LGBTQ Inequality in Engineering Education

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Abstract

Background Researchers over the past three decades have documented processes of gender and racial/ethnic inequality in engineering education but little is known about other axes of difference, including the experiences of lesbian, gay, bisexual, transgender, and queer (LGBTQ) persons in engineering. Despite growing interest in LGBTQ inequality generally, prior research has yet to systematically document day-to-day experiences of inequality in engineering education along LGBTQ status.

Purpose/Hypothesis In this article, we use survey data from students enrolled in eight universities to examine LGBTQ inequality in engineering education. Specifically, we explore whether LGBTQ students experience greater marginalization than their classmates, whether their engineering work is more likely to be devalued, and whether they experience more negative health and wellness outcomes. We hypothesize that LGBTQ students experience greater marginalization and devaluation and more negative health and wellness outcomes compared to their non-LGBTQ peers.

Data/Method We analyzed novel survey data from 1,729 undergraduate students (141 of whom identify as LGBTQ) enrolled in eight U.S. engineering programs.

Results We found that LGBTQ students face greater marginalization, devaluation, and health and wellness issues relative to their peers, and that these health and wellness inequalities are explained in part by LGBTQ students' experiences of marginalization and devaluation in their engineering programs. Furthermore, there is little variation in the climate for LGBTQ students across the eight schools, suggesting that anti-LGBTQ bias may be widespread in engineering education.

Conclusions We call for reflexive research on LGBTQ inequality in engineering education and the institutional and cultural shifts needed to mitigate these processes and better support LGBTQ students.

Keywords sexual orientation; transgender; bias; inclusion; engineering culture

Introduction

A growing interdisciplinary group of scholars has called attention to the persistent patterns of bias and discrimination within engineering education. Despite the energy and resources put toward advancing diversity and the discipline's formal commitment to equality and inclusion, women and many racial/ethnic minority groups continue to be underrepresented and frequently encounter disadvantageous treatment in engineering education (Blair, Miller, Ong, &

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Zastavker, 2017; Brown, Morning, & Watkins, 2005; Cech, Rubineau, Silbey, & Seron, 2011; Foor, Walden, & Trytten, 2007; Leslie, McClure, & Oaxaca, 1998; National Science Foundation, 2009; Ohland et al., 2011). Prior research has found that these demographic patterns are the result of both structural and cultural processes in engineering education that systematically disadvantage women and students of color (Blair et al., 2017; Brown et al., 2005; Cech, 2013; Foor et al., 2007; Ohland et al., 2011; Samuelson & Litzler, 2015).

Despite these important advancements in understanding the foundations of gender and racial/ethnic inequality in engineering, far less attention has been paid to the ways this disadvantage may manifest along other demographic categories, particularly those not always immediately visible or recognizable (Cech & Rothwell, in press). One potentially ubiquitous but underresearched axis of disadvantage is the possible stigmatization and discrimination of persons who identify as nonheterosexual or whose gender identity differs from their sex assigned at birth. Despite recent cultural and legal advancements toward increased inclusion of lesbian, gay, bisexual, transgender, and queer (LGBTQ) persons (Sears & Mallory, 2011), bias and discrimination toward LGBTQ individuals is pervasive across the United States as a whole (Doan, Loehr, & Miller, 2014; Herek, 2007; Ragins, 2008) and in academic institutions specifically (Bilimoria & Stewart, 2009; Patridge, Barthelemy, & Rankin, 2014). LGBTQ persons lack even basic formal employment protections in more than half of this country's states (HRC, 2017), and LGBTQ employees experience systematic biases in the science and engineering workforce and beyond (Cech & Pham, 2017; Hebl, Foster, Mannix, & Dovidio, 2002; Tilcsik, 2011). Although recent attention has been paid to the numeric underrepresentation of LGBTQ individuals in STEM fields (Hughes, 2018), less is understood about the everyday experiences of bias that sexual minority, transgender, and gender nonbinary students face prior to entering the workforce. Focusing on the experiences of LGBTQ students in engineering education allows us to better understand how processes of bias are perpetuated beyond typically visible markers of difference such as gender and race/ethnicity, analyzing not only whether such inequalities exist but what types of everyday experiences in engineering education may be impacted by anti-LGBTQ bias. To address these issues, this study explores how LGBTQ persons fare in U.S. engineering education and the types of disadvantage, if any, they encounter in their day-to-day experiences in their engineering programs, compared to their non-LGBTQ classmates.

The initial research in this area reviewed below suggests that anti-LGBTQ bias flourishes in engineering education and may be fostered not only by the prejudicial behaviors and attitudes of individual students and faculty but also by assumptions and practices embedded in the professional culture of engineering itself (Cech & Waidzunas, 2011; Hughes, 2017; Riley, 2008; Yoder & Mattheis, 2016). This pioneering research suggests that LGBTQ identity may be a powerful differentiator of student experience in engineering education and that LGBTQ-identifying students may face negative experiences not shared by their classmates. However, due to data and access limitations related to the size of the LGBTQ population and its absence in institutional record-keeping, research to date has not yet been able to systematically investigate possible disadvantages in the day-to-day experiences of engineering students across LGBTQ status. Such investigation is vital for advancing scholarly knowledge about inequality in engineering and promoting policy changes that could improve the experiences of LGBTQ students. Absent a direct non-LGBTQ comparison group, skeptics of prior research on LGBTQ students' experiences may argue that there is nothing "special" nor disadvantageous about these experiences in engineering education and any experiences of marginalization

documented in research on LGBTQ-only samples are simply characteristic of the engineering education experience itself.

Using novel survey data from more than 1,700 students across eight U.S. engineering education programs, this research compares the day-to-day experiences of LGBTQ-identifying students with their non-LGBTQ classmates in the same engineering programs. Such a comparison provides an unprecedented opportunity to examine whether LGBTQ students are indeed systematically disadvantaged in engineering and to explore the various ways such inequality may manifest itself.

We examined three areas of potential disadvantage: informal interactional experiences, (de)valuation, and personal health and well-being. Specifically, this study asked: Do LGBTQ students experience greater marginalization from classmates and peers than other students? Are they more likely than their non-LGBTQ classmates to report that their engineering work is devalued? Do LGBTQ students experience more negative health and well-being outcomes than their classmates? Are these more negative health and wellness outcomes partly the result of LGBTQ students' experiences of marginalization and devaluation in their engineering programs? The analyses that follow indicate that LGBTQ students do indeed experience systematic marginalization and devaluation in their engineering programs, and that these experiences, in turn, foster more negative health and wellness outcomes for LGBTQ students. We also found little systematic variation in these disadvantages by school, suggesting that these biases may be a feature of the culture of engineering education more broadly rather than just an artifact of one or two particularly biased school contexts.

Beyond documenting these patterns of disadvantage for LGBTQ engineering students, this study advances theory on inequality in engineering by highlighting how heteronormativity, homophobia, and transphobia, in addition to the sexism and racism documented by prior research, may be embedded in the culture of engineering education across engineering programs and colleges in the United States. This investigation also illustrates how everyday marginalization and devaluation not only impact students' social and academic experiences but also affect students in deeply personal, health-related ways. Finally, because engineering education is a place where neophyte engineers learn the cultural norms and dominant professional identities of engineering (Cech, 2015; Dryburgh, 1999), LGBTQ disadvantages, to the extent that they are built into the cultural norms and practices of engineering training, may accompany engineering graduates into the workforce and perpetuate anti-LGBTQ biases there as well.

