Factors Influencing Retention of Transgender and Gender Nonconforming Students in Undergraduate STEM Majors

Jeffrey Maloy,[†]* Monika B. Kwapisz,[‡] and Bryce E. Hughes[§]
[†]Department of Life Sciences Core Education and Department of Molecular, Cell, and Developmental Biology, University of California, Los Angeles, Los Angeles, CA 90095;
[‡]Department of Industrial and Systems Engineering, University of Washington, Seattle, WA 98195;
[§]Department of Education, Montana State University, Bozeman, MT 59717

ABSTRACT

Despite calls for improved data-collection efforts tracking transgender and gender nonconforming (TGNC) people in science, technology, engineering, and mathematics (STEM) education, there have been no reports of TGNC continuation in STEM majors at the university level. Using national, longitudinal data from the Higher Education Research Institute at the University of California, Los Angeles, we analyzed the experiences of 20,910 students who indicated an initial intent to major in a STEM field and found that TGNC students (n = 117) continue in STEM majors at a rate ~10% lower than their cisgender peers. This gap persists despite TGNC students' high levels of academic ability and academic self-confidence. Through multilevel regression modeling, we found this difference is not explained by experiences that have predicted the likelihood of cisgender students leaving STEM. The only significant predictor of STEM attrition for TGNC students in our model was whether they sought personal counseling; TGNC students who more frequently sought personal counseling were 21% less likely to remain in STEM majors. Overall, TGNC students leave STEM at rates similar to or higher than other minoritized groups, building the case for a multifaced, intersectional approach to addressing diversity and equity in the preparation of the future STEM workforce.

INTRODUCTION

At least 1.4 million adults in the United States identify as transgender or gender nonconforming (TGNC), meaning that their gender identity does not correspond with the sex they were assigned at birth and in some cases may fall outside of the current gender binary (Flores *et al.*, 2017). This broadly inclusive designation encompasses many different non-cisgender and nonbinary identities, including genderfluid, genderqueer, agender, transgender, and other identities (PFLAG, 2016). Younger generations are more likely to identify as TGNC: estimates suggest that as many as 1 in 14 (7%) of adults ages 18–24 identify as TGNC, and this number is increasing over time (Meerwijk and Sevelius, 2017). This suggests that increasing numbers of college students are identifying as TGNC, including many who will enter college intending to major in science, technology, engineering, and mathematics (STEM) fields.

Despite this predicted increase in enrollment, TGNC students face academic, social, and legal challenges not encountered by their cisgender peers (described in detail later in this paper). Between a record number of anti-TGNC bills advancing in state legislatures, a hostile climate for TGNC students in higher education, and anti-TGNC bias permeating STEM fields, it is no surprise TGNC students in STEM report alienation from and disidentification with STEM (Haverkamp *et al.*, 2019). Compounding this problem is the resistance among institutional actors to collect inclusive data on gender identity to monitor inequities in academic achievement (Freeman, 2018). Therefore, it is unclear what proportion of TGNC students who are interested in

Terrell Morton, *Monitoring Editor*
Submitted May 28, 2021; Revised Dec 16, 2021; Accepted Dec 21, 2021
CBE Life Sci Educ March 1, 2022 21:ar13
DOI:10.1187/cbe.21-05-0136
*Address correspondence to: Jeffrey Maloy (jmaloy@ucla.edu).

studying and working in STEM ultimately continue to complete a STEM degree and enter a STEM career, especially if TGNC students leave STEM at a disproportionate rate relative to their cisgender peers. Given trends observed with other minoritized students, if TGNC students are leaving STEM majors at higher rates than their cisgender peers, this pattern might highlight issues with the STEM academic climate that produce an unwelcoming or hostile environment for these students.

The purpose of this study, then, is to test whether TGNC students are retained in STEM majors at a different rate than their cisgender peers and to determine which factors predict a higher likelihood that TGNC students will continue in STEM. This study seeks to answer the following questions:

1. Do TGNC students continue in STEM majors to the fourth year of college at a different rate than their cisgender peers?
2. What factors predict TGNC students' likelihood of continuing in a STEM major to the fourth year of college?

LITERATURE REVIEW

Our primary research questions stem from a hypothesis that differential TGNC student experiences may produce inequitable outcomes for these students compared with their cisgender peers. To formulate this hypothesis, we drew on multiple bodies of literature describing the social context of TGNC people in the United States, the experiences of TGNC students on college campuses broadly, the qualitative experiences of TGNC people in STEM environments, and factors that have been shown to predict STEM retention for students at large. We describe these categories of literature in the following sections to indicate how each has informed our hypothesis, research questions, and study design.

Social Context

The recent increasing visibility of the TGNC population has been accompanied by some advances in legal protections. A landmark Supreme Court case in 2020 affirmed that Title VII of the Civil Rights Act of 1964 prohibits discrimination based on gender identity (Cahill, 2020). However, these limited advances have been paralleled by a massive expansion of legislation targeting the TGNC community, including more than 100 bills advancing an anti-TGNC agenda at the state level in 2021 (American Civil Liberties Union, 2021). Additionally, TGNC people face societal hurdles not experienced by their cisgender peers: TGNC people experience pervasive discrimination and physical abuse, are nearly four times as likely to be homeless or live in extreme poverty, and frequently delay access to medical treatment because of bias in the healthcare system (Grant *et al.*, 2011; Winter *et al.*, 2016). Particularly alarming is the astronomical suicide rate among TGNC individuals: 41% of TGNC people report having attempted suicide, compared with 0.8% of the overall population (Olfson *et al.*, 2017).

TGNC Students on College Campuses

The climate for TGNC students on college campuses has been improving over the past several years, but these societal barriers for TGNC people are reflected on college campuses. Further, the aforementioned politicization of TGNC identities has raised concerns about an associated effect on the harassment and discrimination facing TGNC college students. As a result, a majority of TGNC students rate their mental health as being below average compared with their peers, and nearly half report feeling depressed frequently, a rate four times higher than their cisgender peers (Stolzenberg and Hughes, 2017). One in seven TGNC students (16%) report having left higher education due to harassment they experienced on college campuses (James *et al.*, 2016).

Further, the campus environment is already unwelcoming to TGNC students. Most campuses do not offer TGNC-inclusive resources, such as student health centers, campus facilities like restrooms, and policies and procedures that allow TGNC students to be referred to by the names and pronouns they use (Beemyn, 2021). Even LGBTQ+ resources can be predominated by cisgender LGBQ students, resulting in resources that claim to serve TGNC students yet do not meet their needs (Marine and Nicolazzo, 2014). TGNC students face higher rates of depression and other mental health concerns than their peers, and they face a college environment where they need to advocate for or construct these resources and supports (Stolzenberg and Hughes, 2017). As a result, TGNC students often construct support networks and find resources off campus or online, recognizing that the college environment was not developed to support their academic success (Nicolazzo, 2016; Nicolazzo *et al.*, 2017).

