. L., & DeAntoni, T. (2004). Establishing the benefits of research experiences for undergraduates in the sciences: First findings from a three-year study. *Science Education*, *88*(4), 493–534.

Seyranian, V., Madva, A., Duong, N., Abramzon, N., Tibbetts, Y., & Harackiewicz, J. M. (2018). The longitudinal effects of STEM identity and gender on flourishing and achievement in college physics. *International Journal of STEM Education*, *5*(1), 1–14.

Shafique, N., Gul, S., & Raseed, S. (2017). Perfectionism and perceived stress: The role of fear of negative evaluation. *International Journal of Mental Health*, *46*(4), 312–326. https://doi.org/10.1080/00207411.2017.1345046

Singer, J. D., Willett, J. B., Willett, C. W. E. P. J. B., & Willett, J. B. (2003). *Applied longitudinal data analysis: Modeling change and event occurrence*. New York: Oxford University Press.

Spielberger, C. D. (2013). *Anxiety: current trends in theory and research*. Amsterdam, The Netherlands: Elsevier.

Spitzer, R. L., Kroenke, K., Williams, J. B., & Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092–1097.

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., … & Laski, F. A. (2018). Anatomy of STEM teaching in North American universities. *Science*, *359*(6383), 1468–1470.

Stebleton, M. J., Soria, K. M., & Huesman, R. L., Jr. (2014). First-generation students' sense of belonging, mental health, and use of counseling services at public research universities. *Journal of College Counseling*, *17*(1), 6–20. https://doi.org/10.1002/j.2161-1882.2014.00044.x

Steele-Johnson, D., & Kalinoski, Z. T. (2014). Error framing effects on performance: Cognitive, motivational, and affective pathways. *Journal of Psychology*, *148*(1), 93–111. https://doi.org/10.1080/00223980.2012.748581

Stephens, N. M., Fryberg, S. A., Markus, H. R., Johnson, C. S., & Covarrubias, R. (2012). Unseen disadvantage: How American universities' focus on independence undermines the academic performance of first-generation college students. *Journal of Personality and Social Psychology*, *102*(6), 1178–1197. https://doi.org/10.1037/a0027143

Stipek, D. J. (1993). *Motivation to learn: From theory to practice*. Needham Heights, MA: Allyn & Bacon.

Sullivan, G. M., & Artino, A. R. Jr. (2013). Analyzing and interpreting data from Likert-type scales. *Journal of Graduate Medical Education*, *5*(4), 541–542.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction*, *4*(4), 295–312. https://doi.org/10.1016/0959-4752(94)90003-5

Tharayil, S., Borrego, M., Prince, M., Nguyen, K. A., Shekhar, P., Finelli, C. J., & Waters, C. (2018). Strategies to mitigate student resistance to active learning. *International Journal of STEM Education*, *5*(1), 7. https://doi.org/10.1186/s40594-018-0102-y

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., … & Dunster, G. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences USA*, *117*(12), 6476–6483.

Trenor, J. M., Miller, M. K., & Gipson, K. G. (2011). *Utilization of a think-aloud protocol to cognitively validate a survey instrument identifying social capital resources of engineering undergraduates*. Vancouver, BC, Canada: American Society for Engineering Education.

Turk, C. L., Lerner, J., Heimberg, R. G., & Rapee, R. M. (2001). An integrated cognitive-behavioral model of social anxiety. In Hofmann, S. G., & DiBartolo, P. M. (Eds.), *From social anxiety to social phobia: Multiple perspectives* (pp. 281–303). Boston, MA: Allyn & Bacon. https://doi.org/10.1016/S1077-7229(02)80052-9

Tzoannopoulou, M. (2016). Foreign language anxiety and fear of negative evaluation in the Greek university classroom. *Selected Papers on Theoretical and Applied Linguistics*, *21*, 823–838. https://doi.org/10.26262/istal.v21i0.5272

Udo, M. K., Ramsey, G. P., & Mallow, J. V. (2004). Science anxiety and gender in students taking general education science courses. *Journal of Science Education and Technology*, *13*(4), 435–446.

Üztemur, S. (2020). What if people judge me unfairly: The mediating role of fear of negative evaluation on the relationship between perceived autonomy support and academic risk-taking behaviour in social studies courses. *Journal of International Social Studies*. *10*(1), 62–91.

Watson, D., & Friend, R. (1969). Measurement of social-evaluative anxiety. *Journal of Consulting and Clinical Psychology*, *33*(4), 448.

Weeks, J. W., Heimberg, R. G., Fresco, D. M., Hart, T. A., Turk, C. L., Schneier, F. R., & Liebowitz, M. R. (2005). Empirical validation and psychometric evaluation of the brief fear of negative evaluation scale in patients with social anxiety disorder. *Psychological Assessment*, *17*(2), 179–190. https://doi.org/10.1037/1040-3590.17.2.179

Weeks, J. W., & Howell, A. N. (2012). The bivalent fear of evaluation model of social anxiety: Further integrating findings on fears of positive and negative evaluation. *Cognitive Behaviour Therapy*, *41*(2), 83–95.

Yannier, N., Hudson, S. E., Koedinger, K. R., Hirsh-Pasek, K., Golinkoff, R. M., Munakata, Y., … & McCarty, L. (2021). Active learning: "Hands-on" meets "minds-on." *Science*, *374*(6563), 26–30.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, *18*(5), 459–482. https://doi.org/10.1002/cne.920180503