Background

Inequality in Engineering Education

Researchers have argued that differential persistence in engineering education by demographic category, especially along racial/ethnic and gender lines, is largely the outcome of underrepresented groups' disadvantageous experiences in their engineering education programs (Brown et al., 2005; Foor et al., 2007). These disadvantages include unequal educational opportunities, uneven mentoring, and status biases and stereotypes perpetuated by classmates and professors (Archer et al., 2013; Cech et al., 2011; Cheryan, Siy, Vichayapai, Drury, & Kim, 2011; Moody, 2004; Turner, 2002). Nondominant groups in engineering education are often less likely to feel as though they belong in engineering fields compared to their white male counterparts (Dryburgh, 1999; Foor et al., 2007; Zambrana et al., 2015).

These disparities are not just the result of encounters with a select few overtly prejudiced students or faculty; rather biases are frequently built into the informal, interactional practices of

engineering programs. Members of underrepresented groups commonly report experiencing a chilly climate in their engineering programs, where subtle biases are part of the assumptions and taken-for-granted habits of members of their departments. This climate impacts which students are considered the smartest and most capable and who is included in study and lab groups, extracurricular gatherings, and student clubs (Leslie et al., 1998; Tonso, 1996).

Beyond individual and interactional processes in particular programs, prejudicial practices and ideologies are built into the professional culture of engineering, spanning both engineering education programs and the U.S. engineering workforce more broadly (Cech, 2014). Professional cultures are historically rooted meaning systems built into and around the characteristic tasks and knowledge of a profession (Abbott, 1988). Biases built into professional cultures may serve as particularly insidious mechanisms of disadvantage as these cultural processes are typically less overt and, thus, often go unnoticed and unaddressed (Cech, 2013).

A particularly relevant aspect of engineering culture for our investigation is the cultural emphasis on disengagement, that is, the devaluation of public welfare, social justice, and inequality concerns as tangential to "real" engineering work. Disengagement frames the way neophytes learn how to define the scope of their professional responsibilities and how to accomplish the day-to-day tasks of engineering (Cech, 2014). Three ideological tenets underlie this cultural emphasis on disengagement: depoliticization, or the assumption that "objective" engineering work can and should be separate from issues seen as political or social (Cech & Sherick, 2015; Cech & Waidzunas, 2011; Faulkner, 2007; Wynne, 1992); technical/social dualism, or the privileging of technical skill and competence and the devaluation of social considerations like inequality (Faulkner, 2007); and the meritocratic ideology, or the belief that professional success is due to hard work alone and those who fail are solely responsible for their own outcomes (Cech, 2013; Cech & Waidzunas, 2011; McCall, 2013). Because this cultural feature of engineering frames concerns about sociodemographic inequality as irrelevant to the core concerns of the engineering profession, it can aggravate feelings of isolation and devaluation and diminish the sense of belonging for disadvantaged group members within engineering education (Cech, 2014; Cech & Waidzunas, 2011; Foor et al., 2007).

Although research has documented how processes at the interactional, departmental, and professional cultural levels foster negative experiences for women and racial/ethnic minorities in engineering education, much less is known about the experiences of LGBTQ students. Researchers understand little about how their experiences in their engineering education programs differ from those of their non-LGBTQ-identifying peers and the effects that these experiences have on LGBTQ students' general well-being. Some recent scholarship has begun to unpack the experiences of LGBTQ students in engineering. We next review this literature and then provide the hypotheses we investigated using these data.

Engineering Education and Anti-LGBTQ Bias

The devaluation of sexual minorities and transgender and gender nonbinary persons can result from processes that operate at multiple levels. Heterosexism, an anti-LGBTQ bias that operates at the macrolevel, includes policies, practices, and cultural ideologies that privilege heterosexuality and cisgender status and promote social biases against sexual minorities and noncisgender persons (Kitzinger, 2005). Institutional-level heterosexism might include university policies that exclude same-gender partners from health-care benefits or electronic records systems and that prevent students from changing their preferred gender pronouns. Heteronormativity encompasses more subtle interpersonal and institutional beliefs, such as assumptions that heterosexuality is the most acceptable sexual orientation and that there are

two mutually exclusive, biologically determined sexes (Herek, 2007). At the microlevel, heteronormativity and heterosexism take the form of sexual prejudice and transphobia, or prejudicial attitudes and behaviors that individuals exhibit on the basis of others' actual or presumed sexual orientation or gender expression (Herek, 2007). Transphobia (anti-transgender and gender-nonconformity bias) is tightly linked to bias against nonheterosexual persons as transphobia rests on the belief that there are two natural and complimentary sexes and that heterosexuality is a natural feature of biological sex categories (Schilt & Westbrook, 2009; Westbrook & Schilt, 2014). The devaluation of LGBTQ persons may be especially heightened in engineering contexts. In a sample of LGBTQ and asexual (LGBTQA) identifying individuals in STEM, for example, Yoder and Mattheis (2016) found that LGBTQA individuals in engineering report lower degrees of openness about their status with their colleagues and students than those in other STEM fields.

Early research suggests that heteronormativity, heterosexism, sexual prejudice, and transphobia may be pervasive in engineering and engineering education (Cech & Pham, 2017; Cech & Waidzunas, 2011; Hughes, 2017; Yoder & Mattheis, 2016). For one, sexual minorities have lower persistence in STEM fields such as engineering than heterosexual students (Hughes, 2018). In addition, existing research suggests that LGBTQ engineering students face both overt forms of heteronormativity, transphobia, and sexual prejudice, including blatant anti-LGBTQ sentiments, and more covert forms of bias such as the presumption that all engineering students are heterosexual and cisgender and the silencing of sexual minority and transgender student concerns. This pervasive heteronormativity within engineering education programs appears to foster an educational culture where LGBTQ persons may have more trouble developing an "engineering identity" (Hughes, 2017) and feel as though they must work harder to compensate for their sexual identity to be seen as competent engineering students (Cech & Waidzunas, 2011).

As a result, LGBTQ students in engineering may adopt tactics of passing, covering, and compartmentalization to navigate engineering spaces where they feel their LGBTQ status is devalued or stigmatized (Cech & Waidzunas, 2011; Yoder & Mattheis, 2016). Passing is a tactic where individuals hide their stigmatized identities, such as sexual minorities who work to be seen as straight by others (Yoshino, 2006). Going "stealth" is a form of passing preferred by some transgender individuals who take pride in a successful gender transition and do not openly identify as transgender (Schilt, 2010). Covering is similar to passing, but refers to a practice where individuals may be open about their LGBTQ status to most people but minimize the salience of the traits associated with their stigmatized identity (Goffman, 1963; Yoshino, 2006). For example, LGBTQ students who use the tactic of covering might conceal markers of their LGBTQ identity such as avoiding conversations about romantic or sexual relationships, leisure activity preferences, or gender expression practices. Related, compartmentalization is a tactic where LGBTQ individuals maintain strict separation of their personal lives (where they may be open about their LGBTQ status) from their professional lives at school. Although these tactics may help LGBTQ students circumvent stigma and discrimination in their educational programs, they burden them with additional emotional and academic issues their non-LGBTQ peers do not face and may amplify feelings of social and academic isolation (Cech & Waidzunas, 2011).

The Purpose of This Study

Although previous research suggests that LGBTQ engineering students face marginalization that their classmates may not, due to data limitations, research to date has not been able to isolate how these processes vary across LGBTQ status. This study was able to examine the experiences of LGBTQ students in engineering education programs controlling for other

demographic characteristics such as race/ethnicity and socioeconomic status that may also affect experiences of marginalization and devaluation. Furthermore, we do not yet know how extensively these disadvantageous experiences in engineering education programs might impact students. To address these gaps, this study examined how processes of marginalization and devaluation translate into deeply personal consequences such as stress, insomnia, and emotional health issues.

