Academic social comparison: a promising new target to reduce fear of negative evaluation in large-enrollment college science courses

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Abstract

Background Fear of negative evaluation, defined as a sense of dread associated with being unfavorably evaluated in a social situation, is the primary factor underlying student anxiety in college science courses and is disproportionately experienced by students who are underserved in science. Yet, it is unknown why fear of negative evaluation disproportionately affects these students and what can be done to reduce student fear of negative evaluation. Academic social comparison describes how students perceive themselves compared to their peers with regard to desirability as a groupmate, the extent they fit in among others in their major, and academic talent. We hypothesize that academic social comparison mediates the relationship between student identities and fear of negative evaluation, where individuals with underserved identities in science may perceive themselves as "less than" their peers, contributing to their fear of negative evaluation. We surveyed 909 undergraduate science majors across 15 research-intensive institutions in the United States (U.S.) to assess: (1) To what extent do student identities predict fear of negative evaluation among science undergraduates? and (2) For identities that significantly predict fear of negative evaluation, to what extent does academic social comparison mediate the relationship? We used regression, single-mediator models, and multi-mediator models to address our research questions.

Results Women/non-binary and LGBTQ + science majors reported disproportionately high fear of negative evaluation compared to men and non-LGBTQ + science majors. Women/non-binary and LGBTQ + students also expressed lower academic social comparison relative to their respective counterparts, meaning they perceive themselves as less than their peers with regard to their desirability as a groupmate, the extent to which they fit in among others in their major, and their academic talent. Academic social comparison partially mediated the relationship between fear of negative evaluation and both gender and LGBTQ + status. Major fit, defined as the extent to which students perceive they fit in among others in their major, was found to be the primary mediating subconstruct of academic social comparison for both gender and LGBTQ + identities.

Conclusions Women/non-binary and LGBTQ + science majors perceive themselves as less than their peers to a greater extent than men and non-LGBTQ + science majors, contributing to their higher fear of negative evaluation in college science course. Major fit, defined as the extent to which students feel they fit in with others in their major, is the subconstruct of academic social comparison that had the strongest influence on fear of negative evaluation in our sample. Academic social comparison is a promising target for future efforts aimed at decreasing fear of negative evaluation in active learning college science courses.

Keywords Biology, Undergraduate, Mediation, Social, Comparison, Fear, Negative, Evaluation, Active, Learning

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Introduction

Overwhelming evidence suggests that, compared to traditional lecture, college science students learn more and fail less when they engage in their learning by working together with other students in class (Freeman et al., 2007, 2014; Haak et al., 2011; Johnson & Johnson, 2018; Johnson & Johnson, 2008; Theobald & Freeman, 2014; Trentin, 2010). In science courses, feeling uncomfortable (Theobald et al., 2017) and experiencing feelings of anxiety (Cooper et al., 2018a, 2018b; Downing et al., 2020; England et al., 2019) in small group discussions have been shown to negatively affect students' willingness to participate in class, as well as their performance. Fear of negative evaluation (FNE), defined as a sense of dread associated with being unfavorably evaluated in a social situation (Watson & Friend, 1969; Weeks et al., 2005), is a prominent emotion among undergraduates enrolled in science courses with opportunities to engage in one-on-one, small group, and whole class discussions, and underlies students' feelings of anxiety and discomfort (Busch et al., 2023; Cooper et al., 2018a, 2018b; Downing et al., 2020; Ghosh et al., 2023; Nadile et al., 2021a, 2021b). Reducing student FNE has been identified as an important approach to improving student experiences, performance, and persistence in college science courses that integrate social engagement opportunities in class (Cooper & Brownell, 2020; Cooper et al., 2021; Ghosh et al., 2023; Yannier et al., 2021).

Fear of negative evaluation (FNE)

FNE was first examined in academic environments in the context of foreign language courses, where students are often prompted to practice conversational fluency with other students or in front of the whole class (MacIntyre & Gardner, 1991; Oxford, 1999). However, with the adoption of evidence-based teaching methods, came increases in the number of in-class interactions among students in other disciplines. Historically, college science courses were taught in a traditional manner where professors lectured and students simply listened (Berrett, 2012), but research demonstrates that, on average, students learn more and fail less when they are engaged in learning science through activities and discussions during class (Freeman et al., 2014). This finding prompted many college science instructors to adopt teaching methods that involve students working with each other during class (American Association for the Advancement of Science, 2015; Berrett, 2012; Herreid & Schiller, 2013). As such, FNE has been identified as a common emotion among college science students who engage in discussions during class (Busch et al., 2023; Cooper et al., 2018a, 2018b; Downing et al., 2020). In three interview studies of students enrolled in college science courses that integrate

whole class and small group discussions, students commonly described experiencing FNE or worrying that their peers and science instructors would perceive them as "stupid" or "dumb," if they were to say something incorrect in class (Araghi et al., 2023; Cooper et al., 2018a, 2018b; Downing et al., 2020). Further, undergraduates in these studies revealed that when they experience FNE it can cause them to struggle to think through science problems, experience difficulty articulating their thoughts in front of others, and ultimately avoid participating in social interactions in class. A survey study of 566 students enrolled in college science courses found that undergraduates most commonly report that FNE causes them to overthink their responses and participate less in class (Busch et al., 2023), indicating that alleviating student FNE may be an important step in maximizing students' experiences and performance in college science courses (Cooper & Brownell, 2020; Yannier et al., 2021).

The disproportionate impact of FNE

Importantly, FNE and its consequences do not affect all science undergraduates equally. Data suggest that students with marginalized identities experience higher FNE compared to their peers; this has been demonstrated among an array of contexts, including the undergraduate sciences. For example, in a recent study of 546 undergraduate nursing students in China, female students expressed higher FNE compared to males (Yue & Jia, 2023). In higher education, students who speak English as a second language (ESL) express higher FNE in English-speaking classrooms compared to students whose first language is English (Jain & Sidhu, 2013; Pappamihiel, 2002; Woodrow, 2006) and students with mental health disabilities experience FNE in small-group and whole class discussions across college science courses (Gin et al., 2020). Additionally, a study of undergraduates taking college science courses revealed that first-generation students, LGBTQ+students, and students with disabilities reported significantly higher levels of FNE than continuing-generation college students, non-LGBTQ+students, and students without disabilities, respectively (Busch et al., 2023). In addition to experiencing higher FNE, studies also show that the consequences of FNE are disproportionately burdensome to students who are underserved in science classrooms. For example, compared to their counterparts, women and LGBTQ+students are more likely to report struggling to speak and participating less in class as a result of experiencing FNE in college science courses, and women and first-generation college students disproportionately report that FNE can cause them to struggle to think through science problems (Busch et al., 2023). Given the potentially negative impact of FNE

on undergraduate science students and the potential for FNE to fuel disadvantages experienced by underserved groups of students in science, identifying ways to reduce FNE is an integral step to creating a more equitable scientific community (Cooper & Brownell, 2020; Cooper et al., 2021; Ghosh et al., 2023; Yannier et al., 2021).

A proposed relationship between academic social comparison and FNE

We posit that academic social comparison may help explain why students in different demographic groups experience FNE to a different extent. Social comparison encompasses how students perceive themselves compared to their peers (Allan & Gilbert, 1995). Prior research from our lab has explored undergraduates' FNE in science courses using qualitative interview studies, where themes related to social comparison emerged (Cooper et al., 2018a, 2018b; Cooper & Brownell, 2020; Downing et al., 2020; Nadile Erika et al., 2021). Specifically, students in these studies described that they often compare themselves to other students in their classes regarding their intelligence and the extent to which they perceive others to want to work with them. When they perceive themselves as less intelligent or less likeable than others in class, undergraduates expressed that it sometimes resulted in FNE, or worrying what others would think of them when they contributed to course discussions. The social comparison theory framework (Festinger, 1954) states that individuals have an innate motivation to assess their own abilities and opinions, and do so by comparing themselves to others they perceive to be similar using a variety of personal metrics. Using this framework, Allan and Gilbert (1995) proposed a social comparison scale, measuring how people perceive themselves to others in terms of fitting in with others, physical attractiveness, and social rank. In the specific context of college science, students have described comparing themselves to others based on the extent to which they fit in with fellow science majors (Cooper et al., 2018a, 2018b; Lewis et al., 2017; Taconis & Kessels, 2009; Tellhed et al., 2017), the extent to which they are desirable as a groupmate (Cooper & Brownell, 2020), and based on academic performance (Araghi et al., 2023; Cooper et al., 2018a, 2018b). How one perceives themselves compared to their classmates regarding their fit within the major, desirability as a groupmate, and academic talent may mediate the relation between different student identities and FNE.

