SOCIAL SCIENCES

Coming out in STEM: Factors affecting retention of sexual minority STEM students

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Using a national longitudinal survey data set from the Higher Education Research Institute, this study tested whether students who identified as a sexual minority (for example, lesbian, gay, bisexual, or queer) were more or less likely to persist after 4 years in science, technology, engineering, and mathematics (STEM) fields, as opposed to switching to a non-STEM program, compared to their heterosexual peers. A multilevel regression model controlling for various experiences and characteristics previously determined to predict retention in STEM demonstrated that, net of these variables, sexual minority students were 8% less likely to be retained in STEM compared to switching into a non-STEM program. Despite this finding, sexual minority STEM students were more likely to report participating in undergraduate research programs, and the gender disparity in STEM retention appears to be reversed for sexual minority STEM students.

INTRODUCTION

Diverse teams are more likely to reach scientific breakthroughs and technological innovations because people who bring different perspectives to a problem envision different solutions (*1*). The underrepresentation in science, technology, engineering, and mathematics (STEM) of women, racial and ethnic minorities, and students from other groups is, thus, a problem because broader participation increases the diversity of perspectives in these fields (*2*, *3*). One group that has received little attention in conversations regarding broadening participation in STEM is the LGBQ community—lesbian, gay, bisexual, and queer—or sexual minority. A recent report on the LGBQ climate in physics has drawn attention to some of the major issues faced by sexual minority STEM professionals (*4*), including a heterosexist climate that reinforces gender role stereotypes in STEM work environments (*4*–*6*), a culture that requires, or at least strongly encourages, LGBQ people to remain closeted at work (*7*, *8*), and a general lack of awareness about LGBQ issues among STEM professionals (*9*). National projections suggest a need for an additional 1 million STEM bachelor's degrees in the coming decade (*10*–*12*); approximately 3.5% of Americans identify as lesbian, gay, or bisexual (*13*), amounting to roughly 35,000 additional sexual minority graduates. Much remains to be discovered about these students' experiences in STEM because research institutes that administer national surveys of college students have resisted including sexual orientation demographic variables to aid in disaggregation (*14*–*16*), especially survey programs that track students longitudinally (*17*). Using data from one of the first longitudinal samples of college students that allows disaggregation by sexual orientation, this study addresses this limitation to test whether there is a difference in 4-year retention in a STEM major between sexual minority and heterosexual STEM aspirants.

Throughout this paper, the abbreviation LGBQ will generally be used to reflect the sample selected for this study. At points, other versions of the above abbreviation may be used to reflect differences in how other researchers bounded their samples (for example, LGB, LGBTQ). For precision, because of the focus on sexual identity rather than gender identity, T (standing for transgender) will generally not be included in the acronym, but, at points, is included when intended to refer to the broader LGBTQ community.

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Social attitudes toward sexual minorities have grown increasingly supportive in the United States in recent years (*18*, *19*), but sexual prejudice persists on college campuses across the nation (*20*). Great strides have been made in the arts, humanities, and social sciences to bring LGBQ voices and lives into the curriculum as a way to improve the climate, but the culture within STEM remains resistant to discussions of inequality. Practitioners within STEM fields tend to ascribe to an ideology of depoliticization, or one that frames questions of inequality as tangential to STEM work and irrelevant to technical expertise (*8*). As a result, hostile experiences tend to be overlooked as isolated incidents rather than systemic problems, leading to "chilly" or overtly hostile climates for sexual minorities in STEM degree programs (*21*–*23*). In one study, LGB engineering students reported feeling alienated within their degree programs as a result of compartmentalizing their personal and academic experiences in response to hostility from their classmates (*21*). A second study determined that, in addition to open hostility, perceptions and beliefs about masculinity enacted by predominantly male engineering students demonstrate discomfort with sexual minorities and contribute to this climate (*22*). A third study of computing majors at one university demonstrated that LGB students were less likely to persist in the major than their heterosexual peers, which was attributed to their feeling a lower sense of belonging (*23*). Together, one could reasonably predict that sexual minority STEM students persist in these majors at lower rates than their heterosexual peers.