In response to these challenges, the TGNC population has developed robust strategies for resilience. For example, the National Transgender Discrimination Survey has found that more than 75% of transgender respondents had been able to receive hormone therapy, reflecting widespread self-advocacy (Grant *et al.*, 2011). Additionally, although fewer 18- to 24-year-old TGNC respondents were currently attending school due to a variety of systemic barriers, TGNC people returned to school in large numbers at later ages, with 22% of respondents aged 25–44 currently attending school compared with only 7% of the general population (Grant *et al.*, 2011). These examples demonstrate a strong sense of personal agency and reflect a larger set of unique assets of the TGNC community.

TGNC Students in STEM

TGNC students may experience pervasive harassment and discrimination, access barriers, and mental health concerns even more severely in STEM. Inequities in STEM academic outcomes persist along demographic markers that are associated with privilege and dominance in society. Research has documented the disparities faced by (primarily cisgender) women in STEM as well as people from racial and ethnic groups underrepresented in STEM, and newer research is beginning to reveal inequities along the lines of sexual orientation and gender identity (Chen, 2013; Gayles and Ampaw, 2014; Riegle-Crumb *et al.*, 2019; Lysenko and Wang, 2020; Sansone and Carpenter, 2020). For example, lesbian, gay, bisexual, and queer students are 7% less likely to continue in a STEM major after 4 years, in spite of being more likely to participate in undergraduate research, a factor known to promote retention in STEM (Hughes, 2018).

TGNC students are also hypothesized to be more likely to switch from STEM to non–STEM majors. Perhaps we might frame this hypothesis as an unfair advantage enjoyed by cisgender students in STEM: Cisgender students are not experiencing the current political salience of TGNC identities, for example, which is also likely shaping the climate in higher education

(Dugan *et al.*, 2012; Garvey and Rankin, 2015; Garvey *et al.*, 2019; Rankin *et al.*, 2010). This problem appears to be even more acutely felt in STEM majors (Atherton *et al.*, 2016). TGNC students in STEM majors report chilly campus climates, increased experiences of harassment and bullying, microaggressions, and difficulty finding peer support groups (Yoder and Mattheis, 2016; Cech and Rothwell, 2018). In one national study, cisgender engineering students reported significantly lower levels of identity awareness, or awareness of the impact of their marginalization on their lived experiences, than TGNC engineering students (Haverkamp, 2021). Cisgender students also reported a greater sense of belonging and lessened sense of doubt in engineering than TGNC students. The climate is experienced greatest in group work settings, such as in active-learning classrooms where the increased amount of student interactions increases the chances that TGNC students may be nonconsensually outed as TGNC, misgendered, or exposed to other forms of bias and discrimination (Cooper and Brownell, 2016). In other words, as adoption of evidence-based pedagogies meant to broaden opportunities in STEM majors accelerates in STEM majors, it is likely that these changes will systematically benefit cisgender students unless the climate for TGNC students in STEM improves. TGNC students enter STEM out of a passion or desire to pursue further learning in science and engineering, and navigating a hostile climate adds an additional load (on top of a demanding curriculum) that cisgender students do not carry (Haverkamp *et al.*, 2019).

Compounded with the hostile climate for TGNC students, the notion of being transgender or gender nonconforming can conflict with the culture that permeates STEM fields. First, STEM culture values objectivity as a standpoint from which the best science and engineering operates (Longino, 2002; Douglas, 2004). This cultural value promotes the idea that if a STEM practitioner uses the best methods possible and isolates their bias from the research, they will produce the best science, regardless of the personal identity of the researcher. This commitment has informed a position that the identities of the person performing the science are thus irrelevant to their practice, meaning that TGNC identity should be irrelevant to the practice of science. In the case of gender and sexuality, where the field of biology has been weaponized against the expression of nonheteronormative and noncisnormative identities, it is difficult to accept the premise that identity is irrelevant to science (Ainsworth, 2015; Cooper *et al.*, 2020a).[1] Second, the commitment to objectivity also leads to the premise that STEM fields need to be depoliticized (Cech and Sherick, 2015). The predominant cultural belief in STEM dictates that science should not be directed by political interests, just as good science should not be shaped by a researcher's beliefs or biases. However, TGNC people today are experiencing a great deal of political salience given the amount and speed of legislation being written to criminalize TGNC identities, rendering TGNC people themselves as "political" and thus having no place in a "depoliticized" space like STEM. TGNC students are more than twice as likely to engage in activism or participate in protests and nearly three times more likely to frequently share their opinions on important causes (Stolzenberg and Hughes, 2017). This political engagement means TGNC students may perceive a stronger relationship between TGNC culture and social justice culture than between TGNC culture and STEM culture (Haverkamp *et al.*, 2019). In the study by Haverkamp and colleagues, two TGNC engineering students described experiencing engineering culture as heteronormative and cisgender masculine, which caused them to feel excluded and as though they needed to hide their TGNC identities. Further, as these students determined the need to be politically engaged due to the politicization of TGNC identities, they also observed a lack of political involvement among most of their peers in engineering. As a result, these students experienced TGNC identity as separate from engineering culture, which undermined their sense of belonging in the field, leading to lower levels of trust in engineering departments and higher levels of disidentification with their programs (Haverkamp, 2019)—an experience that has not been reported by cisgender students.

Given the lack of resources or structural support specifically devoted to TGNC students, it may come as no surprise to learn that no study has been able to test whether TGNC students are retained in STEM at a different rate than their cisgender peers. Most studies on retention and/or degree completion in STEM rely on large, existing, longitudinal data sets maintained by government agencies and education research institutes (e.g., Eagan *et al.*, 2014), which until recently have determined gathering demographic data that reflect the diversity of gender identity either of little value or even threatening to their interests. Many still resist collecting these data, especially because of how politicized TGNC people are in the United States. Comparing retention rates between cisgender and TGNC people is finally possible in this study because the Higher Education Research Institute (HERI) at the University of California, Los Angeles (UCLA) began changing how it gathered data on gender in 2015. Other institutes and agencies have been following suit in more recent years. Finally, it must be noted that retention is truly an institutional goal—yes, students who enter STEM expect to learn and succeed in their studies with the goal of earning a STEM degree and pursuing a career pathway that is meaningful for them. That said, TGNC students who enter STEM are multifaceted in their interests and talents—if remaining in STEM requires too great a cost in terms of personal well-being, attrition from STEM may truly reflect an individual student's success (Haverkamp, 2019).

Factors That Predict STEM Retention

Recent studies on student retention in STEM show a modest upward trend in the percentage of students who are still enrolled in college after 4 years and continue in a STEM major. Chang *et al.* (2014) found 62.5% of their sample who started college in 2004 were still enrolled in a STEM major after 4 years; Hughes (2018) found 70% of his sample who started in 2011 had continued in STEM. Both of these studies used data from HERI, the data source for the sample analyzed in this study.