We posit that students who are marginalized in science may be particularly prone to experiencing FNE because they may be less likely than their peers to perceive themselves as fitting in among other science majors, as a desirable groupmate, and as academically talented. If these perceptions exist, they are likely a result of underserved students experiencing bias, microaggressions, and overt discrimination (Ackerman-Barger et al., 2015; Rivera Maulucci, 2010). For example, stereotype threat is an experience when members of a stigmatized group (such as women and persons excluded because of their ethnicity or race (PEERs) in science (Kellow & Jones, 2008; Spencer et al., 1999; Steele, 1997) believe that they may, by virtue of their performance in a domain of relevance, confirm a negative stereotype about members of their stigmatized identity group (Kellow & Jones, 2008). Not only has stereotype threat been found to affect the academic achievement of women and racial minorities (Kellow & Jones, 2008; Spencer et al., 1999; Steele, 1997), there are additional downstream effects. For example, instructors have expressed lowered achievement expectations and made derogatory statements directed at students with underserved identities (Brand et al., 2006; Lynn et al., 2010; Pringle et al., 2010). Beyond gender and race, studies have shown that academic science as a whole has been identified as unwelcoming for members of the LGBTQ+ community (Busch et al., 2022; Cech, 2022; Cech & Pham, 2017; Cech & Waidzunas, 2011) and LGBTQ+ students report worrying that their peers perceive them as less capable because of their LGBTQ+ identity (Cooper & Brownell, 2016). Further, first-generation college students may be at a greater risk for FNE than their continuing-generation peers because they report teaching practices that require speaking, such as cold calling, to be more anxiety-provoking than their continuing generation peers (Hood et al., 2020). First-generation college students also report lower confidence in their academic abilities compared to their peers. Other research has detailed that first-generation students report fewer interactions with faculty and contribute less frequently to course discussions which may be the result of FNE in the classroom (Soria & Stebleton, 2012). Further, students learning languages often have to engage with social interactions practicing conversational fluency with other students or in front of the class, which presents opportunities not only to be evaluated by peers, but for these students to internally compare themselves and their ability to speak with others (MacIntyre & Gardner, 1991; Oxford, 1999). One study of college biology students found that even when controlling for grade-point average, ESL students have lower perceptions of their academic abilities compared to students whose first language is English (Cooper et al., 2018b). We hypothesize that the challenges that academia has presented for students in minority groups may result in lower academic social comparison, or thinking less of themselves in academic science contexts, ultimately contributing to higher levels of FNE.

Notably, there is limited research on the relationship between social comparison and FNE. Some of the earliest research examining the relationship comes from Friend & Gilbert (1973), who studied 65 female students in psychology and found that when individuals feel threatened, they are more likely to compare themselves with people who they perceive to be "less than" themselves, and that this is particularly true for students with higher FNE. However, this study did not examine whether social comparison mediated students' FNE. More recently, a Korean study applied dual mediation analysis to explore the relationship of social comparison orientation on career indecision with FNE and self-esteem as mediators in a sample of 200 undergraduate students (Kim & Lee, 2012). This study assumed social comparison to be a set orientation for an individual and treated it as an outcome. They found that self-esteem and FNE play a serial mediating role in the relationship between social comparison orientation and career indecision. That is, someone who perceives themselves as less than others also indicated low self-esteem, and the lower the students' self-esteem, the higher their fear of negative evaluation, which resulted in more indecision about their future career choice. Although prior research has treated FNE as a mediator to social comparison, we perceive social comparison to be a more appropriate mediator of FNE in the context of college science courses. We base our hypothesis on data from our interview studies of students indicating that academic social comparison results in FNE (Cooper et al., 2018a, 2018b; Downing et al., 2020) and on cognitive theory, where a thought process arouses a specific emotion (Beck & Haigh, 2014; DiGiuseppe et al., 2016). In this case, a student comparing themselves to peers and perceiving themselves as "less than" serves as a negative thought process and FNE is the resulting emotion that is aroused.

Current study

In this study, we aim to assess the extent to which undergraduates with marginalized identities in science express higher levels of FNE in the context of college science courses and test whether academic social comparison mediates the relationship between student identities and FNE. Our proposed general model is depicted in Fig. 1.

Our specific research questions are:

(1) To what extent do student identities predict FNE among science undergraduates in the United States?
(2) For identities that significantly predict FNE, to what extent does academic social comparison mediate the relationship between the identity and FNE?

Methods

Participant recruitment and data cleaning

In November 2022, we sent an email to 141 instructors teaching large-enrollment, defined as 100 students or more, undergraduate biology, chemistry, geosciences, and physics courses at 67 research-intensive universities across the United States. The email asked instructors to send a survey out to their students in exchange for a small amount of extra credit. We chose to recruit from large-enrollment science courses since it is likely that students would have higher levels of FNE in courses with more students (Nadile et al., 2021a, 2021b). In cases where instructors could not offer extra credit, students were incentivized by being entered into a raffle for the chance to win one of two $100 gift cards. Fifteen instructors, each from a different institution, agreed to invite students in their respective science course(s) to complete the survey. After removing incomplete responses, students who were not science
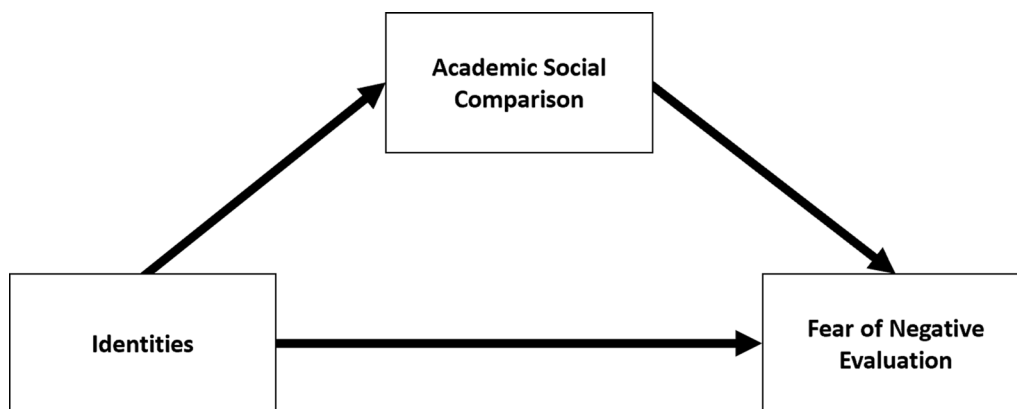
Fig. 1 Proposed mediation between identities and fear of negative evaluation

majors, surveys completed in under three minutes, and participants who did not identify as taking at least one large-enrollment science course where they engaged in whole class discussions, 909 students representing 15 research-intensive institutions were included in the analysis.

Survey measures

We developed a survey to answer our research questions, which is described in the subsequent sections.