One factor that has shown to make a difference in retention for both LGBQ and STEM students is mentoring and support from faculty. For sexual minority students, LGBQ faculty and staff serve as confidants and sources of support, especially for students who feel incredibly uncomfortable disclosing information about their sexual orientation to others (*24*, *25*). Frequent, high-quality interactions with faculty increase STEM students' chances at persisting in the major as well (*26*–*28*), particularly through working on a faculty member's research projects either individually or through formal participation in undergraduate research programs (*17*). However, LGB faculty in STEM also report encountering a hostile climate similar to their students (*16*), and thus, many feel a need to keep information about their sexual orientations private (*29*). That said, science and engineering faculty who have disclosed their sexual minority status reported doing so as a way to serve as mentors to LGB students (*29*) and may be more likely than faculty in other disciplines to be open with and out to their colleagues (*16*).

For STEM students, a second factor that positively affects their persistence is their identification with STEM (*17*, *30*). Science or engineering identity (referred to as STEM identity henceforth) increases students' motivation to pursue a STEM career and their sense of belonging in the field (*31*–*33*). STEM identity reflects the importance of demonstrating competence through one's contributions to the field, being recognized by others as member of the field, and performing disciplinary work (*31*). Several experiences in college contribute to undergraduates' sense of STEM identity, but most especially undergraduate research experiences. These authentic laboratory experiences socialize students into the norms and practices of STEM research (*34*, *35*), helping them develop science or engineering identity that improves their likelihood of persistence in STEM degree programs. These experiences have been particularly demonstrated to increase the persistence of students from underrepresented groups (*36*), especially when the altruistic value of research is emphasized in the laboratory setting (*37*, *38*). Students who participate in these experiences are also more likely to persist to degree completion and pursue graduate study or careers in STEM (*17*, *30*, *39*). However, these settings may also be locations where the gendered nature of STEM culture is experienced, which has been shown to contribute to a chilly or hostile climate for LGBT students (*21*).

RESULTS

This study used a national, longitudinal data set of 4162 STEM-aspiring college students across 78 different institutions to determine whether status as a sexual minority predicted a lower likelihood of retention in a STEM major by the fourth year of college. The data were taken from the 2011 administration of the annual Freshman Survey (TFS) and the 2015 follow-up College Senior Survey (CSS), both administered by the Cooperative Institutional Research Program (CIRP) within the Higher Education Research Institute (HERI) at the University of California, Los Angeles (UCLA). Student responses to the CSS are matched to their initial responses on the TFS to examine change over 4 years of college. Students who expressed an aspiration to a STEM major in their first year were included in the sample; fourth-year major was then used to determine whether these students persisted in STEM or had switched to a non-STEM major. The set of majors classified as STEM followed the scheme used by researchers at HERI (*17*) and is provided in table S1. This scheme generally follows the Department of Education, but notably excludes the social sciences and includes nursing along with other health-related fields.

Figure 1 displays the overall percentage of STEM aspirants retained after 4 years, as well as disaggregated by sexual minority status. Approximately 70% of STEM aspirants were still enrolled in a STEM major at the end of their fourth year of college. The cross-tabulation between STEM retention and sexual minority status was significant, $\chi^2(1) = 4.433$, $P < 0.05$. Of the heterosexual students, 71.1% had been retained in STEM, slightly above the average, whereas 63.8% of the sexual minority sample was retained, a difference of about 8 percentage points between these groups.

Several items from the CSS instrument were used to examine student experiences that increase the likelihood of retention in STEM, and descriptive tests were used to determine whether participation in these experiences differed significantly by sexual minority status. The only experience that differed significantly between heterosexual and sexual minority students was participation in undergraduate research: 49.4% of sexual minority STEM aspirants reported having participated in undergraduate research, whereas 41.1% of heterosexual STEM aspirants had $\chi^2(1) = 5.818$, $P < 0.05$. This difference was also confirmed with a multilevel, multivariate regression model, as presented in table S2; sexual minority status remained a significant predictor of research participation controlling for a number of other predictors including precollege academic preparation and motivation for entering STEM. Expecting a heteronormative environment, sexual minority students who enter STEM may be more committed to STEM fields than their heterosexual peers, which would explain the difference in research participation. Regardless, undergraduate research tends to be one of the most significant contributors to STEM retention (*17*), yet sexual minority students are still less likely to be retained in STEM.