Binary gender and race/ethnicity have long been demonstrated to predict retention in STEM. Students from racial and ethnic groups that are underrepresented in STEM are less likely to continue in a STEM major than their peers (58.4% compared with 73.5% for Asian-American students and 63.5% for white

[1]For a more detailed discussion of the ways in which biology education has suppressed understanding of noncisnormative identities, see this talk by Sam Sharpe: https://www.genderinclusivebiology.com/newsletter/other-neither-both-talk-by-sam-sharpe

students; Chang *et al.*, 2014), much of which is attributable to racial disparities in precollege academic preparation and experiences in college. Park *et al.* (2020) demonstrated that one of these college experiences is perceived discrimination from faculty on the basis of race; this experience predicted a lower likelihood of retention in STEM for underrepresented racial or ethnic minority (URM) students. The observed difference by race/ethnicity also appear to be unique to STEM when compared with other fields in college: STEM was the only field of study where Black and Latinx students were more likely than white students to switch to another field entirely, and STEM was the only field of study where racial differences in leaving were still observed after accounting for social background characteristics and academic preparation before college (Riegle-Crumb *et al.*, 2019). Women are also less likely to continue in or complete a STEM degree relative to men (48.8% for women who completed a STEM degree in 6 years; 55.8% for men; reported in Gayles and Ampaw, 2014; see also Chang *et al.*, 2014); however, studies investigating differences in the STEM experience by gender typically measure gender as a binary variable, overlooking individuals whose gender does not align with the traditional gender binary and ignoring the unique experiences of transgender people, whether or not they align with this binary. This study will help build on these findings by focusing on TGNC identities specifically.

Precollege academic preparation also predicts continuation in a STEM major. Overall, students who score higher on standardized college entrance exams, such as the quantitative Scholastic Aptitude Test (SAT) score, and students with higher high school grades are more likely to be retained in STEM (Chang *et al.*, 2014; Redmond-Sanogo *et al.*, 2016; Hughes, 2018; Park *et al.*, 2020). Differences in precollege academic preparation help explain additional inequities beyond race/ethnicity; first-generation students are also less likely to complete STEM degrees, but first-generation students also on average score lower on standardized tests and grades, take fewer advanced high school math and science courses, and have less access to role models in STEM, such as a parent employed in a STEM field (Bettencourt *et al.*, 2020).

Students' self-perceptions and self-concept have been measured as intrinsic factors that predict the likelihood of continuing in STEM. Academic self-concept, and science identity specifically, predict a higher likelihood of continuing in STEM (Chang *et al.*, 2014; Hughes, 2018). These intrinsic factors reflect students' perceptions of their own abilities relative to skills necessary to succeed in STEM. One experience known to promote science identity and the development of self-efficacy to succeed in STEM is undergraduate research (Seymour *et al.*, 2004). Undergraduate research participation predicts retention in STEM (Chang *et al.*, 2014), and LGBQ students are 10% more likely to participate in undergraduate research than heterosexual students (Hughes, 2018). Studying with other students also predicts a higher likelihood of being retained in STEM (Chang *et al.*, 2014; Hughes, 2018), though attending study groups has been observed to decrease the likelihood of STEM degree completion, particularly for women (Gayles and Ampaw, 2014). The latter finding may more narrowly reflect students who are struggling and seeking out formal study groups as opposed to students who report studying with peers in any manner.

Conceptual Framework

Drawing on factors previously implicated in retention of students in STEM majors, and in line with established models for measuring college impact on student outcomes (e.g., Tinto, 1987; Bean and Eaton, 2001; Astin and Antonio, 2012), we offer a conceptual framework that accounts for various influences on students' decisions to stay in or leave a STEM major (Figure 1). Person inputs include aspects of identity, self-beliefs, and personal background characteristics that influence a student's interests and perceived ability to pursue a given major. Students' experiences in various classroom and university settings arise as a result of participation in various STEM or non–STEM environments, and those experiences in turn play an important role in a student's continuous re-evaluation of major and career decisions. As discussed earlier, experiences thought to be particularly important in shaping student decisions whether to continue in STEM or leave STEM majors include mentorship experiences, peer support, interest development, and experiences of belonging. Finally, a student's decision to continue in or leave a major reflects their sense of personal agency in shaping educational outcomes. This sense of agency can be reflected in both academic and nonacademic decisions, including the decision to seek personal counseling or effect institutional or societal change by demonstrating for a cause. We used the resulting conceptual framework to situate our understanding of the data associated with major decisions for TGNC students.

METHODS

The data for this study were gathered from several administrations of the annual College Senior Survey (CSS) developed and run by HERI at UCLA (Astin *et al.*, 1966). The CSS is administered to students toward the end of their fourth year of college and was developed as a longitudinal follow-up survey to HERI's ongoing CIRP (Cooperative Institutional Research Program) Freshman Survey (Higher Education Research Institute and Home of Cooperative Institutional Research Program, n.d.). For this study, CSS administrations from 2015 to 2019 were pooled to identify an adequate sample size of transgender students. National estimates of the representation of transgender, gender nonconforming, and gender nonbinary people are quite low (ranging from a half a percent to 1.5%). Although 23,523 students completed the 2015 CSS, narrowing that down to the number of transgender students who initially majored in STEM would decrease the data sample by a significant degree (James *et al.*, 2016). Pooling data across administrations means capturing a cohort of students who attended college around the same time and overcoming statistical limitations by increasing the sample size to achieve a desired level of statistical power.

For this study, we used a data set provided by HERI in which they had matched student responses to the CSS with their responses to the Freshman Survey (TFS), administered at the very beginning of students' first year of college. The TFS is the longest-running national survey of incoming first-time college students at 4-year colleges and universities, and the instrument is designed to capture precollege experiences and attitudes both to track trends in incoming college students each Fall and to provide important control variables for longitudinal research. Students who took the CSS in 2019 took the TFS in 2015, the 2018 CSS group took the 2014 TFS, and so on. Both