Social comparison scale (adapted)

We adapted the Social Comparison Scale (Allan & Gilbert, 1995) to measure academic social comparison. The 11-item Social Comparison Scale (SCS) is a widely used instrument in psychology research (Allan & Gilbert, 1995; Feinstein et al., 2013; Gerber et al., 2018; Gilbert, 2000; Gilbert & Procter, 2006; Lup et al., 2015; Selten et al., 2013). The SCS items are bipolar, meaning a participant is presented with two opposing descriptions and asked to report, on a ten-point scale, to what extent they relate to one side (starting with a rating of 1 on the left side) or the other (ending with 10 on the right side). Using perceived intelligence as an example, if a participant perceives themselves to be less intelligent than most others, they might select 3; if they perceive themselves as having average intelligence, they would select 5; and they might select 7 if they identify as somewhat more intelligent than others. The original scale (Allan & Gilbert, 1995) comprised three sub-constructs: (1) group fit, which assesses the extent to which a participant feels that they belong in relation to others; (2) attractiveness, which assesses how physically attractive they perceive themselves to be in relation to others around them; and (3) social rank, which assess if participants perceive themselves as inferior or superior to others around them. The higher a participant scores, the greater their self-perception in comparison to others; the lower an overall score, the weaker their self-perception is compared to others.

We adapted the original 3-factor scale to create an academic social comparison scale which included 3 sub-constructs that reflected concepts that had emerged from interview studies of students with FNE (Araghi et al., 2023; Cooper et al., 2018a, 2018b; Downing et al., 2020), with the intent to preserve the internal structure of the sub-constructs of the original SCS. The 3 adapted sub-constructs included: (A) major fit, the extent to which students feel they belong among those in their major compared to their peers; (B) groupmate desirability, how attractive students feel as a groupmate in relation to their peers, and (C) academic talent, the extent to which students perceive themselves as academically inferior

or superior compared to others in their science major. For all sub-constructs, the question stem was changed to prompt students to think specifically about other students majoring in science (i.e., "Compared to other science majors I feel…"). For the major fit subconstruct, the original verbiage for each item was maintained (e.g., "left out [to] accepted"), as it now applied to how students perceived themselves in relation to other students with science majors. The questions in the original attractiveness subconstruct were modified to assess groupmate desirability. For example, instead of rating how they perceived themselves from "undesirable [to] desirable", we asked students to rate how they perceived themselves from "undesirable as an in-class partner" to "desirable as an in-class partner"). Likewise, the social rank subconstruct was revised to specify academic talent for each item. For example, instead of rating oneself as "inferior [to] superior", students rated themselves from "academically inferior [to] academically superior". We assessed the face validity of the revised scale by conducting five think-aloud interviews with undergraduate science majors (Trenor et al., 2011). We made minor revisions to enhance clarity after each of the first two think-aloud interviews, and no revisions were needed after the remaining three think-aloud interviews due to consistent item interpretation among participants. The internal consistency of this revised measure in the present study is excellent (Cronbach's alpha $\alpha = 0.94$, McDonald's omega $\omega = 0.96$). The full academic social comparison scale, confirmatory factor analysis (CFA) output, and fit indices are reported in the *Appendices*.

Brief fear of negative evaluation (adapted)

We adapted the Brief Fear of Negative Evaluation (BFNE) scale (Leary, 1983) to assess student FNE. The BFNE scale is a widely used instrument in social anxiety research (Leary, 1983; Rodebaugh et al., 2004; Weeks et al., 2005). Prior studies have validated the latent structure of the original 12-item, 2-factor BFNE model in student and non-student populations where one factor used 8 positively phrased items and the other used 4 negatively phrased items (Duke et al., 2006; Rodebaugh et al., 2004; Weeks et al., 2005). However, the second construct demonstrates lower evidence for convergent validity which could introduce misinterpretation from participants, leading to the development of a single factor model of positively framed items (Duke et al., 2006; Rodebaugh et al., 2004; Weeks et al., 2005). In a prior study, our research group modified the stems of the 8-item BFNE to prompt participants to think about their classmates in their large-enrollment college science courses, e.g., "When I am talking with a classmate in my large-enrollment college science courses, I worry

about what they may be thinking about me" (Busch et al., 2023). These modifications underwent 3 rounds of think-aloud interviews for face validity and CFA for internal consistency using responses from a sample of 566 undergraduate science students. Participants responded to each item using five Likert response options ranging from "not at all characteristic of me" (equal to 1) and "extremely characteristic of me" (equal to 5). We used this revised version of the BFNE for the current study. The internal consistency of this revised measure in the present study is excellent ($\alpha = 0.94$; $\omega = 0.94$). The revised BFNE used in our study is provided in the *Appendices*.

Student identities
We collected student identities including gender, race/ethnicity, college generation status, LGBTQ+status, and household language. A copy of the analyzed survey questions can be found in the *Appendices*.

Analyses
Research question 1: to what extent do student identities predict FNE among a national sample of science undergraduates?
We assessed the extent to which student identities predict FNE by running a linear regression in base R (R Core Team, 2023). For this model, the outcome variable was students' FNE scores and our predictors were gender (woman and non-binary/man), race (Asian/PEER/White), LGBTQ+status (LGBTQ+/non-LGBTQ+), college generation status (first-generation/continuing-generation), and household language (English/other). Reference categories were in all analyses man, White, non-LGBTQ+, continuing-generation, and English language. We selected these identities because each has been shown to be predictive of undergraduate FNE (Allen et al., 2022; Busch et al., 2023; Hamzah & Asokan, 2016; Posselt & Lipson, 2016), but none have been specifically examined across a national sample of undergraduate science students. There were a relatively small number of non-binary and gender-queer participants who responded to our study, but we did not want to exclude these students from the analysis and further erase their experiences in science (Casper et al., 2022). So, the responses of those who identified as non-binary, gender-queer, and women were combined. The experiences of non-binary and gender-queer individuals are thought to be more similar to women in science compared to men, who have historically experienced privilege within academia (Cech, 2022; Cooper et al., 2020). 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 (Asai, 2020), owing to low sample sizes. While those who identify as Asian are not considered to be underserved in science disciplines (National Science Foundation, 2021), we acknowledge that Asian individuals experience acts of discrimination and prejudice that White students do not (Ruiz et al., 2020). For this reason, White students and Asian students were treated as separate groups with White students set as the reference group. Variance inflation factor (VIF) was used to confirm there was minimal multicollinearity. Heteroskedasticity was checked via a Q–Q plot. All other assumptions were checked and met. (Model: FNE [continuous] ~ gender + race/ethnicity + LGBTQ status + college generation + household language).

Research question 2: for identities that significantly predict FNE, to what extent does academic social comparison mediate the relationship between the identity and FNE?
For each identity that significantly predicted FNE (gender and LGBTQ+status), we assessed the extent to which academic social comparison mediated this relationship by running two single-mediator models using lavaan (R Core Team, 2023; Rosseel, 2012), where the mediator was academic social comparison, the outcome variable was FNE, and the independent variable was gender and LGBTQ+status, respectively. The distribution of the product method was used to test the statistical significance of mediated effects (MacKinnon et al., 2004; O'Rourke & MacKinnon, 2015). We report both mediated effects and standardized mediated effects, which is an ideal effect size measure for binary independent variables. A standardized mediated effect is the change in standard deviation units of the dependent variable for one unit change in the independent variable, corresponding to the two different groups (MacKinnon, 2012).

The model with gender (men versus women/non-binary students) as the independent variable showed partial mediation. The model with LGBTQ+(LGBTQ+status or non-LGBTQ+status) as the independent variable demonstrated inconsistent partial mediation and a possible XM interaction. Moderation, or a nonzero XM interaction, occurs when the relationship between an independent and dependent variable differs across levels of the independent variable (Gonzalez & Valente, 2022; MacKinnon, 2012). An XM interaction may also be introduced via a non-linear relationship between the independent variable and the mediation (Gonzalez & Valente, 2022). In this case, a linear XM interaction between LGBTQ+status and academic social comparison was investigated using the R mediation package (Tingley et al., 2014) to extract the simple mediated effects for those who identified

as LGBTQ+and non-LGBTQ+separately (MacKinnon, 2008; Preacher et al., 2007). These simple mediated effects were plotted, and the size of the XM interaction was visually determined to be statistically significant, although minimal (XM=− 0.114, se=0.011, $p<0.001$), such that the interpretation of the mediation effect with and without the XM interaction was the same. Both the LGBTQ+and non-LGBTQ+slopes had overall linear trends in the same direction (*see Appendices*). Given that the trends were in the same direction, and that the XM interaction was not a focus of our research questions, we report models without the XM interaction (alternative exploratory models with the XM interaction are reported in the Appendices).