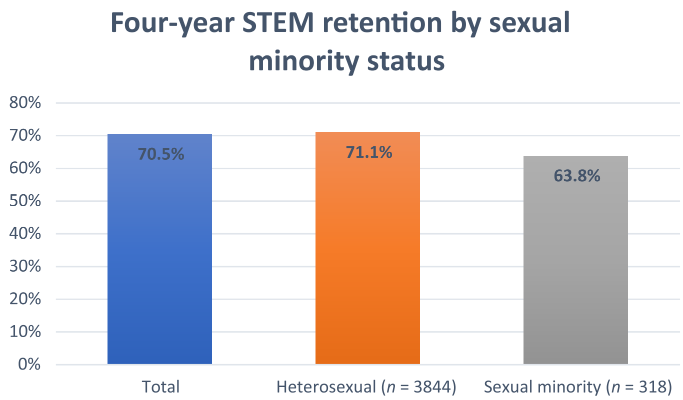

Fig. 1. Proportion of students who aspired to a STEM degree at college entry, in 2011, and who also indicated a STEM major at the end of their fourth year, in 2015, in total and disaggregated by sexual minority status.

Multilevel, multivariate modeling [hierarchical generalized linear modeling (HGLM)] was then used to isolate the unique variance shared between sexual minority status and retention in STEM, and the full results of the final model are presented in table S3. In the final model, sexual minority status remained a significant predictor of STEM retention after several key confounding factors were accounted for. Lesbian, gay, bisexual, and queer students were 9.54% less likely to be retained in STEM than their heterosexual peers, net of other experiences. That is, sexual minority STEM aspirants who are similarly positioned to succeed in STEM as their heterosexual counterparts are still less likely to be retained to the fourth year. The *t* ratio was even larger than that for gender, suggesting that sexual minority status to be a stronger predictor of STEM retention than gender.

Undergraduate research participation increased a student's likelihood of being retained in STEM by 13.46%, the largest delta *P* value for any variable in the data set. This finding on its own is not surprising, as the vast body of literature on research participation consistently demonstrates an effect on retention, degree completion, and pursuit of graduate study in STEM. Coupled with the descriptive finding that LGBQ students were nearly 10 percentage points more likely to participate in undergraduate research than their heterosexual peers, one may infer that LGBQ students would be even less likely to be retained in STEM were it not for this difference. An interaction term between sexual minority status and undergraduate research participation was tested to see whether the effect of undergraduate research participation on retention differed by group, but this interaction term was not significant.

STEM identity seems to be the strongest predictor of retention in STEM. The variable with the largest *t* ratio was the personal importance of making a theoretical contribution to science, an indicator of STEM identity, which increased a student's likelihood of being retained in STEM by 13.25%. Several background characteristics and precollege experiences also predicted a student's likelihood of being retained in STEM. All else being equal, having a parent employed in a STEM field increases a student's likelihood of being retained in STEM by 4.23%, and higher high school grade point averages and standardized test scores predicted a higher probability of retention in STEM as well. Women, unsurprisingly, were 5.66% less likely to complete a STEM degree than men, consistent with previous research (*17*, *40*). As it has been previously postulated that heterosexist stereotypes in STEM disadvantage sexual minority men more than sexual minority women (*21*), an interaction term between sex and sexual minority status was tested. This interaction term was significant: sexual minority men's expected probability of retention in STEM was lower than that for heterosexual men (0.45 versus 0.54), whereas sexual minority women's expected probability exceeded that of heterosexual women (0.39 versus 0.32). An interaction term between race and sexual orientation was also tested to determine whether race and sexual orientation together affect retention differentially, but the interaction term was not significant.

DISCUSSION

Previous research on LGBT students in STEM fields have suggested that these students would be retained in STEM at rates lower than their heterosexual peers (*21*–*23*, *41*); this study has supported this hypothesis with a national, longitudinal sample of students. Descriptively, 8% fewer sexual minority students were retained in STEM fields than their heterosexual peers after 4 years in college, and this likelihood increases to nearly 10% when controlling for other factors that support retention in STEM. Previous studies have also posited that factors that create a "chilly" climate for women in STEM also affect sexual minority students because of the relationship between gender stereotypes and sexual orientation (*21*, *22*). As both sex and sexual minority status were significant negative predictors of retention in the final model, the findings of this study point to a further need to address the climate in STEM around gender.