Drawing on the literature reviewed above, we offer several hypotheses. First, based on research suggesting that LGBTQ engineering students feel excluded by their peers, we expect that LGBTQ respondents in our sample will be more likely than their non-LGBTQ peers to experience marginalization; that is, to feel isolated from other students and less likely to feel secure participating in informal interactions with their classmates. Second, beyond social exclusion, we expect that LGBTQ students will be less likely to report that their engineering abilities are respected by their peers and teachers or to feel comfortable working in teams with other students.

Third, we anticipate that students may be affected personally and deeply by heteronormativity, heterosexism, and transphobia in their engineering education programs, resulting in negative outcomes for their health and wellness. Specifically, compared to their peers, LGBTQ students may more frequently experience exhaustion, stress, predepressive symptoms, and sleeping problems. This outcome would be consistent with research showing that health and wellness for LGBTQ individuals are frequently impacted by the cultural and structural circumstances in which they are embedded (Solazzo, Brown, & Gorman, 2018).

However, these analyses only indicate whether LGBTQ students report more negative health and wellness outcomes than their peers; they do not tell us if such differentials are driven by LGBTQ students' more negative experiences in their engineering program or by unrelated personal experiences outside of school. To examine this directly, we conducted mediation analyses to determine whether LGBTQ students' experiences of marginalization and devaluation in their departments help explain why they are more likely to report more negative health and wellness outcomes. Significant mediation effects would indicate that LGBTQ students' experiences with marginalization and devaluation in their engineering programs impact them more deeply than just their social experiences and coursework.

Finally, we are interested in whether LGBTQ bias is isolated to only a few engineering programs or whether it seems to be widespread across the culture of engineering education more broadly. Based on the literature cited previously, which suggests that anti-LGBTQ bias may be part of the culture of engineering education generally (Cech & Waidzunas, 2011; Hughes, 2017), we hypothesized that participants will rate the climate of their engineering programs for LGBTQ students similarly across the schools in the sample. Significant school effects would indicate that the climate for LGBTQ students in engineering education varies from school to school, suggesting that the differences found in testing the first three hypotheses may be driven by the results from a handful of particularly heterosexist or transphobic engineering programs. Few differences across schools, on the other hand, may suggest that LGBTQ bias is not isolated to only certain schools but is part of the culture of engineering education generally.

Methods

The ASEE Diversity and Inclusion Survey was fielded in Spring 2016 to undergraduate engineering students enrolled in eight engineering programs in the United States. These programs were identified through an initial survey of U.S. engineering deans and program

directors in Fall 2015 (for details, see Cech, Waidzunas, & Farrell, 2016). Ninety deans and program directors participated in this survey, with 23 agreeing to be contacted to discuss the possibility of surveying the engineering students and faculty in their programs. Of these, eight deans agreed to send survey links to undergraduate students in their engineering programs. Given this selection process, we expect that the engineering programs in our sample are more supportive of diversity and inclusion issues on average than schools in the United States generally as these deans or program directors expressed at least nominal concern for such issues by agreeing to include their programs in the study. As such, the patterns of disadvantage we identify here are likely conservative estimates of broader patterns, and engineering programs in the United States may have similar, if not more extreme, patterns of disadvantage on average than those reported here.

The survey asked students a broad range of questions about their experiences in their engineering classrooms, their perceptions of the engineering profession, and their more general experiences as college students. The invitation email mentioned LGBTQ status only briefly in conjunction with other axes of disadvantage: "This study will help engineering educators, scholars, university administrators, and national policymakers attempting to foster inclusion in engineering education programs for women, racial/ethnic minorities, and LGBTQ (lesbian, gay, bisexual, transgender and queer) students."

While we do not name the schools involved in the study to protect confidentiality, Table 1 provides a general description of the types of institutions included in the study. The sample size for each school ranged from 82 students (School 101) to 909 students (School 109) and response rates ranged from a low of 4% to a high of 45%, with an average of 17% across the eight schools (see Table 1). These rates are consistent with student survey research, which typically has response rates between 15% and 30% (National Survey of Student Engagement, 2016).

A total of 2,575 students began the survey, but we use only the 1,729 respondents who passed an attention filter question. Attention checks significantly improve the quality of the data by excluding respondents who are not reading the options carefully. For this survey, we included a check that was worded as follows: "As a consistency check, please choose 'Almost every day' for this question." Respondents choosing something other than this option were coded as having failed the attention filter (Oppenheimer, Meyvis, & Davidenko, 2009). Supplemental analyses were run with this full sample of 2,575 students and with models sequentially excluding the schools with the lowest response rates; these produced the same patterns of results as those presented here. The robustness checks section below reviews these supplemental analyses.

Dependent Measures

Marginalization measures We included five measures of the extent to which respondents feel marginalized by their classmates. The first two focused on how accepted they feel by their fellow students in their classes (1 = not accepted at all to 5 = very accepted) and if they are invited when their classmates get together outside of class (1 = strongly disagree to 5 = strongly agree). The remaining three measures asked how often in the last year they avoided a social event, felt the need to lie about their personal life, and stayed home from school because they felt unwelcome (1 = never to 5 = almost every day). Finally, we included a question about the extent to which respondents had read, heard, and/or seen insensitive comments. See Table A1 for precise question wording.

Table 1 Means and Standard Deviations for Independent and Dependent Measures for All Students and Separately by LGBTQ Status ($N = 1{,}729$)

	All		LGBTQ		Non-LGBTQ		
	Mean	SE	Mean	SE	Mean	SE	*p*
LGBTQ (yes = 1, no = 0)	0.087	0.007	–	–	–	–	
Hispanic (yes = 1, no = 0)	0.037	0.005	0.079	0.023	0.034	0.005	
Asian (yes = 1, no = 0)	0.120	0.008	0.122	0.028	0.120	0.009	
Black (yes = 1, no = 0)	0.034	0.005	0.014	0.010	0.036	0.005	
White (yes = 1, no = 0)	0.835	0.009	0.878	0.028	0.831	0.010	
Native American/Pacific Islander (yes = 1, no = 0)	0.017	0.003	0.017	0.012	0.017	0.003	
Other racial/ethnic group (yes = 1, no = 0)	0.018	0.003	0.014	0.010	0.018	0.004	
Woman (yes = 1, no = 0)	0.350	0.012	0.528	0.043	0.333	0.012	
SES (1 = working class to 5 = upper class)	2.564	0.032	2.698	0.109	2.554	0.033	
First-generation student (yes = 1, no = 0)	0.144	0.009	0.189	0.033	0.140	0.009	
Marginalization							
Accepted by students in department (1 = not accepted at all to 5 = very accepted)	3.544	0.017	3.335	0.064	3.563	0.017	***
Avoided social event (1 = never to 5 = almost every day)	2.036	0.026	2.524	0.104	1.991	0.027	***
Included in social gatherings (1 = strongly disagree [SD] to 5 = strongly agree [SA])	3.434	0.024	3.092	0.098	3.463	0.025	***
Hide personal life (1 = never to 5 = almost every day)	1.777	0.026	2.511	0.111	1.706	0.026	***
Offensive comments (1 = SD to 5 = SA)	2.567	0.034	3.137	0.127	2.516	0.035	***
Devaluation							
Treated as equally skilled student (1 = SD to 5 = SA)	3.997	0.020	3.762	0.076	4.017	0.021	***
Students respect engineering work (1 = SD to 5 = SA)	4.056	0.019	3.842	0.079	4.076	0.019	***
Avoided team or project (1 = never to 5 = almost every day)	1.967	0.029	2.510	0.106	1.918	0.030	***
Health and Wellness							
Exhausted from compartmentalization (1 = never to 5 = almost every day)	2.149	0.032	2.547	0.116	2.115	0.034	***
Nervous (1 = never to 5 = almost every day)	3.773	0.026	4.115	0.078	3.743	0.028	***
Depressed or sad at school (1 = never to 5 = almost every day)	2.444	0.032	3.072	0.113	2.386	0.033	***
Sleeping troubles (1 = never to 5 = almost every day)	2.552	0.030	2.871	0.107	2.524	0.031	**
LGBTQ students face veiled hostility (1 = SD to 5 = SA)	2.193	0.023	2.439	0.087	2.170	0.023	**
Colleagues condescending to LGBTQ students (1 = SD to 5 = SA)	2.744	0.028	3.053	0.101	2.716	0.029	**
Witnessed mistreatment of LGBTQ student (1 = yes, 0 = no)	0.092	0.008	0.359	0.043	0.067	0.007	***
Schools							
School 101: small, private school in the NE ($N = 82$, response rate [RR] = 18%)	0.029	0.004	0.022	0.012	0.030	0.004	