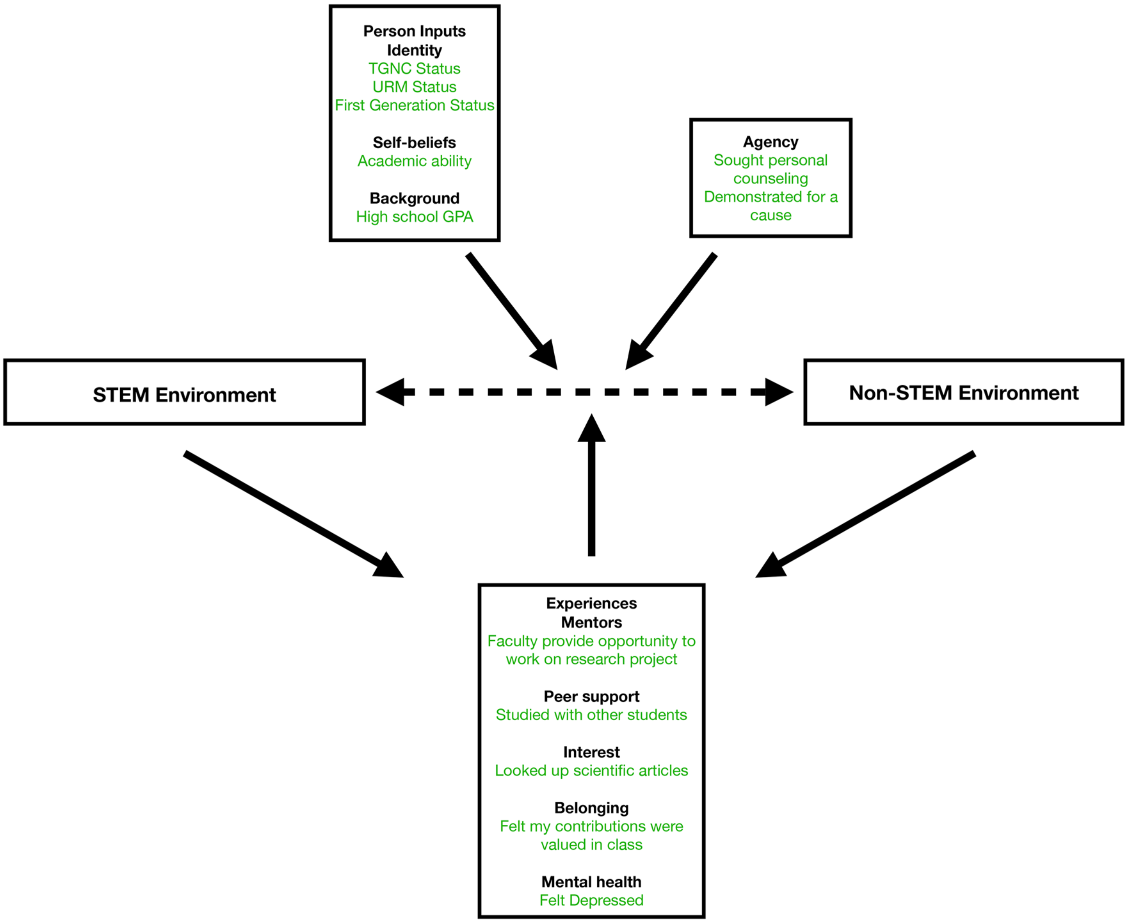

FIGURE 1. Theoretical framework illustrating the impact of three categories of predictors on student major decisions. The decision to remain in a given major or to change majors between STEM and non–STEM fields (dotted line) is influenced by person inputs, student agency, and student experiences. Each of these boxes contains specific subitems that align with HERI survey data collected for students in our data set (survey items are shown in green). The academic and social cultures in different STEM versus non–STEM environments impact student experiences, creating a recursive feedback loop affecting student major decisions.

instruments were developed through a process of expert review, cognitive interviews with representative survey participants, and validity and reliability testing using item response theory.

All HERI surveys are reviewed on an annual basis and revised as needed to maintain reliability and validity. The resulting longitudinal data set could then be analyzed with controls for factors affecting retention in STEM attributed to background differences among students. The sample was then reduced to all students who indicated they planned to major in STEM when they entered college. The ongoing review of HERI surveys did pose a limitation in terms of the available items. To keep the survey length reasonable, HERI does rotate some college experience questions from year to year to track trends on several variables beyond what would be reasonable to capture in a single survey. This rotation did mean that some variables that could have been relevant for modeling were not available every year, and thus could not be included; however, the most important variables were available every year. For a disaggregated analysis with only TGNC students, modeling limitations required a small set of essential variables available on every administration of the survey.

Variables

Our modeling follows the lead of Chang *et al.* (2014) and Hughes (2018), both of which used similar data and focused on other minoritized populations in STEM, with this study's contribution being our focus on TGNC identities. The dependent variable was a dichotomous variable indicating whether students indicated a STEM major on the CSS or not. As the sample included only students who planned to major in STEM when they entered college, the dependent variable then reflected whether these students had been retained in STEM by the end of their fourth year of college, or if they had at any point switched into a non–STEM major within that period. A full list of majors considered STEM for this study is provided in Supplemental Table S1. This list of majors is consistent with other research using HERI data to study STEM education. Supplemental Table S2 provides a list of all variables used for modeling along with information concerning how variables were coded.

For the full sample model, the primary independent variable tested in the model was whether students reported identifying gender identity with a category considered to be transgender, gender nonconforming, or gender nonbinary (TGNC). HERI added an item to their surveys in 2015 to capture whether students identified as transgender and then revised this item in 2018 to better capture the range of gender identities with which students may identify. As our data pooled CSS administrations from 2015 to 2019, this revision did pose some limitation to capturing all students who identify with identities considered TGNC. Specifically, students who identify as gender nonconforming or gender nonbinary, but not transgender, may not have selected "transgender" on surveys where this was their only option. However, this limitation does mean that our sample is quite conservative in terms of capturing students who identity as transgender.

A set of control variables was then selected as informed by the literature on STEM retention, most specifically Chang *et al.* (2014) and Hughes (2018), to isolate factors known to promote retention in STEM. Descriptive statistics for all variables are presented in Supplemental Table S3. We generally followed Astin's model for assessing college impact, typically referred to as the I-E-O (inputs, environments, outcomes) model, to aid with variable selection, though we aimed for parsimony in modeling, given the statistical power we expected to achieve with our disaggregated TGNC student sample (Astin, 1993).

In addition to our primary independent variable (TGNC status) and our outcome (STEM retention), we identified other college experiences that would be important to include because they have either been shown to be influential for retaining student in STEM or for shaping the experiences of TGNC students in college. Given what the literature has shown about mental health concerns and political engagement of TGNC students, we included variables that measure how frequently students felt depressed, sought personal counseling, and demonstrated for a cause. Variables we selected due to the literature showing their relationship to retention in STEM include participation in undergraduate research, studying with peers, feeling class contributions were valued, and searching research articles (Lopatto, 2004; Seymour *et al.*, 2004; Espinosa, 2011; Chang *et al.*, 2014).

We then included a set of input variables to control for differences between students shown to predict retention in STEM before entering college. Foremost among these were measures of precollege academic preparation, including high school grade point average (GPA) and SAT Mathematics score, to ensure that effects in the model could not be confounded with differences in academic performance. We also controlled for a set of variables measuring how students rated their own abilities in areas pertaining to STEM, including math ability, computer skills, and overall academic ability. Finally, we included two other demographic variables representing groups who are also less likely to be retained in STEM: sexual minority status (LGBQ+) and underrepresented racial/ethnic minority status (Espinosa, 2011; Chang *et al.*, 2014; Hughes, 2018). This set of variables was chosen to replicate the same regression model with both the full sample of students and the subsample of TGNC students.

Statistical Analysis

Cross-tabulations were used to compare STEM retention rates for different groups of students, and statistical significance was determined using Fisher's exact test to account for differences in sample size between demographic groups. The 95% confidence intervals for proportions were calculated using the adjusted Wald method. For bivariate comparisons of academic self-confidence measures and undergraduate experiences, statistical significance was determined using the Mantel-Haenszel test of linear association. A p value of 0.05 was used as the cutoff for statistical significance.