It was unsurprising that undergraduate research participation affected students' likelihood of STEM retention to a great extent, as prior research has well established the positive impact of undergraduate research participation on various desired STEM academic outcomes (*17*, *30*, *34*, *35*, *39*). What was surprising was that sexual minority STEM aspirants participated in undergraduate research at higher rates, but were still less likely to be retained to the fourth year. This finding implicates STEM faculty development around recruiting and mentoring students in their laboratory environments. First, future research should compare participation in structured undergraduate research programs with participation in research with faculty outside these programs. The case may be that sexual minority students gravitate toward structured programs, as they may be less likely to be mentored by faculty in heteronormative STEM disciplines. Second, faculty should remain cognizant about the biases and assumptions they make about students in their courses and laboratories. Programs like Safe Zone trainings and oSTEM (Out in Science, Technology, Engineering, and Mathematics) club chapters can help raise the visibility of queer issues in STEM to address these assumptions and provide a sense of community for LGBQ STEM students and faculty. That said, STEM educators should be encouraged that sexual minority STEM aspirants are participating in undergraduate research at higher rates—nearly one in two students in this study had—and perhaps assess these experiences in relation to the broader climate in STEM.

These findings were especially significant given the exclusion of students who had not been retained in STEM, because the sample only included students who had completed both surveys. An examination of the factors affecting the attrition of sexual minority STEM aspirants from higher education is warranted because students who leave higher education altogether differ from those who switch into non-STEM majors (*42*). Faculty, however, may more readily interpret attrition as resulting from poor academic preparedness rather than poor fit with STEM. STEM aspirants who are still enrolled in college after 4 years, but have chosen to switch to a non-STEM major, most likely switch out of STEM due to a poor fit in terms of the climate and culture in STEM (*43*). In this study, the difference in persistence between sexual minorities and heterosexuals is still observed after controlling for differences in precollege academic preparation and experiences in college that research demonstrates contribute to success in STEM, suggesting that nonacademic factors are contributing to these decisions. Research has long demonstrated that students from backgrounds underrepresented in STEM who are as academically prepared as, or even more prepared than, their peers leave STEM at higher rates (*17*, *43*). This study confirmed these findings for sexual minority students in addition to women and students from underrepresented racial and ethnic groups.

Increasing diversity in the STEM workforce is critical to fostering creativity and innovation (*1*), and the underrepresentation of STEM professionals from historically marginalized groups undermines this goal. This study extended work on diversity in STEM to lesbian, gay, bisexual, and queer students, a group that has until recently been mostly overlooked in the literature. By broadening how diversity is conceived in STEM, STEM degree programs can better develop the talents of future researchers and practitioners, bringing a wider range of perspectives to the field and reversing the effects of past exclusion of people underrepresented and marginalized in STEM.

MATERIALS AND METHODS

Data Source and Sample

The data for this study were gathered from the 2015 administration of the annual CSS developed and run by the HERI at UCLA. 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 TFS. For this study, student responses to the 2015 CSS were matched to their responses to the 2011 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. Both 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.

Variables

Table S4 provides a list of all variables included in the HGLM along with coding. The dependent variable was a dichotomous variable indicating whether students indicated a STEM major on the CSS. Because 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 whether they had at any point switched into a non-STEM major within that period.

The primary independent variable tested in the model was whether students reported identifying as a sexual minority (for example, gay, lesbian, bisexual, queer) on the CSS. HERI added sexual orientation demographic items to their surveys in 2015, which made this administration the first to include the item, and taking the item as reported on the CSS rather than the TFS captured students who had begun identifying as a sexual minority during college as well as prior. A host of control variables were then selected as informed by the literature on STEM retention as well as a college persistence conceptual framework used to understand factors that affect student persistence beyond the first year of college (*44*). Descriptive statistics for all variables are presented in table S5. Variables were grouped according to the temporal order in which they are hypothesized to influence retention in STEM: background demographics and characteristics, precollege academic performance, institutional differences (level 2 variables), self-concept and expectations before college, and college academic and social experiences previously demonstrated to influence STEM persistence.