(Continued)

Table 1 Continued

	All		LGBTQ		Non-LGBTQ		
	Mean	SE	Mean	SE	Mean	SE	*p*
School 108: large, public flagship in the NE (*N* = 233, RR = 7%)	0.091	0.007	0.086	0.024	0.092	0.008	
School 109: small tech school in the Midwest (*N* = 909, RR = 45%)	0.359	0.012	0.439	0.042	0.350	0.013	*
School 110: large public in the NE (*N* = 128, RR = 4%)	0.044	0.005	0.072	0.022	0.042	0.005	
School 114: small Catholic school in the West (*N* = 215, RR = 30%)	0.101	0.008	0.129	0.029	0.098	0.008	
School 116: large public school in the South (*N* = 290, RR = 7%)	0.092	0.007	0.079	0.023	0.094	0.008	
School 117: large public flagship in the South (*N* = 620, RR = 11%)	0.238	0.011	0.101	0.026	0.251	0.011	**
School 120: mid-size public school in the NE (*N* = 98, RR = 8%)	0.046	0.005	0.072	0.022	0.043	0.005	

***$p < .001$; **$p < .01$; *$p < .05$ (two-tailed test).

Devaluation measures Devaluation of students' engineering work was measured using two questions that asked the extent to which their peers respect them for the work they do and whether they believe their engineering work is respected (1 = strongly disagree to 5 = strongly agree). To assess students' reactions to the social and intellectual devaluation they may encounter from peers in group work settings (see, e.g., Cech & Waidzunas, 2011), we also included a question that asked the extent to which they have avoided working with teams or on projects in their schoolwork (1 = never to 5 = almost every day). (See Table A1 for question wording.)

Health and wellness measures We used four measures to assess negative health and wellness outcomes. Specifically, we asked how frequently over the past 12 months respondents felt exhausted from keeping their personal and professional lives separate, had sleep issues that affected their performance, felt nervous or stressed, and felt unhappy or stressed at school (response ranges: 1 = never to 5 = almost every day). The latter two are often used in national studies as predepression and preanxiety indicators (e.g., the National Survey on Drug Use and Health conducted by the Substance Abuse and Mental Health Services Administration).

Engineering program climate questions Finally, we included three measures asking respondents to assess the climate in their engineering programs for LGBTQ-identifying students. The first two asked respondents to indicate the extent to which they agree that LGBTQ students in their programs are met with thinly veiled hostility (e.g., scornful looks or icy tone of voice) and that some faculty and students seem condescending toward colleagues who are LGBTQ (1 = strongly disagree to 5 = strongly agree). Third, we asked students if in the last 3 years they had been aware of instances in which students in their engineering/engineering technology classes had been treated negatively due to their sexual identity (1 = yes, 0 = no) or gender expression or transgender status (1 = yes, 0 = no). Students who indicated yes to either question were coded as yes on the aggregated measure of whether they had observed unfair treatment toward LGBTQ students.

Independent Measures

LGBTQ status is measured by a set of indicators that asked separately about students' sexual identity and gender expression. First, respondents were asked, "Please mark your sexual identity from the categories below" and could choose between the following options: "Heterosexual or straight," "Gay or Lesbian," "Bisexual," "Queer," "Don't know," or "Something else." Those who marked "Something else" were invited to specify with a text box. Anyone who marked "Gay or Lesbian," "Bisexual," or "Queer" for this question were included in our LGBTQ category. Because respondents who marked "Don't know," or "Something else" did not choose to identify with one of the categories in the LGBTQ acronym, we did not include them in the LGBTQ category.

Gender expression was measured with a set of three questions. The first question asked "What sex were you assigned at birth?" "Male" or "Female." The second question asked "How do you currently describe yourself?" "Male," "Female," "Transgender Male" or "Transgender Female," "Something else," or "I don't know." Respondents whose answer on the second question was different from their answer on the first were asked the following follow-up question: "Just to confirm, you were assigned a different sex at birth than how you currently describe yourself. Is that correct?" "Yes" or "No." This confirmation question limits the number of false positives for transgender or gender nonbinary identity—an important step for appropriately capturing proportionally small populations such as noncisgender individuals. Those who answered yes to this confirmation question were included in the LGBTQ category. Respondents who marked "something else" or "I don't know" in the current gender identity question were coded as "gender nonbinary" for their current gender category. Due to the very small proportion of respondents in this gender nonbinary category and the need to protect the confidentiality of respondents, we do not provide data as a separate category for gender nonbinary respondents. Instead, the indicator for "women" is contrasted against both the categories for men and gender nonbinary students in our models.

Students who indicated that their current gender identity is female (whether they are cisgender or transgender) were included in the category "women"; men who indicated their current gender identity as male (whether they are cisgender or transgender) were included in the category "men."

We also included several measures of other important demographic characteristics that may impact students' likelihood of experiencing marginalization and devaluation. We controlled for their racial/ethnic category (respondents could choose more than one): Hispanic, Black, Asian, Native American/Pacific Islander, White, and other racial/ethnic category (1 = yes, 0 = no). In addition, we controlled for respondents' self-report of the socioeconomic status (SES) of their family of origin: "working class" = 1, "lower-middle class" = 2, "middle class" = 3, "upper-middle class" = 4, and "upper class" = 5. We also controlled for first-generation college students by specifically asking if they were the first person in their immediate family (parents/guardians, siblings) to attend college (1 = yes, 0 = no). Finally, each model includes controls for school, with School 114 serving as the comparison category. Including these measures in our models allows us to identify the effect of LGBTQ status on marginalization, devaluation, and health and wellness measures holding constant possible variation by race/ethnicity, SES, first-generation status, and school.

Analytic Strategy

The analyses below used ordinary least squares (OLS) regression, ordered logistic regression, or logistic regression models as appropriate to predict each outcome variable of interest.

Table 1 below provides the means and standard errors for all respondents and for LGBTQ and non-LGBTQ students separately. Table 2 predicts the marginalization variables one at a time with LGBTQ identity and controls. Next, we predicted the devaluation measures (Table 3) and health and wellness measures (Table 4). To test for effects of marginalization and devaluation on the health and wellness measures, we utilized structural equation modeling (SEM). SEM is a useful empirical tool that allows us to test for indirect (mediating) effects; in other words, whether part of the statistical relationship between two factors (here, LGBTQ status and the health and wellness measures) can be explained by variation on a third factor (here, the marginalization or devaluation measures) (see Byrne, 2010). Table 5 presents the direct effects of LGBTQ status on health and wellness measures and the indirect effects of LGBTQ status on each health and wellness measure through each of the marginalization and devaluation measures.