An important part of the interpretation of mediation analysis is the consideration of confounding variables that may explain research conclusions. In our model, academic social comparison is a mediator and not a confounder because a confounder would imply that academic social comparison causes gender or LGBTQ+status. A confounder could explain the observed relation between social comparison and fear of negative evaluation, the mediator (M) to outcome (*Y*). A mediation plot assessing sensitivity to confounding of the M to Y relation (Imai et al., 2010; Rubin, 2005; Tingley et al., 2014) demonstrated low risk for confounds (see Appendices). Confounding risk aside, we also outline the assumptions of mediation analysis used in this research study, and how we considered each assumption in the present study (see *Appendices*).

Subconstructs of academic social comparison We sought to glean additional insight into the relationship between student identities, academic social comparison, and FNE by assessing to what extent the subconstructs of academic social comparison (major fit, groupmate desirability, and academic talent) mediate the relationship between gender/LGBTQ+status and FNE. A multiple mediator model expanding upon the single mediation model of gender was estimated with the R lavaan package (Rosseel, 2012). Through structural equation modeling, the three sub-scales of academic social comparison were treated as multiple mediators; major fit (M1), groupmate desirability (M2), and academic talent (M3). These mediators were allowed to correlate. Gender was the independent variable (X) and FNE was the outcome variable (Y). Parameter estimates with confidence intervals were estimated. The model was estimated twice, once with mean scores and then factor scores and the conclusions of both methods of analyses were the same. We report the results of mean scores for simplicity of interpretation. The mediation assumption of no unmeasured confounding of M to Y remains for

the multiple mediator model. For the multiple mediator model where LGBTQ+versus non-LGBTQ+status is the independent variable, the same steps were repeated as in the gender (men versus women/non-binary students) multiple mediator model.

Post hoc exploratory analysis of majors We tested for interactions between gender and major (biology, chemistry, biochemistry, geosciences/physics) and between LGBTQ+status and major in predicting the major fit subconstruct of social comparison. Owing to low sample size, we aggregated physics and geosciences majors; the literature suggests that there can be substantial overlap between geosciences and physics curricula and that both fields are generally considered to be unwelcoming to women (Mattheis et al., 2022; Santana & Singh, 2021; Shaw, 2022; Stokes et al., 2015). Students who selected more than one major were also excluded from these post hoc analyses (n=38). Variance inflation factor (VIF) was used to confirm there was minimal multicollinearity. Heteroskedasticity was checked via a Q–Q plot. All other assumptions were checked and met. We first examined gender (Model; Social Comparison Group Fit [continuous] ~ gender+major+gender:major). This process was also replicated for LGBTQ+status (Model; Social Comparison Group Fit [continuous] ~ LGBTQ+major+LGBTQ:major).

Software information

Rstudio and R 4.2.3 was used for statistical analysis. R packages psych (Revelle & Revelle, 2015), tidyverse (Wickham et al., 2019), dplyr (Wickham et al., 2015), lavaan (Rosseel, 2012), mediation (Tingley et al., 2014), and metaSEM (Cheung, 2015) were used for statistical analysis. PowerPoint was used for graphics.

Results

Study participants

The majority of participants were biology majors (79.5%), followed by biochemistry (15.2%), and chemistry (12.3%) majors. Participants most commonly identified as women (65.3%), white (55.1%), non-LGBTQ+(75.6%), continuing-generation college students (67.4%), and spoke English as the primary language at home growing up (74.8%). Participant demographics are summarized in Table 1. Aside from the overrepresentation of biology majors, this sample approximately represents the demographics of undergraduate students enrolled in science programs at U.S. institutions (National Center for Science & Engineering Statistics, 2023).

Table 1 Participant demographics

N = 909		n	%
Gender	Woman	594	65.3
	Man	275	30.3
	Non-binary	31	3.4
	Other	9	1.0
Race/ethnicity	American native	8	0.9
	Asian	198	21.8
	Black	66	7.3
	Hispanic	96	10.6
	Other	36	4.0
	Pacific Islander/Hawaiian	4	0.4
	White	501	55.1
LGBTQ+	No	687	75.6
	Yes	222	24.4
College generation	First	296	32.6
	Continuing	613	67.4
Primary language at home	English	680	74.8
	Other	229	25.2
Major[a]	Biology	723	79.5
	Biochemistry	138	15.2
	Chemistry	112	12.3
	Geosciences	34	3.7
	Physics	20	2.3

[a] includes double majors, students were allowed to select all majors that apply

Research question 1: to what extent do student identities predict FNE among science undergraduates in the United States?

Finding 1: women/non-binary and LGBTQ + science majors report significantly higher FNE compared to men and non-LGBTQ + science majors

Women/non-binary individuals ($p < 0.001$) and LGBTQ+ students ($p < 0.001$) reported disproportionately high FNE compared to men and non-LGBTQ+ individuals, respectively (Fig. 2). Within our regression model, race/ethnicity, college generation status, and language spoken at home had no significant differences compared to their majority counterparts.

Research question 2: for identities that significantly predict FNE, to what extent does academic social comparison mediate the relationship between the identity and FNE?

Finding 2: academic social comparison partially mediates the relationship of FNE on gender and LGBTQ + status in large-enrollment college science courses

We estimated two separate mediator models to test the extent to which academic social comparison mediates the relationship between gender and FNE (Fig. 3) as well as LGBTQ+ status and FNE (Fig. 4).

Gender There was a statistically significant effect of gender on academic social comparison ($a = -0.577$,
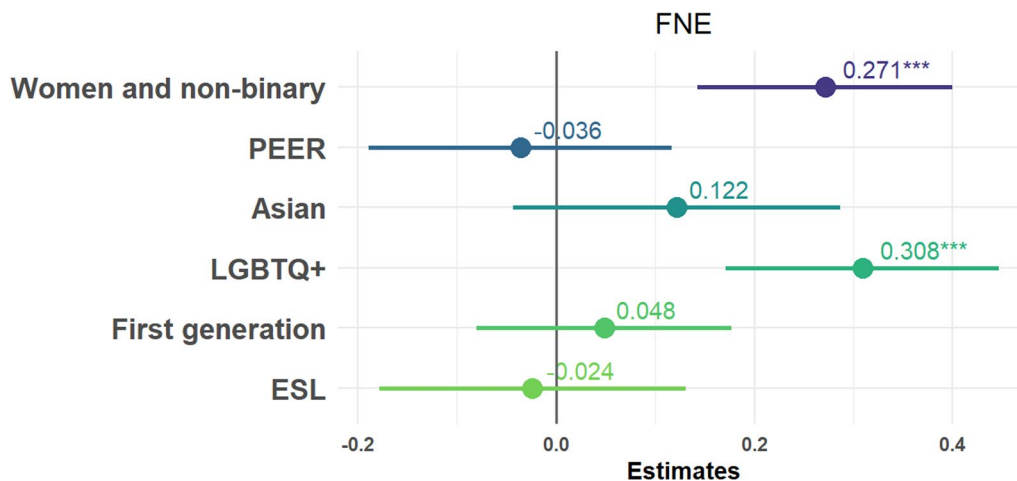