For multivariate analysis, missing values were examined for each variable used in the analysis to determine the need to impute missing values. When data can be assumed to be missing completely at random, and the sample size is sufficiently large, the subset of complete data can be assumed to be a simple random sample of the larger sample and the estimated parameters representative of the overall sample (Allison, 2002). Typically, data are assumed to be missing at random, meaning that missingness cannot be ignored, but missingness itself can be modeled as a function of observed values on other variables. The data for this study met the assumption for data missing at random, and a multiple imputation procedure was employed to estimate missing values. Imputation was especially important for modeling continuation in STEM for TGNC students, a small subset of the overall sample. Multiple imputation estimates several versions of the data set by incorporating random error drawn from residual distribution of each variable into each estimate in order to prevent type 1 statistical error from inflating standard errors as a result of imputing missing values. These multiple data sets are analyzed separately, and the results from each analysis are pooled into a single estimate of parameters for the sample. For this study, multiple imputation with chained equations was used, meaning that several regression equations predicting the estimated values for each variable were simultaneously estimated, using the regression form appropriate for the level of measurement of each variable (e.g., multiple regression for continuous variables, logistic regression for binary variables). Ten separate data sets were estimated for analysis.

Two separate regression analyses were performed for the two samples analyzed in this study. One tested factors identified in the literature to determine the unique effect of TGNC status on retention in STEM, and the second was a disaggregated analysis to determine which factors matter most for TGNC continuation in STEM. For the full sample of students, hierarchical generalized linear modeling (HGLM) was used. HGLM is the multilevel form of logistic regression, used when the dependent variable is a dichotomous categorical variable. HGLM is more appropriate with data that are "nested" in structure, that is, the individual cases belong to larger shared groups (Raudenbush and Bryk, 2002). Nested data violate the assumption of independence due to the potential for intragroup correlations that may affect model parameter estimates, increasing the likelihood of a type I statistical error in comparison to standard logistic regression and other single-level regression techniques. For this study, individual-level cases, or students, are nested within institutions. HGLM then parses the variance of the dependent variable into within-group variance (level 1), or variance among students within institutions, and between-group variance (level 2), or variance among institutions.

Multilevel modeling is only appropriate when the average number of individuals per group is large enough to adequately assess how much variance is present at the group level. Some "rules of thumb" include 30/30 (30 groups averaging 30 cases each), 50/20, and even 100/10, depending on the interest in the fixed parameters primarily, cross-level interactions, or random components, respectively (Hox, 2010). When the sample is disaggregated to only TGNC students, the ratio shrinks to an average of 2.5 cases across 47 groups. In this case, single-level logistic regression was used, but standard errors were adjusted for clustering by institution. This method is also appropriate for accounting for the nonindependence of cases clustered by institution, particularly because no level 2 variables are included in the model.

To improve interpretability of the model parameters, we calculated delta-*p* statistics for all significant coefficients. Delta-*p* statistics are an estimate of the expected change in probability associated with a one-unit change in an independent variable, or the difference between two groups for dichotomous variables. These changes in probability tend to be more straightforward for interpretation than odds ratios. Additionally, a post hoc power analysis was performed using G*Power for the disaggregated TGNC sample to determine the power achieved in estimating each significant coefficient at α = 0.05% (Faul *et al.*, 2007). The power achieved is reported in the table notes.

Positionality

A statement of positionality is typically not included in quantitative analyses, likely grounded in the presumption that quantitative research is unbiased and objective—the researchers themselves have little bearing on the data or the results of these analyses. Critical quantitative researchers have argued, especially in social science research dealing with identity, the researchers still play an active role in the process in terms of the selection of questions or hypotheses pursued, decision making for model building, and interpretation of the study results. As such, we include a statement of our positionalities to help the reader understand our positionality in relation to the focus on TGNC student retention in STEM.

The first and third researchers are cisgender men (J.M. and B.E.H.; pronouns: he/him/his), and the second researcher is nonbinary (M.B.K.; pronouns: they/them/theirs), all of whom are white and come from middle- to upper middle-class backgrounds. All three authors are part of LGBTQIA+ communities; J.M. and B.E.H. identify as gay, and M.B.K. as queer. All three authors are affiliated with R1 research universities; J.M. and B.E.H. are tenure-track faculty members, and M.B.K. is a doctoral student. All three authors are deeply committed to LGBTQIA+ visibility and inclusion in higher education and STEM.

Naming these positionalities provides insight into our privilege relative to the topic and context of this study. In the cultural context of the United States where this research took place, cisheteropatriarchy has shaped cultural beliefs and attitudes regarding what is viewed as "normal" versus "other" (Valdes, 1996). This context can lead to the framing of LGBTQIA+ and TGNC people's experiences from a deficit perspective, wherein LGBTQIA+ and TGNC people are viewed as cultural others who should aspire to live up to and conform to norms established by cisgender and heterosexual people. Given the positionalities of the authors as members of the LGBTQIA+ community, we have taken care to counter this cisheteropatriarchical narrative by centering the experiences of TGNC students. As a nonbinary person, the second author has used their own lived experience to ensure that TGNC students are not "othered" by the research narrative laid out in this article. As cisgender people, the first and third authors have taken care to prioritize the experiences and perspectives of TGNC people, including the second author, and have sought and incorporated feedback and advice from TGNC people throughout the research design, analysis, and writing process.

The authors also recognize our privilege as white scholars. By acknowledging this privilege and being mindful of its influence in our work, we hope to contribute to conversations about intersectionality between racial, sexual, and gender identities and highlight the interlocking systems of oppression that permeate the culture of STEM education.

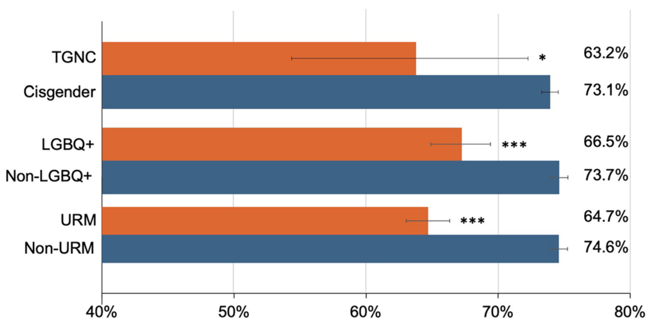

FIGURE 2. Proportion of students who aspired to a STEM degree upon entering college and remained in a STEM major until graduation. Error bars represent 95% confidence intervals calculated using the adjusted Wald method. Note: LGBQ+ population does not include TGNC students, unless those students also indicated a sexual minority identity. TGNC: *n* = 117; cisgender: *n* = 20,205; LGBQ+: *n* = 1,763; non-LGBQ+: *n* = 18,279; URM: *n* = 3,247; non-URM: *n* = 17,072; *$p < 0.05$ ***$p < 0.001$.