A second analysis was run to test whether sexual minority status predicted likelihood of participation in undergraduate research, controlling for other factors that might confound this relationship. For this second analysis (presented in table S2), the regression model used was similar to the model described above with the exception that undergraduate research participation was included as the dependent variable, not an independent variable, and STEM retention was not included in this model.

Analysis

The primary analysis used for this study was HGLM. HGLM is used when the dependent variable is a dichotomous categorical variable, such as logistic regression, but also accounts for data that are "nested" in structure, or the individual cases belong to larger shared groups. 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 (*45*). 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.

That said, multilevel modeling is only necessary when the percentage of variance at level 2 is a large enough proportion of the overall variance in the dependent variable, and when the level 2 variance component is statistically significant (*46*). When these conditions are met, the groups are different enough to require multilevel modeling. Thus, two steps were taken to determine the appropriateness of HGLM for this analysis. First, the intraclass coefficient (ICC), which indicates the proportion of variance shared among groups, was computed for the model and found to be 0.098, meaning 9.8% of the variance is shared at level 2. One recommended standard to determine the warrant for multilevel modeling is 5% (*46*), which the computed ICC exceeds. Second, a χ^2 test was used to determine whether variance at level 2 is statistically significant from 0 or the multilevel structure of the data is nonignorable. The level 2 variance component was significant, $\chi^2(76) = 284.83$, $P < 0.001$.

Several steps were taken to improve interpretability of the model parameters. First, all continuous and ordinal variables were grand mean–centered, which means that the overall grand mean for each variable was subtracted from the value for each case. Grand mean centering means the intercept can be interpreted as the average expected value for the outcome variable, and the coefficients represent the average effect of the independent variable on the dependent variable (*45*). Second, delta *P* statistics were calculated for all significant coefficients (*47*, *48*). 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. Last, expected probabilities were computed to illustrate the interaction between gender and sexual minority status in predicting STEM retention. Expected probabilities were computed using the mixed form of the multilevel regression equation (see Supplementary Materials for the explanation of the statistical model). All parameters were set to 0 with the exception of the coefficients for gender, sexual minority status, and the interaction term. The appropriate value based on variable coding was used to compute expected probabilities for each of the four groups (for example, for sexual minority women, gender was 2, sexual minority status was 2, and the interaction term was set to 4).

The final HGLM is presented in table S3, but successive models were run to examine whether including any specific group of variables in the model caused the primary independent variable to lose significance. The first model tested only sexual minority status, and then models were run in a hierarchical fashion to add each set of control variables to the overall model. Sexual minority status never lost significance in any step. After the final model was run, two interaction terms were tested to determine whether sexual minority status interacted with another variable to predict STEM retention as well. These terms tested interactions between sexual minority status and participation in undergraduate research as well as sex. Interaction terms were tested separately in different models controlling for all other independent variables. The results of these tests are also reported in table S3, although the reported coefficients for the main effects for each variable in the model are those from the final model excluding interaction terms—the interaction terms correlate strongly with both variables used to develop these terms, meaning multicollinearity problems could adversely affect interpretation of other coefficients when interaction terms are included in the model.

In addition to HGLM, descriptive statistical tests were used to examine group differences in STEM retention rate as well as two significant factors from the model: sex and participation in undergraduate research. Cross-tabulations with χ^2 tests of significance were used to test these differences because all variables included were categorical dichotomous variables. χ^2 tests of significance are sensitive to sample size (*49*), so to avoid committing type I statistical errors, as the full sample is 90% or more heterosexual, a stratified random sample of heterosexual students similar in size was compared to the full sample of sexual minority students. The percentages reported are from the full sample, but significance tests were run using the subsample of heterosexual students and the full sample of sexual minority students.

SUPPLEMENTARY MATERIALS

Supplementary material for this article is available at http://advances.sciencemag.org/cgi/content/full/4/3/eaao6373/DC1

Supplementary Text

table S1. List of STEM majors.

table S2. Hierarchical generalized linear model predicting likelihood of participation in an undergraduate research experience (n = 4162).

table S3. Hierarchical generalized linear model predicting likelihood of persistence in a STEM degree after 4 years (n = 4162).

table S4. List of all variables included in modeling and respective coding.
table S5. Descriptive statistics for all variables included in HGLM.
Reference (*50*)

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