Fig. 2 Forest plot depicting the results of fear of negative evaluation scores regressed on gender, race/ethnicity, LGBTQ+ status, college generation status, and language spoken at home. Reference groups are men, White students, non-LGBTQ+ students, continuing-generation college students, and English. Numbers to the right of the vertical gray line indicate a positive estimate, or a higher FNE score, whereas scores to the left of the vertical gray line indicate 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 mean score ~ gender + race/ethnicity + LGBTQ+ status + college generation status + language spoken at home)
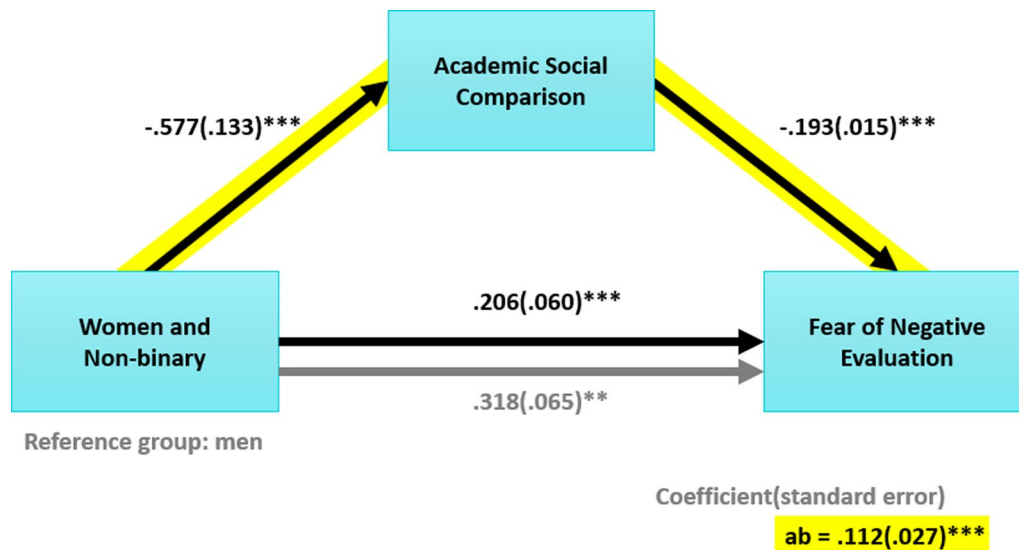
Fig. 3 Single mediator model of academic social comparison on the relationship of gender and FNE. Numbers outside of parenthesis are regression coefficients. Numbers inside parenthesis are standard errors. The black arrows indicate mediation analysis results. The yellow highlight behind the a-path and b-path arrows visualize the ab-path and represent the highlighted ab-path estimate at the bottom of the diagram. The gray arrow indicates a regression of the dependent variable (fear of negative evaluation) on the independent variable (gender [men, women/non-binary]) prior to mediation analysis. A reduction in absolute value from the bottom gray arrow to the bottom black arrow suggests partial mediation. All paths are significant at ***$p < 0.001$
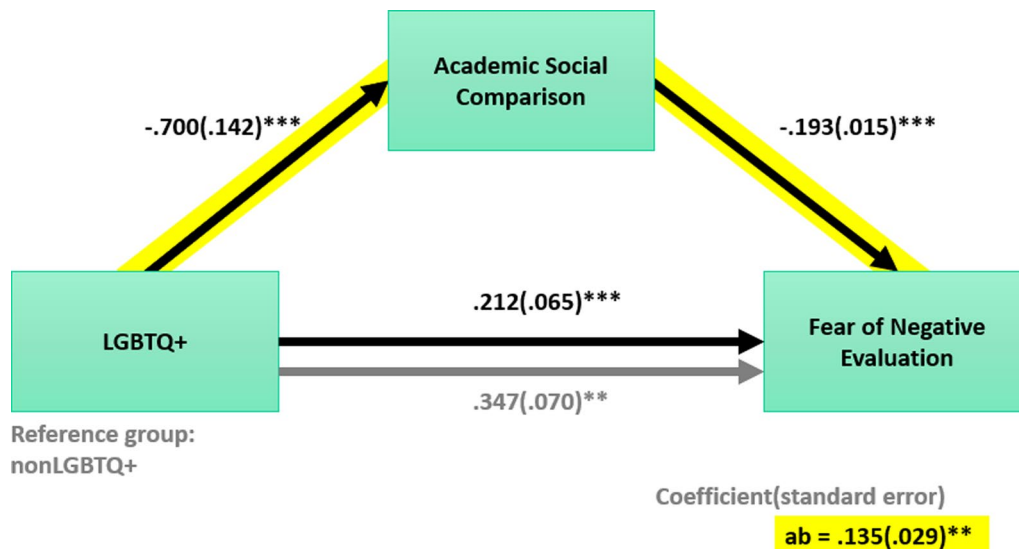
Fig. 4 Single mediator model of academic social comparison on the relationship of LGBTQ + status and FNE. Numbers outside of parenthesis are regression coefficients, also called path estimates. Numbers inside parenthesis are standard errors. The black arrows indicate mediation analysis. The yellow highlight behind the a-path and b-path arrows visualize the ab-path and represent the highlighted ab-path estimate at the bottom of the diagram. The gray arrow indicates a regression of the dependent variable (fear of negative evaluation) on the independent variable (LGBTQ + status [LGBTQ +, non-LGBTQ +]) prior to mediation analysis. A significant reduction in absolute value from the bottom gray arrow to the bottom black arrow suggests partial mediation. All paths are significant to ***$p < 0.001$

$se_a = 0.113$, $p < 0.001$). Individuals who identified as women or non-binary reported lower scores on academic social comparison than individuals who identified as men, suggesting that women and non-binary individuals perceive themselves as less than their peers to a greater extent than men. The relation of the academic social

comparison mediator on FNE was statistically significant ($b = -0.193$, $se_b = 0.015$, $p < 0.001$). A 1-unit increase in academic social comparison (perceiving themselves better than their peers) was associated with $a - 0.193$ decrease in FNE (fearing negative evaluation to a lesser extent). The direct effect of gender was statistically significant ($c' = 0.206$, $se_{c'} = 0.060$, $p < 0.001$). There was a decrease in the absolute value of c' (0.206) compared with c (0.318), meaning that mediation of academic social comparison partially mediates FNE differences found between men and women/non-binary individuals in science classroom settings (ab estimate $= 0.112$, se $= 0.027$, $p < 0.01$; standardized effect $= 0.123$). In sum, women/non-binary individuals perceive themselves as less than their peers to a greater extent than men do, which partially explains their disproportionately high FNE (Fig. 3).

LGBTQ + status The effect of academic social comparison on the relationship between LGBTQ + status and FNE varies by identity ($a = -0.700$,