Finally, to examine the extent to which the climate for LGBTQ persons varies by school, we ran OLS and logistic regression models to predict the climate measures by school and other demographic measures (Table 6). As is recommended practice, we used multiple imputation (MI) to handle missing data. Specifically, we used the MI chained technique in Stata 14 with 20 imputations for the OLS and ordered logistic regression models, and maximum likelihood with robust standard errors for the SEM models (Allison, 2001).

Results

Table 1, which lists the means and standard errors of each independent and dependent variable for all respondents and separately by LGBTQ status, shows approximately 8.7% ($N = 141$) of the sample identifies as LGBTQ. This percentage, while higher than the population-level estimates of college-educated Americans who identify as LGBTQ (2.8%, Gates & Newport, 2012), reflects a trend where a larger proportion of young adults identifies as LGBTQ than in previous generations (Risman, 2018).

Among our sample, 24% identify as a member of a racial/ethnic minority group, and 35% of respondents identify as women, 64% as men, and approximately 1% as gender nonbinary. While we include gender nonbinary respondents as part of the LGBTQ indicator, because of concerns about revealing the identities of participants in this small population, we do not include it as a dichotomous indicator in the models nor provide the precise percentage of the gender nonbinary population in Table 1. For this reason, the category "woman," which includes those who identify as cisgender and transgender women, is compared in the models to both men, which includes cisgender and transgender men, and gender nonbinary respondents.

Compared to national statistics on engineering students (National Center for Science and Engineering Statistics, 2015), our sample has proportionally larger representations of women (20% nationally, 35% here) and racial/ethnic minorities (13% nationally, 24% here). Fourteen percent of the sample are first-generation college students. There are no significant differences between LGBTQ and non-LGBTQ students along these demographic axes, meaning that gender and racial/ethnic diversity are similar for both groups of students.

The remaining rows in Table 1 present the means and standard errors for the outcome variables of interest and the proportion of the sample enrolled in each school. Suggesting a broad pattern of disadvantage, LGBTQ students have significantly more negative values on all of the marginalization, devaluation, and personal health and wellness measures, and are more likely to report negative LGBTQ climates in their engineering programs. The analyses

Table 2 OLS Regression Models Predicting Marginalization Measures with LGBTQ_Status and Controls ($N = 1{,}792$)

	Feel accepted by other students		Avoided a social event with classmates		Feel included in invitations to social gatherings		Felt the need to hide personal life		Stayed home from school b/c did not feel welcome		Seen or heard offensive comments in engineering spaces	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
LGBTQ_	−0.214 ***	0.057	0.503 ***	0.095	−0.330 ***	0.094	0.813 ***	0.093	0.318 ***	0.052	0.441 ***	0.117
Hispanic	−0.080	0.093	0.050	0.145	−0.078	0.141	−0.017	0.140	0.093	0.076	0.091	0.174
Asian	−0.154 **	0.059	0.219 *	0.088	−0.042	0.083	0.144	0.081	0.177 ***	0.049	0.056	0.105
Black	−0.220 *	0.091	0.149	0.154	−0.052	0.144	−0.095	0.149	0.095	0.082	0.131	0.191
Native American/ Pacific Islander	−0.035	0.137	0.184	0.206	−0.002	0.210	0.408 *	0.202	0.066	0.119	0.417	0.257
Other racial/ ethnic group	−0.277	0.143	0.051	0.199	−0.242	0.195	0.067	0.188	0.145	0.122	0.182	0.257
Woman	−0.124 ***	0.034	0.226 ***	0.056	−0.081	0.055	0.131 *	0.052	0.077 *	0.030	0.627 ***	0.069
SES	0.010	0.013	0.002	0.021	−0.016	0.021	0.005	0.020	−0.003	0.011	0.037	0.025
First-generation student	−0.010	0.049	0.010	0.076	−0.020	0.076	−0.060	0.072	0.060	0.041	0.008	0.093
School 101	−0.055	0.099	0.073	0.160	0.176	0.165	0.019	0.155	0.078	0.089	0.066	0.201
School 108	0.020	0.077	−0.110	0.114	−0.035	0.119	−0.077	0.112	−0.036	0.064	0.046	0.145
School 109	−0.038	0.064	−0.120	0.088	0.020	0.093	0.033	0.086	0.058	0.050	0.247 *	0.112
School 110	−0.155	0.090	0.053	0.143	−0.070	0.148	0.214	0.139	0.013	0.079	0.122	0.179
School 116	0.043	0.089	−0.278 *	0.111	−0.072	0.117	−0.133	0.108	−0.004	0.063	−0.204	0.140
School 117	0.018	0.065	−0.121	0.093	−0.054	0.099	−0.082	0.091	0.088	0.053	0.008	0.119
School 120	0.032	0.084	−0.273 *	0.138	0.003	0.145	−0.090	0.136	0.012	0.078	0.057	0.170
Constant	3.617 ***	0.067	1.990 ***	0.098	3.574 ***	0.103	1.659 ***	0.097	1.060 ***	0.056	2.105 ***	0.121

***$p < .001$; **$p < .01$; *$p < .05$ (two-tailed test).

School 114 is the comparison category for institution; White is the comparison category for race/ethnicity; men and gender non-binary are the combined comparison category for women.

Table 3 OLS Regression Models Predicting Devaluation Measures with LGBTQ Status and Controls

	Classmates treat me with respect		My work is respected		Avoided working with a certain team or on a certain project	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
LGBTQ	−0.195 **	0.073	−0.212 **	0.068	0.575 ***	0.100
Hispanic	−0.065	0.106	−0.013	0.104	−0.007	0.150
Asian	−0.112	0.062	−0.139 *	0.058	−0.004	0.093
Black	−0.031	0.114	−0.115	0.107	−0.171	0.155
Native American/Pacific Islander	−0.097	0.158	−0.153	0.151	0.451 *	0.223
Other racial/ethnic group	−0.326	0.167	−0.021	0.161	0.063	0.206
Woman	−0.255 ***	0.042	−0.153 ***	0.040	0.274 ***	0.060
SES	0.001	0.016	0.018	0.015	−0.018	0.023
First-generation student	−0.082	0.058	−0.016	0.054	−0.016	0.080
School 101	−0.155	0.123	−0.237 *	0.116	0.045	0.175
School 108	−0.018	0.088	−0.077	0.082	−0.046	0.125
School 109	0.050	0.068	−0.008	0.063	0.056	0.097
School 110	−0.063	0.111	−0.037	0.103	−0.180	0.157
School 116	0.057	0.087	0.004	0.080	−0.203	0.122
School 117	0.032	0.072	0.001	0.067	−0.050	0.103
School 120	−0.030	0.107	0.023	0.102	0.052	0.159
Constant	4.110 ***	0.074	4.114 ***	0.070	1.889 ***	0.110

***$p < .001$; **$p < .01$; *$p < .05$ (two-tailed test).
School 114 is the comparison category for institution; White is the comparison category for race/ethnicity; men and gender nonbinary are the combined comparison category for women.

in the next subsection explore whether these differences remain controlling for variation by school and other demographic characteristics.