RESULTS

Cisgender Students Are More Likely to Remain in STEM Majors

For this study, we pooled data across the 2015–2019 administrations of the CSS. These data were matched by case to students' individual responses to the TFS. After reducing the sample to students who initially indicated an aspiration to obtain a STEM degree on the TFS, this data set encompassed 20,910 students across 150 institutions, of whom 117 identified as TGNC (66 as transgender and 51 as gender nonconforming). We then determined the percentage of students who indicated a STEM major at the end of their fourth year of college to ascertain the proportion of students who continued in STEM and how this proportion differed by TGNC status. Information regarding the STEM majors and variables used in our analyses, the coding of these variables, and univariate descriptive statistics are presented in Supplemental Tables S1–S3. Overall, we found that TGNC students were almost 10 percentage points less likely to remain in STEM majors compared with their cisgender counterparts ($p = 0.018$; Figure 2). This difference in STEM retention rate mirrors a difference in retention for URM students and lesbian, gay, bisexual, queer, and other sexual minority students (LGBQ+), which is consistent with findings produced

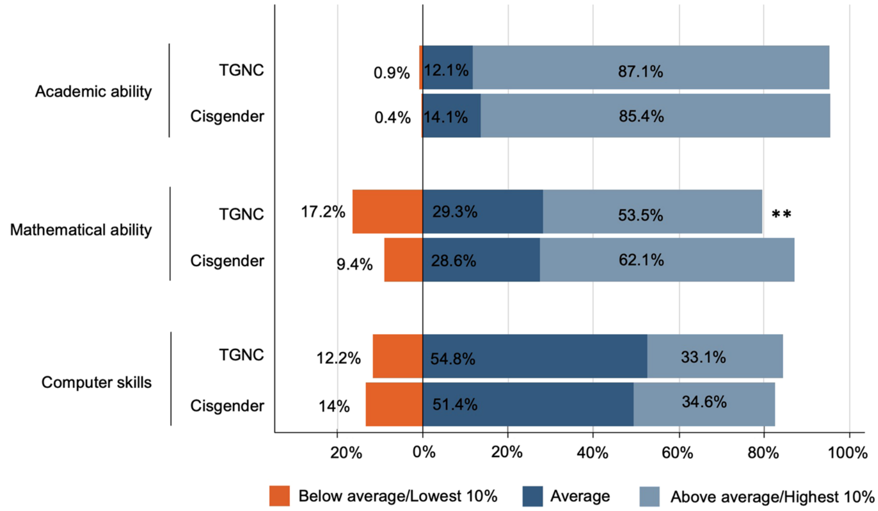

FIGURE 3. Academic self-confidence measures for TGNC and cisgender students in TFS. Bars to the left of the vertical axis indicate students who rated themselves below average or in the lowest 10%; bars to the right indicate students who rated themselves average or higher. **$p < 0.01$.

by similar data sets (Chang *et al.*, 2014; Hughes, 2018). Despite the observed attrition of TGNC students from STEM majors, TFS responses indicated that incoming TGNC students, like their cisgender counterparts, exhibited high degrees of academic ability and academic self-confidence (Figure 3). We did not observe significant differences between SAT scores ($p = 0.271$) or high school GPA ($p = 0.303$) for these groups (Supplemental Table S3). As previously reported for women and URM students, mathematical self-confidence was lower in TGNC students (Nguyen and Ryan, 2008).

TGNC Students Report Different College Experiences Than Their Cisgender Peers

The lack of difference in academic ability upon entering college led us to explore college academic and social experiences as possible explanatory variables contributing to the difference in retention. Based on previous work examining the factors affecting undergraduate students' decisions to leave STEM majors, we hypothesized that a combination of factors contributing to a hostile environment for TGNC students in STEM majors and positive factors attracting TGNC students into non–STEM majors contributed to students' decisions whether to remain in STEM majors (Seymour, 1997). We first tested several of these factors descriptively to compare TGNC students and their peers. As expected, we observed significant differences in emotional health and civic engagement for TGNC students (Figure 4). Nearly 54% of TGNC students reported feeling depressed frequently, and 30% frequently sought personal counseling, compared with 15% and 8%, respectively, of their peers. The academic experiences of TGNC students were similar to those of their peers, but TGNC students exhibited a much greater extent of civic engagement than their cisgender peers; 67% of TGNC students occasionally or frequently demonstrated for a cause during their college experience, while only 27% of cisgender students did the same. Collectively, these measures indicate that, despite entering college with equivalent academic ability and high levels of academic self-confidence, TGNC students experience a qualitatively different environment at the university.

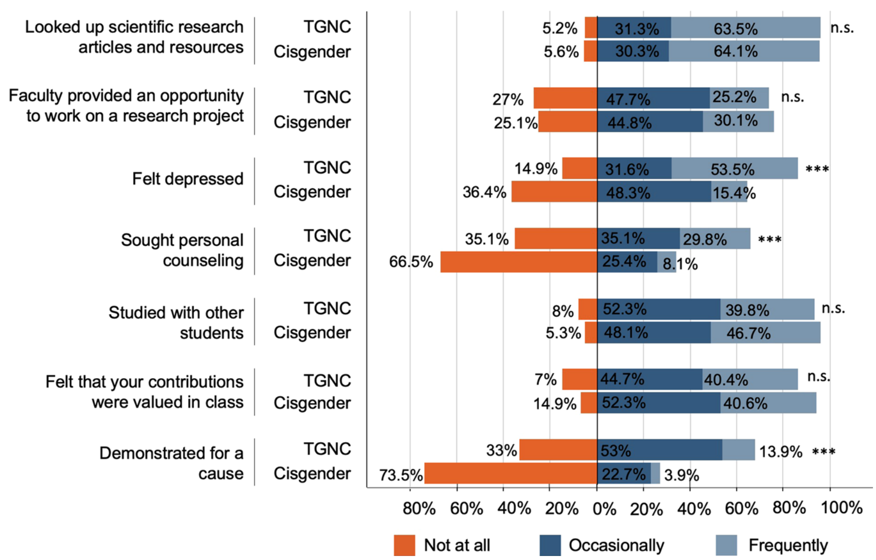

FIGURE 4. Undergraduate experiences reported by students in CSS. Bars to the left of vertical axis indicate students reporting the absence of an experience; bars to the right indicate students reporting the experience occasionally or frequently. ***$p < 0.001$; n.s. = not significant.