$se_a = 0.142$, $p = <0.001$). Individuals who identified as LGBTQ + reported lower scores on academic social comparison than individuals who identified as non-LGBTQ +, suggesting that LGBTQ + students perceive themselves as less than their peers to a greater extent than non-LGBTQ + students (Fig. 4). The relation of the academic social comparison mediator on FNE was statistically significant ($b = -0.193$, $se_b = 0.015$, $p < 0.001$). A 1-unit increase in academic social comparison (perceiving themselves better than their peers) was associated with a -0.193 decrease in FNE (fearing negative evaluation to a lesser extent). The direct effect of LGBTQ + status was statistically significant ($c' = 0.212$, $se_{c'} = 0.065$, $p < 0.001$). There was a decrease in the value of c' (0.212) compared with c (0.347), which suggests that academic social comparison significantly mediates the relationship between one's LGBTQ + identity and FNE (ab estimate $= 0.113$, se $= 0.025$, $p < 0.01$; standardized effect $= 0.124$). In other words, LGBTQ + students
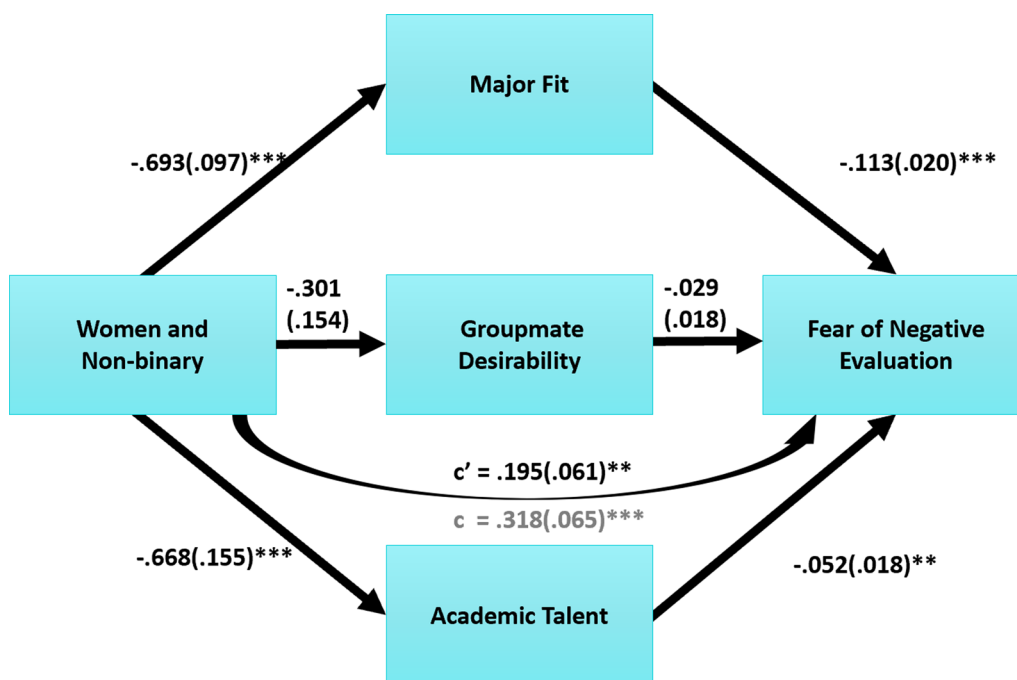
Fig. 5 Multiple mediator model of academic social comparison subconstructs (major fit, groupmate desirability, and academic talent) on the relationship of gender and FNE. Significance: $p > 0.05$, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$. Numbers outside of parenthesis are regression coefficients, also called path estimates. Numbers inside parenthesis are standard errors. The black arrows indicate mediation analysis. The gray text on the curved arrow indicates a regression of the dependent variable (fear of negative evaluation) on the independent variable (gender [men, women/non-binary]) prior to mediation analysis. The black text on the curved arrow indicates a regression of the dependent variable with mediation in the model. A reduction in absolute value from the gray text on the curved arrow to the black text on the curved arrow suggests partial mediation. Mediators were allowed to relate, but this is not depicted to simplify the figure. The arrows stemming from the independent variable [women/non-binary] that connect with a mediator [middle boxes] are a-paths. The arrows pointing from a mediator into the dependent variable [FNE] are b-paths. Each whole pathway, an a-path and its connecting b-path, multiplied together generate mediated effects (Table 2). Note that having a significant a-path and a significant b-path can suggest an overall significant mediated effect, but it is not guaranteed. If either an a-path or b-path are insignificant, the associated mediated effect of both paths considered together will also be insignificant
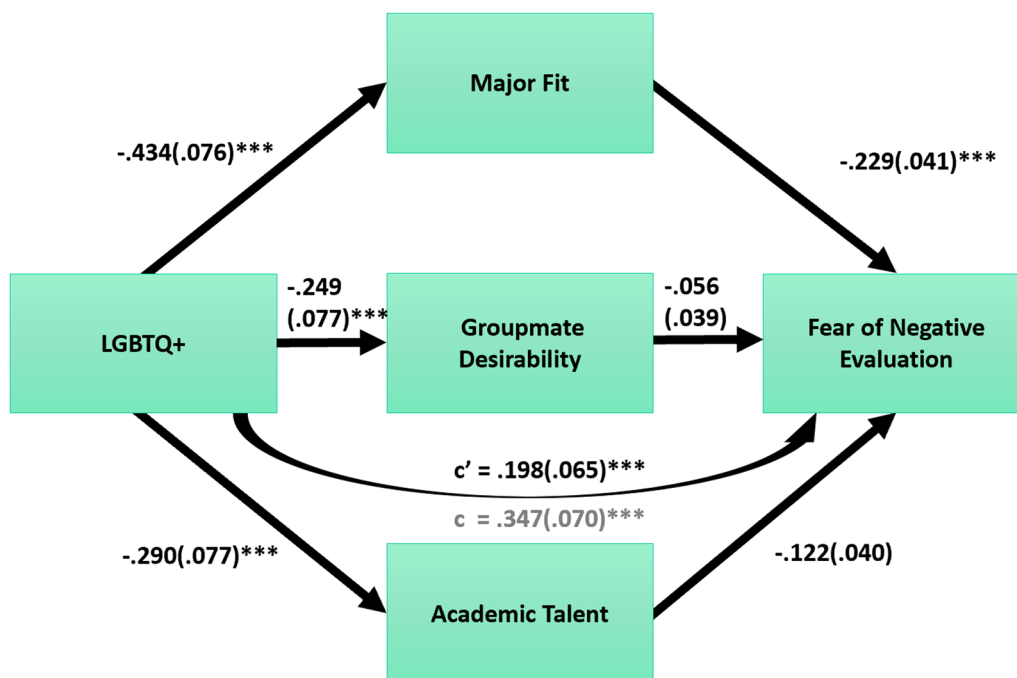
Fig. 6 Multiple mediator model of academic social comparison subconstructs (major fit, groupmate desirability, and academic talent) on the relationship of LGBTQ + status and FNE. Significance: $p > 0.05$, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$. Numbers outside of parenthesis are regression coefficients, also called path estimates. Numbers inside parenthesis are standard errors. The black arrows indicate mediation analysis. The gray text on the curved arrow indicates a regression of the dependent variable (fear of negative evaluation) on the independent variable (LGBTQ + status [LGBTQ +/non-LGBTQ +]) prior to mediation analysis. The black text on the curved arrow indicates a regression of the dependent variable with mediation in the model. A reduction in absolute value from the gray text on the curved arrow to the black text on the curved arrow suggests partial mediation. The arrows stemming from the independent variable (LGBTQ + status) that connect with a mediator (middle boxes) are a-paths. The arrows pointing from a mediator into the dependent variable (FNE) are b-paths. Each whole pathway, an a-path and its connecting b-path, multiplied together generate mediated effects (Table 3). Note that having a significant a-path and a significant b-path can suggest an overall significant mediated effect, but it is not guaranteed. If either an a-path or b-path are insignificant, the associated mediated effect of both paths considered together will also be insignificant. Mediators were allowed to relate but not depicted to simplify the figure

perceive themselves as less than their peers to a greater extent than non-LGBTQ + students do, which partially explains their disproportionately high FNE (Fig. 4).

Finding 3: Major fit is the strongest subconstruct mediating the relationship of disproportionately high FNE in women/ non-binary individuals, as well as for student who identify as part of the LGBTQ + community

Provided that academic social comparison is a statistically significant partial mediator for the disproportionately high levels of FNE expressed by women/non-binary and LGBTQ + students, we sought to identify what specific aspect of academic social comparison is the most influential. We estimated two separate multiple mediator models to test the extent to which the subconstructs of academic social comparison mediate the relationship between gender and FNE (Fig. 5) as well as LGBTQ + status and FNE (Fig. 6).

Gender There was a statistically significant effect of gender on major fit ($a_1 = -0.693$, $se_{a1} = 0.097$, $p < 0.001$).

Students who identified as woman or non-binary reported lower scores on major fit than students who identified as men, suggesting that women/non-binary individuals perceive that they fit in less in their major to a greater extent than men do. The relation of the major fit mediator on FNE was statistically significant ($b_1 = -0.113$, $se_{b1} = 0.020$, $p < 0.001$), meaning a decrease in major fit was associated with an increase in FNE. The mediated effect was significant ($ab_1 = 0.078$, $se = 0.021$, $p < 0.001$), meaning the subconstruct of major fit among other science major peers partially mediates the relationship between FNE and gender.