Experiences of Marginalization

The first set of multivariate models examines whether LGBTQ students are more likely than their classmates to experience marginalization and isolation in their engineering programs, controlling for variation along other demographic measures. Multivariate regression models help determine whether LGBTQ status is a significant predictor of experiences of marginalization, holding constant any variation by gender identity, race/ethnicity, SES, first-generation status, and school. Table 2 presents the regression coefficients, significance levels and standard errors on the LGBTQ status measure and controls for each of the five experiences of marginalization variables. As the first column, which measures students' perception that they feel accepted by other engineering students, shows, the LGBTQ coefficient is significant and negative ($B = -0.214$, $p < .001$). This result means that, controlling for the variation explained by gender, race/ethnicity, SES, first-generation status, and school, LGBTQ-identifying students are significantly less likely than non-LGBTQ students to report that they feel accepted by their engineering classmates. In addition, LGBTQ students are more likely to report negative experiences along the other marginalization measures as well, and they are less likely to be included in invitations to social gatherings with their engineering classmates, more frequently avoid social events, are more likely than their classmates to feel the need to hide their personal lives from

Table 4 OLS Regression Models Predicting Personal Health and Wellness Outcomes with LGBTQ_Status and Controls

	Felt exhausted from spending energy keeping personal and professional life separate		Felt nervous or stressed		Felt unhappy or depressed at school		Had trouble sleeping to the point that it affected your performance in/out of school	
	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
LGBTQ_	0.436 ***	0.117	0.256 ***	0.089	0.638 ***	0.112	0.291 **	0.105
Hispanic	−0.115	0.173	0.008	0.135	−0.104	0.164	−0.017	0.164
Asian	0.255 *	0.105	−0.296 ***	0.079	0.007	0.099	0.013	0.093
Black	0.226	0.183	−0.548 ***	0.139	−0.121	0.171	0.084	0.163
Native American/Pacific Islander	0.292	0.253	0.188	0.194	0.282	0.251	0.481 *	0.228
Other racial/ethnic group	0.070	0.231	−0.178	0.185	0.174	0.234	0.362	0.223
Woman	0.154 *	0.068	0.539 ***	0.053	0.254 ***	0.065	0.327 ***	0.062
SES	0.013	0.026	0.018	0.020	0.013	0.025	−0.006	0.024
First-generation student	0.024	0.090	0.074	0.073	−0.021	0.087	0.246 ***	0.083
School 101	−0.027	0.197	0.068	0.154	0.105	0.191	0.089	0.183
School 108	0.016	0.142	0.007	0.110	0.011	0.137	0.136	0.131
School 109	0.016	0.110	0.105	0.085	0.174	0.107	0.208 *	0.101
School 110	0.339	0.174	0.160	0.135	0.259	0.169	0.137	0.162
School 116	0.121	0.137	−0.059	0.107	−0.019	0.133	0.086	0.127
School 117	0.121	0.117	0.187 *	0.091	0.146	0.113	0.187	0.108
School 120	−0.189	0.177	0.008	0.132	−0.042	0.175	0.012	0.161
Constant	1.924 ***	0.128	3.470 ***	0.095	2.164 ***	0.121	2.233 ***	0.112

***$p < .001$; **$p < .01$; *$p < .05$ (two-tailed test).

School 114 is the comparison category for institution; White is the comparison category for race/ethnicity; men and gender nonbinary are the combined comparison category for women.

Table 5 Coefficient Estimates and Standard Errors from Structural Equation Models for Direct and Indirect Effects of LGBTQ Status, Marginalization, and Devaluation on Health and Wellness Outcomes

	Direct effect of LGBTQ→health/ wellness measure		Indirect effect of LGBTQ status via marginalization measure		Indirect effect of LGBTQ status via devaluation measure		CFI (*C*) and RMSEA (*R*) fit statistics
	Coeff.	SE	Coeff.	SE	Coeff.	SE	
Outcome: Felt Exhausted from Spending Energy Keeping Personal and Professional Life Separate							
Mediators: Marginalization							
Mediator: Feel accepted	0.384 **	0.056	0.074 **	0.023	–		$C = 0.791$ $R = 0.044$
Mediator: Avoided social event	0.270 *	0.109	0.196 ***	0.036	–		$C = 0.891$ $R = 0.031$
Mediator: Included in social gatherings	0.407 ***	0.113	0.042 **	0.015	–		$C = 10.00$ $R = 0.000$
Mediator: Hide personal life	0.028	0.106	0.447 ***	0.051	–		$C = 0.961$ $R = 0.023$
Mediator: Stayed home, not welcome	0.306 **	0.111	0.156 ***	0.029	–		$C = 0.869$ $R = 0.029$
Mediator: Offensive comments	0.409 ***	0.113	0.063 **	0.019	–		$C = 0.878$ $R = 0.055$
Mediators: Devaluation							
Mediator: Classmates treat with respect	0.342 **	0.113	–		0.131 ***	0.028	$C = 0.735$ $R = 0.035$
Mediator: Work is respected	0.403 ***	0.112	–		0.055 **	0.018	$C = 0.848$ $R = 0.021$
Mediator: Avoid working on projects	0.226 *	0.109	–		0.206 ***	0.036	$C = 0.792$ $R = 0.041$
Outcome: Felt Nervous or Stressed							
Mediators: Marginalization							
Mediator: Feel accepted	0.206 *	0.044	0.072 ***	0.020	–		$C = 0.917$ $R = 0.047$
Mediator: Avoided social event	0.147	0.086	0.133 ***	0.025	–		$C = 0.924$ $R = 0.030$
Mediator: Included in social gatherings	0.245 **	0.088	0.024 *	0.010	–		$C = 10.00$ $R = 0.000$
Mediator: Hide personal life	0.036	0.087	0.245 ***	0.032	–		$C = 0.964$ $R = 0.023$
Mediator: Stayed home, not welcome	0.195 *	0.088	0.075 ***	0.018	–		$C = 0.910$ $R = 0.029$
Mediator: Offensive comments	0.211 *	0.087	0.075 ***	0.018	–		$C = 0.718$ $R = 0.057$
Mediators: Devaluation							
Mediator: Classmates treat with respect	0.183 *	0.088	–		0.101 ***	0.022	$C = 0.867$ $R = 0.035$
Mediator: Work is respected	0.226 *	0.087	–		0.047 **	0.015	$C = 0.944$ $R = 0.021$
Mediator: Avoid working on projects	0.154	0.087	–		0.128 ***	0.024	$C = 0.927$ $R = 0.029$

(Continued)

Table 5 Continued

	Direct effect of LGBTQ→health/ wellness measure		Indirect effect of LGBTQ_status via marginalization measure		Indirect effect of LGBTQ_status via devaluation measure		CFI (*C*) and RMSEA (*R*) fit statistics
	Coeff.	SE	Coeff.	SE	Coeff.	SE	
Outcome: Felt Unhappy or Depressed at School							
Mediators: Marginalization							
Mediator: Feel accepted	0.517 **	0.051	0.158 ***	0.041	–		*C* = 0.908 *R* = 0.048
Mediator: Avoided social event	0.409 ***	0.101	0.275 ***	0.047	–		*C* = 0.942 *R* = 0.030
Mediator: Included in social gatherings	0.569 ***	0.108	0.090 ***	0.025	–		*C* = 10.00 *R* = 0.000
Mediator: Hide personal life	0.172	0.099	0.511 ***	0.056	–		*C* = 0.974 *R* = 0.025
Mediator: Stayed home, not welcome	0.469 ***	0.107	0.198 ***	0.034	–		*C* = 0.911 *R* = 0.029
Mediator: Offensive comments	0.586 ***	0.109	0.097 ***	0.024	–		*C* = 0.588 *R* = 0.058
Mediators: Devaluation							
Mediator: Classmates treat with respect	0.533 ***	0.110	–		0.145 ***	0.029	*C* = 0.855 *R* = 0.035
Mediator: Work is respected	0.559 ***	0.106	–		0.112 ***	0.031	*C* = 0.942 *R* = 0.021
Mediator: Avoid working on projects	0.441 ***	0.104	–		0.245 ***	0.041	*C* = 0.934 *R* = 0.029
Outcome: Had Trouble Sleeping to the Point That It Affected Your Performance in/out of School							
Mediators: Marginalization							
Mediator: Feel accepted	0.218 *	0.103	0.103 ***	0.029	–		*C* = 0.851 *R* = 0.047
Mediator: Avoided social event	0.158	0.102	0.164 ***	0.031	–		*C* = 0.887 *R* = 0.030
Mediator: Included in social gatherings	0.252 *	104	0.057 **	0.018	–		*C* = 10.00 *R* = 0.000
Mediator: Hide personal life	0.028	0.102	0.298 ***	0.038	–		*C* = 0.952 *R* = 0.023
Mediator: Stayed home, not welcome	0.143	0.103	0.168 ***	0.030	–		*C* = 0.897 *R* = 0.029
Mediator: Offensive comments	0.250 *	0.118	0.081 ***	0.021	–		*C* = 0.608 *R* = 0.051
Mediators: Devaluation							
Mediator: Classmates treat with respect	0.198	0.105	–		0.131 ***	0.027	*C* = 0.817 *R* = 0.035
Mediator: Work is respected	0.239 *	0.102	–		0.078 **	0.023	*C* = 0.910 *R* = 0.022
Mediator: Avoid working on projects	0.149	0.102	–		0.179 ***	0.032	*C* = 0.905 *R* = 0.029