Undergraduate Academic and Nonacademic Experiences Contribute to the Difference in TGNC Retention Rates

We next sought to determine whether these differences in experiences might contribute to the observed difference in STEM retention rates for TGNC students. We used HGLM to isolate the variance in STEM retention rates for the variables described earlier. This technique allowed us to control for the quantitative differences in the undergraduate experiences of TGNC students and isolate the effect of each individual variable on retention rates. We also ran a separate model with TGNC students disaggregated from the overall sample. For this model, we ran a logistic regression with robust standard errors adjusted to account for clustering by institution. Too many group sizes were too small for HGLM;

TABLE 1. HGLM predicting STEM retention, full sample ($n = 20{,}910$)

Variable	*et al.*	SE	*t*	*p*	Significance	Delta-*p*
Constant	–0.1666	0.204	–8.17			
TGNC status	–0.454	0.228	–2	0.046	*	–9.7%
URM status	–0.261	0.052	–5	<0.001	***	–5.3%
High school GPA	0.201	0.019	10.47	<0.001	***	3.7%
First-generation status	–0.186	0.060	–3.09	0.002	**	–3.7%
Faculty provide opportunity to work on research project	0.255	0.028	9.14	<0.001	***	4.6%
Studied with other students	0.244	0.032	7.6	<0.001	***	4.4%
Looked up scientific articles	0.422	0.031	13.49	<0.001	***	7.3%
Felt my contributions were valued in class	–0.308	0.036	–8.57	<0.001	***	–6.4%
Self-rating: academic ability	0.168	0.029	5.76	<0.001	***	3.1%
Sought personal counseling	–0.126	0.032	–3.94	<0.001	***	–2.5%
Felt depressed	–0.078	0.031	–2.53	0.012	*	–1.5%
Sense of belonging on campus	–0.032	0.029	–1.1	0.273		
Demonstrated for a cause	–0.232	0.035	–6.67	<0.001	***	–4.7%

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

cluster-adjusted robust standard errors provided a separate method for accounting for statistical dependence within groups.

Nearly all the variables were significant for the full sample; the only variable that was not significant was sense of belonging (Table 1). Holding all else equal, TGNC students are 9.7% less likely to continue in STEM; first-generation college students (–3.7%) and URM students (–5.3%) are also less likely to continue. Higher high school grades (3.7%), working on faculty research (4.6%), studying with other students (4.4%), looking up more scientific articles and resources (7.3%), and increased sense of academic ability (3.1%) all predict a higher likelihood of continuing in a STEM major. Feeling contributions are valued in class (–6.4%), seeking personal counseling (–3.1%), feeling depressed (–1.5%), and demonstrating for a cause (–4.7%) all predict a lower likelihood of continuing in STEM. Students who leave STEM are more likely to report these experiences, which may reflect experiences that more likely to occur in non-STEM environments, pulled them away from STEM, or that are more likely to occur in non–STEM majors.

In the TGNC-only model, two variables were significant predictors of retention in STEM (Table 2). Holding all else equal, TGNC students who are first generation are 43.4% more likely to continue in STEM, and TGNC students who seek personal counseling more frequently are 20.8% less likely to continue in STEM. We advise caution in interpreting the finding for first-generation TGNC students, as a post hoc estimation of statistical power for the model coefficient did not reach 80% (β = 38%), but the estimation of the statistical power for seeking counseling exceeded 80% (β = 86%). No other variable in the model was a significant predictor of retention in STEM, including several variables that have been shown across multiple studies to predict retention of students in STEM (e.g., working on faculty research, high school grades, URM status).

DISCUSSION

Taken together, our results indicate that TGNC students are less likely to continue in STEM majors and that there are few aspects of the TGNC student experience available in the data set

TABLE 2. HGLM predicting STEM retention, TGNC subsample ($n = 117$)

Variable	*B*	SE	*t*	*p*	Significance	Delta-*p*[a]
Constant	–3.260	2.458	–1.33	0.815		
URM status	–0.609	0.721	–0.84	0.399		
High school GPA	–0.054	0.216	–0.25	0.803		
First-generation status	2.647	0.997	2.65	0.008	**	43.4%[i]
Faculty provide opportunity to work on research project	0.415	0.303	1.37	0.17		
Studied with other students	0.182	0.439	0.42	0.678		
Looked up scientific articles	0.570	0.564	1.01	0.312		
Felt my contributions were valued in class	0.542	0.400	1.35	0.176		
Self-rating: academic ability	0.166	0.372	0.45	0.655		
Sought personal counseling	–0.847	0.379	–2.23	0.025	*	–20.8%[ii]
Felt depressed	–0.054	0.415	–0.13	0.896		
Sense of belonging on campus	0.099	0.336	0.29	0.769		
Demonstrated for a cause	0.436	0.446	0.98	0.328		

[a]47 clusters: (i) achieved power 38%; (ii) achieved power 86%.
*$p < 0.05$.
**$p < 0.01$.

analyzed that are robust predictors of retention. In other words, not only do cisgender students continue in STEM at a higher rate, but it also appears that the extant literature on STEM retention is most likely reflective only of cisgender student retention in STEM (e.g., Chang *et al.*, 2014; Hughes, 2018). Although previous research would have suggested a decreased retention rate for TGNC students based on qualitatively less favorable views of the STEM climate (e.g., James *et al.*, 2016; Nicolazzo, 2016; Haverkamp, 2019), the extent to which TGNC students are drawn out of STEM majors at rates equivalent to or greater than other groups historically marginalized in STEM majors is alarming for STEM fields.

Predictors of Retention Differ for TGNC versus Non-TGNC Students

Although we identified factors that appear to predict retention in STEM, what seems to be more telling is the number of predictors that have been found to predict retention in STEM in previous research that do not significantly predict retention for TGNC students. As noted through the conceptual framework, given the various influences that can impact student decisions to continue in or leave a STEM environment, we were not surprised to find quantitative differences between TGNC and non-TGNC students in many agency and experiences variables. For example, we found that TGNC students were more likely to report feeling depressed, being less likely to study with peers, and being more likely to participate in demonstrations, all of which predict decreased STEM retention among all students. Surprisingly, these were not significant predictors for TGNC students, meaning they did not differ in whether students continued in STEM. TGNC students may be less likely to study with peers, especially in STEM, given the climate experienced in STEM and the greater likelihood of finding community either off campus or in virtual spaces (Nicolazzo, 2016; Haverkamp, 2019)—studying with peers more frequently may expose them to a greater degree of bias and harassment (Cooper and Brownell, 2016). The politicization of TGNC identities in society today likely engages TGNC students in political action regardless of major (Garvey *et al.*, 2019; Haverkamp, 2021). The lack of association between these two experiences and STEM retention likely reflects that these two experiences are common for TGNC students regardless of major.

This study also failed to replicate a finding that has informed a significant amount of research and intervention conducted to improve retention of minoritized students in STEM (Chang *et al.*, 2014). Participation in undergraduate research was not a significant predictor of retention in STEM for TGNC students. Coupled with a finding by Hughes and Kothari (2021) that undergraduate research participation does not predict STEM retention for LGBQ students, new questions should be asked about what the undergraduate research experience is like for LGBTQ+ students overall. In neither of these studies is undergraduate research a predictor of retention or attrition—could the lack of significance indicate the retention difference could be even greater if students did not participate in these experiences? Or are we observing an aggregate experience of a chilly or hostile environment for LGBTQ+ people within research labs? Similar to Cooper and Brownell's (2016) observation that active learning and group work can be harmful for LGBTQIA+ students, future research should explore these "microclimates" (Vaccaro, 2012) to better understand the culture of academic research regarding LGBTQ+ people.