Groupmate desirability was not a significant pathway in the model ($ab_2 = 0.009$, $se = 0.007$, $p = 0.215$).

There was a statistically significant effect of gender on academic talent ($a_3 = -0.668$, $s_{a3} = 0.155$, $p < 0.05$). Individuals who identified as woman or non-binary reported lower scores on academic talent than individuals who identified as men, suggesting that women/non-binary students perceive themselves as less academically

Table 2 Mediated effects of academic social comparison subconstructs for women and non-binary students

SCS subconstruct $X =$ gender	Standardized mediated effect	Estimate	Standard error	z-value	p-value	CI lower	CI upper	[a]
Major fit	0.086	0.078	0.021	3.651	0.000	0.036	0.120	***
Groupmate desirability	0.010	0.009	0.007	1.239	0.215	-0.005	0.023	
Academic talent	0.038	0.035	0.015	2.386	0.017	0.006	0.064	*
total	0.349	0.318	0.065	4.882	0.000	0.190	0.445	***

[a] Significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

talented than their peers to a greater extent than men do. The relation of the academic talent mediator on FNE was statistically significant ($b_3 = -0.052$, $se_{b3} = 0.018$, $p < 0.05$). An increase in academic talent (perceiving themselves as academically better than their peers) was associated with a decrease in FNE. The mediated effect was significant ($ab_3 = 0.035$, $se = 0.015$, $p < 0.05$), suggesting that the subconstruct academic talent partially mediates the relationship between FNE and gender.

The direct effect of gender was statistically significant ($c' = 0.195$, $s_{c'} = 0.061$, $p < 0.001$). There was a decrease in the value of c' (0.195) from the original c-path ($c = 0.195$, $se_{c'} = 0.061$, $p < 0.01$), meaning academic social comparison, as a whole, partially mediates the relationship of FNE differences found between men and women/non-binary students in science classroom settings (Fig. 5). Standardized mediated effects for each ab-path with p-values can be found in Table 2. Mediators were allowed to correlate with each other; see Appendices for full model output including mediator covariances, confidence intervals, and a full table of the model.

LGBTQ+ status There was a statistically significant effect of LGBTQ+ status on major fit ($a_1 = -0.434$, $se_{a1} = 0.076$, $p < 0.001$). Individuals who identified as LGBTQ+ reported lower scores on major fit than individuals who identified as non-LGBTQ+, suggesting that LGBTQ+ perceive themselves as not fitting in with others in their major to a greater extent than non-LGBTQ+ individuals. The relation of the major fit mediator on FNE was statistically significant ($b_1 = -0.249$, $se_{b1} = 0.077$, $p < 0.001$). An increase in perception of

major fit was associated with a decrease in FNE. The mediated effect was significant ($ab_1 = 0.10$, $se = 0.025$, $p < 0.001$), meaning the perception of major fit among other science major peers partially mediates the relationship between FNE and LGBTQ+ status.

There was a statistically significant effect of LGBTQ+ status on groupmate desirability ($a_2 = -0.249$, $se_{a2} = 0.077$, $p < 0.001$). Individuals who identified as LGBTQ+ reported lower scores on groupmate desirability than individuals who identified as non-LGBTQ+, suggesting that LGBTQ+ perceive themselves as less desirable groupmates than their non-LGBTQ+ peers. However, the relation of the groupmate desirability mediator on FNE was statistically insignificant ($b_2 = -0.056$, $se_{b2} = 0.039$, $p > 0.05$). The mediated effect was insignificant ($ab_1 = 0.014$, $se = 0.011$, $p > 0.05$), meaning groupmate desirability amongst other science major peers does not mediate the relationship FNE and LGBTQ+ status in this sample.

There was a statistically significant effect of LGBTQ+ status on academic talent ($a_3 = -0.290$, $se_{a3} = 0.077$, $p < 0.001$). Individuals who identified as LGBTQ+ reported lower scores on academic talent than individuals who identified as non-LGBTQ+, suggesting that LGBTQ+ students perceive themselves as less academically talented than their peers to a greater extent than non-LGBTQ+ students. The relation of the academic talent mediator on FNE was statistically significant ($b_3 = -0.122$, $se_{b3} = 0.040$, $p < 0.05$). The mediated effect is significant ($ab_3 = 0.036$, $se = 0.015$, $p < 0.05$) thus, the perception of academic talent amongst other science major

Table 3 Mediated effects of academic social comparison subconstructs for LGBTQ+ students

SCS subconstruct $X =$ LGBTQ+	Standardized mediated effect	Estimate	Standard error	z-value	p-value	CI lower	CI upper	[a]
Major fit	0.110	0.100	0.025	4.018	0.000	0.051	0.148	***
Groupmate desirability	0.015	0.014	0.011	1.316	0.188	− 0.007	0.035	
Academic talent	0.040	0.036	0.015	2.395	0.017	0.006	0.065	*
total	0.381	0.347	0.070	4.994	0.000	0.211	0.483	***

[a] Significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

peers partially mediates the relationship of FNE and LGBTQ+identity in this sample.

The direct effect of LGBTQ+status was statistically significant ($c' = 0.198$, $se_{c'} = 0.065$, $p < 0.05$) There was a decrease in the value of c'-path (0.198) from the original c-path ($c = 0.347$, $se_c = 0.070$, $p < 0.001$), meaning that academic social comparison partially mediates the FNE differences found between non-LGBTQ+ and LGBTQ+students in science classroom settings (Fig. 6). Standardized mediated effects for each ab-path with *p*-values can be found in Table 3. Mediators were allowed to relate to each other; covariances are not depicted in Fig. 6 for clarity, see Appendices for full model.

Post hoc analyses Given the importance of the major fit component of academic social comparison in our models, we wanted to know whether major fit varied by a student's science major and whether there was an interaction with gender. For example, is the gender difference in major fit greater in chemistry compared to biology? We regressed major fit on gender, major, and added interaction terms for major and gender. We found that neither major nor the interactions between major and gender identities were significant predictors of students' major fit (see Appendices for regression results). This process was replicated for LGBTQ+status, and neither major nor the interactions between major and LGBTQ+identities were significant predictors of students' major fit (see Appendices for regression results).

Discussion

In this study sample, women/non-binary and LGBTQ+students reported significantly higher FNE compared to men and non-LGBTQ+students, respectively. It has been well documented that women participate less in college science courses compared to men (Bailey et al., 2020; Eddy & Brownell, 2016; Eddy et al., 2014) and that men in particular are prone to underestimating the intelligence of the women in their courses (Grunspan et al., 2016). The higher levels of FNE among women/non-binary students may help explain these phenomena. Women/non-binary college science students are more likely than men to report that FNE causes them to participate less and to struggle articulating their thoughts in science courses (Busch et al., 2023). If women struggle to articulate their ideas in front of their peers because of their FNE, it may contribute to how others perceive their intelligence in science (Grunspan et al., 2016). LGBTQ+students are also more likely than their counterparts to report that FNE causes them to participate less and struggle to articulate their thoughts in science courses (Busch et al., 2023). While participation gaps have not been examined among LGBTQ+students in science,

undergraduate LGBTQ+students report being reluctant to participate in class (Cooper & Brownell, 2016) and are less likely to persist in science majors compared to their straight and cis-gender peers (Hughes, 2018; Maloy et al., 2022). As such, lessening FNE among women/non-binary and LGBTQ+students may be important to closing gaps in perceived intelligence, promoting equitable participation, and ultimately retaining these populations in college science.