***$p < .001$; **$p < .01$; *$p < .05$ (two-tailed test).

Each row represents coefficients from a separate structural equation model.

All models include standard controls for gender, race/ethnicity, first-generation status, SES, and school.

Table 6 OLS and Logistic Regression Models Predicting School Climate Measures

	LGBTQ students face veiled hostility*		Some faculty and students seem condescending toward LGBTQ* people		Have witnessed instances of unfair treatment toward LGBTQ students†	
	Coeff.	SE	Coeff.	SE	Coeff.	SE
LGBTQ	0.313 ***	0.082	0.381 ***	0.100	2.132 ***	0.231
Hispanic	−0.034	0.120	0.162	0.146	−0.148	0.520
Asian	0.213 ***	0.072	0.163	0.085	−0.050	0.327
Black	0.176	0.125	0.191	0.153	−0.457	0.805
Native American/Pacific Islander	0.245	0.181	0.163	0.220	−0.884	1.089
Other racial/ethnic group	−0.059	0.165	−0.077	0.208	0.508	0.707
Woman	−0.047	0.048	−0.071	0.057	0.648 **	0.210
SES	−0.006	0.018	0.044 *	0.021	0.074	0.078
First-generation student	0.129 *	0.064	0.027	0.079	0.236	0.273
School 101	−0.076	0.146	−0.037	0.173	0.106	0.697
School 108	−0.051	0.104	−0.052	0.121	0.155	0.544
School 109	0.127	0.082	0.215 *	0.093	0.634	0.382
School 110	0.163	0.133	0.166	0.151	0.502	0.569
School 116	0.076	0.100	0.225	0.121	0.487	0.486
School 117	0.173 *	0.086	0.282 **	0.100	0.766 *	0.388
School 120	−0.039	0.125	0.066	0.151	0.072	0.566
Constant	2.058 ***	0.092	2.416 ***	0.103	−3.657 ***	0.442

*OLS regression model.
†Logistic regression model.
***$p < .001$; **$p < .01$; *$p < .05$ (two-tailed test).
School 114 is the comparison category for institution; White is the comparison category for race/ethnicity; men and gender nonbinary are the combined comparison category for women.
The first two columns present OLS regression models; the third column presents the results of a logistic regression model.

their peers, and are more likely to stay home from school because they do not feel welcome. Finally, LGBTQ students are more likely than their classmates to report having seen or heard offensive comments in their engineering programs.

Consistent with research on the marginalization of women in engineering programs (e.g., Dryburgh, 1999; Faulkner, 2009), the models also indicate that women report significantly more negative values for each measure except for the social gatherings measure compared to men and gender nonbinary respondents. The models also indicate marginalization experienced by racial/ethnic minority students: Asian students are more likely than White students to avoid social events and to stay at home from school because they do not feel welcome, and less likely to feel accepted by other students. Finally, Black students are significantly less likely than White students to feel accepted by other students, and Native American/Pacific Islander respondents are more likely than White students to report that they feel the need to hide their personal lives at school.

Devaluation of Engineering Work

Next, we examined whether LGBTQ students are more likely than their non-LGBTQ classmates to have their work devalued in their engineering programs. Specifically, controlling for variability by school and demographic factors, we found that LGBTQ students are less likely than their classmates to report that their engineering peers treat them as equally skilled students and respect their engineering work (see Table 3). Possibly related to their experiences of devaluation in team settings, LGBTQ students are also more likely to report avoiding working on certain projects or teams at school.

As with marginalization, we see significant differences by gender and race/ethnicity on these devaluation measures, women are significantly more likely to report devaluation on each measure compared to others, while Black students are more likely than White students to report that their work is disrespected, and Native American/Pacific Islander students are more likely than White students to report that they have avoided working on certain projects or teams.

Health and Wellness Measures

The third set of measures examines the extent to which LGBTQ students experience negative consequences that affect their personal health and wellness. Specifically, we investigated whether LGBTQ identity is related to feeling exhausted from spending energy on compartmentalization, the frequency of feeling nervous or stressed, of feeling unhappy or depressed at school, and of having trouble sleeping to the point that it negatively impacts their school performance. We found that LGBTQ status is significantly related to all of these measures, indicating that LGBTQ students experience more negative health and wellness outcomes than their non-LGBTQ classmates (see Table 4), controlling for other demographic factors.

As with the previous measures, we see significantly more negative experiences for women across all measures, that Asian students are more likely than White students to feel exhausted from compartmentalization, that Black and Asian students are more likely to feel nervous or stressed, and that Native American/Pacific Islander students and first-generation college students are more likely to have sleeping problems than White and nonfirst-generation students.

Mediation Effects

The next set of analyses tests whether these more negative health and wellness outcomes for LGBTQ students (Table 4) are partly attributable to their greater likelihood of experiencing marginalization and devaluation in their engineering programs (Tables 2 and 3). We tested

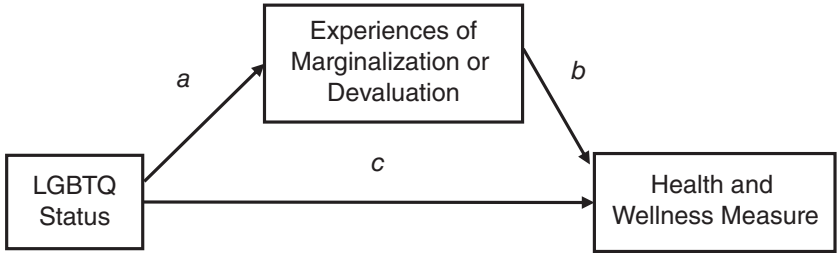

Figure 1 Schematic of structural equation models for mediation effects.

this possibility through mediation analyses with structural equation models. Mediation analysis indicates the extent to which the relationship between LGBTQ status and the health and wellness outcomes can be attributed to the marginalization and devaluation that LGBTQ students experience. Figure 1 provides a schematic of these relationships. Direct effects between LGBTQ status and the health and wellness measures are represented by path *c*. The indirect effects through the marginalization or devaluation measures is represented by *a*b*.