Another potential explanation is that the lack of significant predictors of STEM retention for TGNC students suggests broader, persistent concerns about the climate for TGNC students on college campuses beyond whether they major in STEM. Though our conceptual framework acknowledges the role and potential influence these constructs may play in student decision making, it does not speak to the degree to which they individually or collectively impact student retention, particularly for TGNC students. Our findings demonstrate that no student experience variable acted as a significant predictor of STEM retention for TGNC students. Given the predictive power of TGNC status on STEM retention, if very little explains this effect, then we may be observing the effect of bias against TGNC students in STEM (Beemyn, 2021). Previous research has indicated that this bias may be mitigated or exacerbated in part by individual instructor identities and specific adaptations to course structure (Cooper and Brownell, 2016). Future research should test robust measures of the TGNC climate in STEM and on campus to determine how this experience helps explain the difference between TGNC and cisgender students in their likelihood of continuing a STEM major.

Mental Health Experiences for TGNC Students Are Nuanced

With respect to mental health, one variable in our model that reliably predicted STEM attrition for TGNC students was whether or not a student sought personal counseling. At first glance, seeking counseling may be an indicator of poorer mental health, which can result from adjusting to the demands of college (and a STEM major specifically); trauma inflicted on upon TGNC students by a cisheteropatriarchical society, reflected in interactions with instructors, peers, and mentors on campus; or a combination of the two. Previous research has shown that TGNC students rate their mental health lower than their cisgender peers do (Stolzenberg and Hughes, 2017). However, feeling depressed, a more direct indicator of mental health, did not significantly predict retention in STEM for TGNC students. Further, previous research supports the idea that STEM fields may disproportionately stigmatize help-seeking behaviors and conversations surrounding mental health issues (Lauber *et al.*, 2005; Miles *et al.*, 2020). Therefore, seeking counseling can also be viewed as a proactive step toward tending to one's mental health, a form of agency students can maintain that can potentially impact their retention. This means that TGNC people who leave STEM may find themselves in environments that encourage addressing needs around mental health. This finding may indicate that a deeper issue is to what extent seeking counseling is stigmatized or discouraged within STEM, especially because this variable is significant for the full sample as well. More research is needed to examine the nuanced experiences of these students with intersecting identities and explore the interplay between first-generation status and TGNC identity, especially given the limitations of our subsample size, as observed in the post hoc power analysis.

Recommendations

Given the results described in this paper, there are multiple concrete steps that the STEM education community can take to improve the climate for TGNC students. Recognizing that TGNC students exhibit everyday resilience in frequently hostile social, academic, and professional environments, we approached the recommendations we offer here using a trauma-informed educational practice lens (Carello and Butler, 2015). This framework provides the guiding principle that each of the recommendations we offer should be designed to 1) ensure safety and minimize the possibility of retraumatization for members of the TGNC community and 2) maximize the possibilities of educational success for these students. With these guidelines in mind, we outline here some key recommendations. These recommendations are also summarized in Supplemental List S1.

First, although initial strides have been made toward improving data-collection efforts as they pertain to nonbinary gender identities, more work is needed. To that end, recent work has laid out some recommendations for producing data that are more inclusive of sexualities and gender identities (Cooper *et al.*, 2020a). These recommendations include asking participants about gender with two items: the first asking about gender identity with corresponding options (e.g., man, woman, nonbinary, genderqueer, other) and the second asking if someone identifies as transgender, if important to the study. Researchers should consider providing open-ended items that allow people to name their gender identities instead of choosing from a predefined list, though be prepared for hostile or resistant responses as well.

Second, our results suggest that the stigma surrounding personal counseling and mental health conversations in STEM environments not only harms all STEM students but may be particularly harmful for TGNC students. Taking actions toward decreasing this stigma and promoting conversations about mental health and personal counseling are likely to have disproportionately positive effects for TGNC students and other minoritized students in STEM majors (Eleftheriades *et al.*, 2020). Examples of actions in a course environment include being explicit with students that instructors recognize mental illness as a valid sickness, acknowledging that struggling with mental health issues is common, and allowing students the flexibility to take time off to address mental health issues and/or seek personal counseling (Cooper *et al.*, 2020b). This can be done by explicitly including information on a course syllabus or on a presentation on the first day of class regarding mental health policies in the course. An example passage in a syllabus attendance policy section might include the following: "I recognize that mental illness is a valid sickness just like any physical illness you might encounter. Just as our course absence policy allows for you to miss class days if you are physically ill, you are also not expected to attend class on days that might require you to focus on your mental health. If you need to take time off for your mental health, you may simply inform me that you will be out sick, and you will not be penalized." Additionally, instructors can foster a sense of agency in students who may benefit from counseling by familiarizing themselves with campus resources, including these resources on course syllabi, and referring students appropriately (Hsu and Goldsmith, 2021).

Finally, we found that college experiences differentially impacted TGNC students versus cisgender students; many of the factors that predicted retention for cisgender students were not predictive of TGNC retention. This result mirrors previous findings that high-impact practices long presumed to universally foster STEM retention may not produce the same results in LGBQ+ populations (Kilgo *et al.*, 2019). Therefore, a one-size-fits-all approach is unlikely to promote retention of TGNC students in STEM majors. Instead, solutions must be tailored to the specific needs of the TGNC student population. In the classroom, instructors can consider the needs of TGNC students by including multiple anonymous opportunities for students to provide constructive feedback regarding the climate of the course. Further study of this historically ignored student population is essential to identify these needs and develop appropriate intervention strategies. In particular, qualitative work is needed to describe the experiences of TGNC students who continue in STEM majors or leave STEM majors in their own words. This work will constitute an important step in identifying themes in the TGNC student experience that may inform further action.

Steps toward More Equitable STEM Culture

In 2012, the President's Council of Advisors on Science and Technology issued a report highlighting the need for a more equitable STEM culture and a more diverse scientific workforce (President's Council of Advisors on Science and Technology, 2012). The data presented here are a stark example of this unmet need for TGNC students, who represent an increasingly visible segment of our society. Furthermore, many TGNC students are also members of other minoritized communities underserved by STEM. Meeting the charge of producing an equitable STEM culture necessitates the expansion of conversations surrounding diversity and equity in STEM into a space where complex and intersectional identities are acknowledged and their impacts on the STEM experience are investigated. To produce more equitable outcomes for TGNC students, we must first understand what aspects of the undergraduate experience promote positive academic and psychosocial environments for TGNC students in STEM majors, and this study represents a major step forward in that regard with the first quantitative picture of TGNC retention in undergraduate STEM fields.

ACKNOWLEDGMENTS

We would first and foremost like to thank the TGNC undergraduate students who participated in HERI surveys for their willingness to be out and report their experiences in college; without their effort, this work would not be possible. We thank Maren Greathouse for her help in discussing potential issues facing TGNC people in STEM environments. We also thank Andrea Haverkamp for her critical feedback regarding how TGNC people are represented in this study. We also thank HERI at UCLA for assistance in preparing data sets. Data reported in this paper are collected and maintained by HERI at UCLA. These data were made available to the researchers through an agreement with HERI; inquiries about data access should be directed to the institute. HERI makes data that are more than 10 years old available to researchers at no cost via their website (www.heri.ucla.edu), but more recent data are subject to a licensing agreement and fee. Please contact the institute for further information.

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