There are published recommendations about how to reduce FNE through intentional teaching decisions. For example, researchers have suggested that avoiding cold call or random call (Downing et al., 2020; Yannier et al., 2021) and allowing students to engage in the think and pair but not the whole class share of a think–pair–share (Cooper et al., 2021) may substantially reduce students FNE in college science courses. While these suggestions reduce the potential for FNE by limiting the number of opportunities for evaluation, they do not change students' ability to cope with FNE. To address this gap, clinical psychologists and science education researchers developed a brief online single-session intervention to help undergraduates understand and navigate their FNE in the context of college science courses. The intervention introduces students to the biological underpinnings of FNE, engages them with examples of real college students experiencing FNE, and identifies ways to reduce their FNE during class. A pilot randomized controlled trial found that the intervention boosted students' confidence contributing to whole class and small group discussions (Ghosh et al., 2023), but did not examine the impact of the intervention on FNE directly.

Based on qualitative data from undergraduates who experience FNE in the context of college science courses and drawing from cognitive theory (DiGiuseppe et al., 2016), we hypothesized that the negative thought process of academic social comparison mediates the relationship between students' identities (in this case students' gender and LGBTQ+identities) and their FNE, which may serve as a promising future interventional target. Our hypothesis was correct; FNE partially mediated the relationship between both gender and LGBTQ+identities and FNE. That is, women/non-binary individuals and LGBTQ+students reported lower academic social comparison scores, meaning they perceived themselves as "less than" others in their major to a greater extent than men and non-LGBTQ+students, which contributed to their higher levels of FNE.

In this study, we assessed three subconstructs of academic social comparison: the extent to which students feel as though they fit in among others in their major, the extent to which they feel desirable as a groupmate, and the extent they feel academically talented compared

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to their peers. When examining these subconstructs, we found that women/non-binary individuals reported significantly lower perceptions of their academic talent and major fit compared to their peers who identify as men. These findings align with the literature about women in college science. For example, a study of undergraduate physiology students which found that women with an average GPA perceived they were smarter than 54% of their classmates, while men with the same GPA perceived they were smarter than 66% of their classmates (Cooper et al., 2018a, 2018b). Further, when asked about the student they worked with most often in class, and controlling for GPA, women were 3.2×less likely than men to perceive they were smarter than their groupmate. Women have also been reported to switch out of STEM majors at higher rates than men (National Science Foundation, 2009). Additionally, our study demonstrated that LGBTQ+students reported fitting in less among students in their major to a greater extent than their non-LGBTQ+peers, which partially explained their lower levels of FNE. Academic science as a whole has been identified as unwelcoming for members of the LGBTQ+community (Busch et al., 2022; Cech, 2022; Cech & Pham, 2017; Cech & Waidzunas, 2011; Cooper et al., 2020). Among undergraduates specifically, LGBTQ+biology students report feeling as though they do not fit in amongst their science peers, and that this is particularly true in courses where they are asked to engage in discussions with other students (Cooper & Brownell, 2016). While students in the physical sciences are more likely to report knowing other LGBTQ+students than students studying education or professional programs (Garvey et al., 2023), the results of our study show that LGBTQ+students still do not see themselves as fitting in among their science classmates to the extent that their straight and cis peers do.

Our findings suggest that academic social comparison poses a promising target for future interventions aimed at lessening student FNE. Indeed, cognitive theory (Beck & Haigh, 2014), which posits that negative thought processes, such as academic social comparison, results in negative emotions, like negative fear of evaluation, supports this approach. One way to potentially enhance students' academic social comparison is to introduce students to the idea of normative expectations, which is a phenomenon where people dictate how they think and act based on perceived underlying social norms (Andrighetto et al., 2015). For example, students often think in extremes: presuming they are the only one in the class who does not know the answer to a question or expecting that most students in the class will judge them if they say something wrong in front of the whole class (Cooper et al., 2018a, 2018b; Downing et al., 2020).

Through classroom interventions that target negative internal perceptions, we may decrease the extent to which students perceive themselves as less than their peers. These lessons could take a variety of forms. For example, before class presentations an instructor can ask students to voluntarily raise their hands if they have ever thought someone would judge them for their presentation skills and allow students to look around the room to acknowledge that they are not alone in this thought. By understanding where they stand in relation to others, rather than making potentially biased inferences (e.g., thinking "I am the only person worried about what others think", which would fuel any existing fear of negative evaluation), they may be more likely to perceive they fit in with others in their major and feel less worried about being negatively evaluated. Alternatively, an instructor could introduce their class to literature showing that some groups, such as women, are prone to underestimating how they compare to their peers academically (Cooper et al., 2018a, 2018b; Yamin et al., 2019), highlighting that even when students feel academically inferior, they may not be.

Limitations and future directions

These findings should not be generalized beyond undergraduate science majors, particularly biology, chemistry, and biochemistry majors, in large-enrollment science courses that incorporate whole class discussions. Although gender and LGBTQ+status are treated as constant variables for the purposes of analysis, these identities exist on a spectrum that can shift over time (Monro, 2005). No pre-existing literature exists on the temporal order of academic social comparison and FNE. Temporal order bias is unaccounted for in this study, as the data are cross-sectional in nature and the current analysis does not use modeling where there are ways to manage temporal order bias (Georgeson et al., 2023). Ideally, data could be examined longitudinally showing how status, social comparison, and FNE change over time. We would expect a "diminishing returns" trend when using a within-subjects approach, where first-year students demonstrate high mediated effects with reduced mediated effects for each subsequent year of university. That being said, some of the temporal order bias risk is mitigated by using demographic identities as independent variables which are relatively stable over time (Rohrer et al., 2022). Further, a selection bias (Heckman, 1990) may be present due to the two survey incentives used in this study: extra credit and entering a gift card drawing. These incentives may attract students who are particularly interested in bolstering

their grade or winning a financial prize. Women and students with higher grade-point averages are most likely to participate in extra-credit activities (Harrison et al., 2011). While we were unable to collect data on student academic performance, the percentage of women in our study approximately reflects the percent of women across biology, chemistry, and biochemistry majors (National Center for Science & Engineering Statistics, 2023). If we under-sampled students who struggle academically, we may have recorded less variation in student academic social comparison, particularly when it comes to academic talent. To avoid interpreting data from students who completed the survey without reading it, presumably for the potential financial or course credit incentive, we removed any responses from surveys completed in under 3 min. We were surprised to find that major fit did not differ by which major a student declared. However, we had a low sample size for physics and geosciences students.

We encourage future studies to further examine the experiences of students in other science majors, particularly physics and geosciences. Additionally, there are likely other constructs that mediate the relationship between student identities and fear of negative evaluation that warrant exploration. Research suggests that social support and instructor immediacy, particularly in the context of large-enrollment science courses, may help alleviate feelings of FNE among undergraduates (Busch et al., 2023; Cooper & Brownell, 2020; Eddy et al., 2015; R. Theobald & Freeman, 2014). Finally, this study aims to encourage future research to create and test interventions that target academic social comparison with the intent of lessening FNE among college science students.

Conclusions

In this nation-wide study of U.S. college science students, we identified that women/non-binary students and LGBTQ+students report higher fear of negative evaluation (FNE), or a sense of dread associated with being unfavorably evaluated in a social situation (Weeks et al., 2005) in the context of college science courses, compared to men and non-LGBTQ+students, respectively. We found that academic social comparison, or how students perceive themselves with regard to the extent they fit in with others in their major, their appeal as a groupmate, and their academic ability, significantly and partially mediated the relationship between gender and LGBTQ+identities and FNE. That is, women/non-binary and LGBTQ+science majors perceive themselves as less than their peers to a greater extent than men and non-LGBTQ+science majors, contributing to their higher FNE in college science courses.

Abbreviations

FNE	Fear of negative evaluation
LGBTQ+	Lesbian, gay, bisexual, trans, queer
SCS	Social comparison scale
CFA	Confirmatory factor analysis
BFNE	Brief fear of negative evaluation (scale)
ESL	English as a second language

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40594-024-00501-7.

> Supplementary material 1

Availability data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was done with an approved Institutional Review Board (IRB) protocol no. 00016674 from Arizona State University.

Consent for publication

All participants consented to their data being published under IRB protocol no. 00016674.

Competing interests

The authors declare that they have no competing interests.

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