Table 5 presents results from the mediation analyses using SEM. Specifically, it provides the coefficients, standard errors, and significance levels for the direct effects between LGBTQ status and the focal health or wellness measure (path *c* in Figure 1) as well as the indirect paths between the marginalization and devaluation measures and the focal health and wellness measure (*a*b* in Figure 1). Column 2 presents the indirect effects of the six marginalization measures on each of the four health and wellness measures, and Column 3 presents the indirect effects of the three devaluation measures on the four health and wellness measures. Table 5 also provides the comparative fit index (CFI) and root mean square error of approximation (RMSEA) fit statistics for each SEM model.

In each case, the indirect effects of the marginalization and devaluation measures are significant and negative, indicating that part of the reason LGBTQ students report more negative health and wellness outcomes is that they are more likely to encounter devaluation and marginalization in their engineering programs. Column 1 indicates that most of the direct effects between LGBTQ status and the health and wellness measures remain significant, suggesting that other factors contribute to these negative outcomes beyond marginalization and devaluation, such as differential treatment by faculty or more institution-wide biases.

Variation by School Context

Our sample includes students from schools across a spectrum of approaches to engineering education, from a small, religiously affiliated college to a regional technical institute to a large flagship public university. These data allow us to address the question of whether the climate for LGBTQ students varies by school context. Table 6 presents the OLS and logistic regression models predicting three indicators of chilly climate for LGBTQ engineering students. Specifically, students were asked to rate their programs on the extent to which LGBTQ students face veiled hostility, whether faculty and students sometimes treat LGBTQ students condescendingly, and whether respondents have observed instances of unfair treatment toward students on the basis of sexual identity or gender expression. As expected, LGBTQ students themselves are more likely to report negative climates for LGBTQ persons than their non-LGBTQ peers.

Here, we are particularly interested in whether there are large differences across schools in students' assessment of their engineering programs: many significant school effects would indicate that heteronormativity, transphobia, and heterosexism depend in large part on the particular climate of the engineering program and/or school; very few school effects, on the other hand, would suggest that these LGBTQ biases are similar across these engineering programs. Of the seven school controls across the three climate measures, only a few significant school differences emerge: controlling for variation by demographic measures, students at School 117 (large public flagship university in the South) were more likely than students at School 114 (a small religiously affiliated college, the reference category) to report negative climate for LGBTQ persons across the three indicators; students at School 109 (small tech school in the Midwest) were more likely than students at School 114 to report that faculty and students are sometimes condescending toward LGBTQ students. There is no other significant variation by school. In supplemental analyses, we replicated these models among LGBTQ students only and found a similar consistency in the climate across schools.[1]

Robustness Checks and Supplemental Analysis

To ensure that these results are not an artifact of our modeling strategy, we also tested the hypotheses using additional analytic approaches. First, we reran the analyses with the entire sample of respondents ($N = 2{,}575$) regardless of whether they failed the attention check. Second, we replicated the models without MI, and third, we replicated the models excluding those schools with less than a 10% response rate. In each of these cases, the patterns of results and statistical significance were replicated.[2] Table A2 provides the effect sizes (Cohen's *d*) and results of the post hoc power analysis for differentials across LGBTQ status for each of the focal outcome measures.

We also conducted supplemental analyses to test for intersectional patterns among LGBTQ students by gender and race/ethnicity. For each marginalization, devaluation, and health and wellness measure, we ran analyses among LGBTQ students only ($N = 141$) to examine if LGBTQ women or LGBTQ students of color (using a dichotomous indicator for whether students identify as non-White) more frequently reported negative experiences within their engineering programs when compared to White LGBTQ men (the LGBTQ sample included 85 women and 21 students of color). Although a larger dataset is necessary to parse these intersectional patterns in depth, we found a few patterns of note. Specifically, LGBTQ-identifying women were marginally more likely than other LGBTQ students to report encountering offensive comments ($B = .444$, $p = .079$) and marginally less likely to report that their classmates treat them with respect ($B = -.275$, $p = .073$). The non-White status indicator did not reach statistical significance in these models, perhaps due to the small sample of non-White

[1]Ideally, we would have conducted these focal analyses for school effects among only the LGBTQ students as they are in the best position to assess such climate issues. However, due to the small sample size, these results cannot stand alone. The null findings across the eight schools were underpowered in the LGBTQ-only analysis, and, thus, we cannot rule out type II errors. For this reason, we included all students in the assessment of LGBTQ climate in Table 6 rather than just the LGBTQ students.

[2]The only difference in any of these models using the alternative modeling strategies was that in the third iteration of robustness checks, the LGBTQ effect on the "equally skilled" variable dropped to marginal significance. This change is likely the result of the reduced sample size used for this analysis rather than a reduction of bias as a result of removing schools with lower response rates.

LGBTQ students. More detailed analyses with larger samples are needed to articulate these intersectional patterns along specific racial/ethnic categories.

Discussion

The purpose of this research was to examine whether LGBTQ students face significant disadvantages in their engineering programs compared to their classmates. These data provide the first opportunity to systematically compare the day-to-day experiences of LGBTQ-identifying individuals with their non-LGBTQ-identifying peers in the same engineering programs and to identify several axes along which these disadvantages manifest.

We identified three such areas of inequality. First, we found that LGBTQ students are significantly more likely than non-LGBTQ students to experience marginalization in their engineering programs. Not only do LGBTQ students feel less accepted and more ignored by their classmates, they are less comfortable joining social events with peers and more likely to avoid participating in group projects. They are also more likely to report hearing or reading derogatory comments in their engineering programs. Second, LGBTQ students are less likely than their peers to feel that their work as engineering students is respected. These findings suggest that not only is LGBTQ inequality an issue of social isolation within engineering education but one of professional devaluation as well. This result resonates with qualitative research which has found that many sexual minority students feel they have to give "110%" to be taken seriously (e.g., Cech & Waidzunas, 2011).

Third, our findings suggest that these difficulties affect LGBTQ students personally: compared to their peers, LGBTQ students are significantly more likely to report emotional, sleep, stress, and anxiety difficulties and are more likely than their classmates to feel exhausted by efforts to compartmentalize their lives. Importantly, we found that these negative health and wellness outcomes are partly explained by LGBTQ students' experiences of marginalization and devaluation in their engineering programs.

Finally, we investigated the extent to which the negative climate for LGBTQ students varies by school. Although the schools in our study range from a top-rated flagship public institution to a small, religiously affiliated private school, there did not appear to be a drastic variation in the climate for LGBTQ persons across the engineering programs in these schools. Supporting previous theoretical, ethnographic, and interview-based research (Cech & Waidzunas, 2011; Faulkner, 2009; Schiebinger, 1999), this lack of strong variation across schools suggests that anti-LGBTQ bias is not only a manifestation of the climate of individual programs but part of the culture of engineering education more broadly, embedded in its taken-for-granted practices and ideologies.

Limitations

This study has several limitations worth noting. First, our dataset is not large enough to explicate detailed intersectional patterns with race/ethnicity, gender, and other demographic categories, nor to disaggregate categories within the LGBTQ acronym. Second, the students in this study came from programs where the deans expressed support for the ASEE Diversity and Inclusion Survey and agreed to let us collect data from their students. It is likely that these programs may be more concerned than others about issues related to diversity and inclusion within their student populations. Thus, the results from this study may actually provide conservative estimates of the disparities between LGBTQ and non-LGBTQ engineering students as they pertain to devaluation, inclusion, and health and wellness outcomes.

Finally, our goal was to sketch the landscape of possible LGBTQ biases in engineering education. Space limitations in the survey meant that we were unable to include multivariate measures of each of the dimensions of marginalization, devaluation, and health and wellness outcomes we investigated. We leave it to future studies to develop and test scales that more precisely operationalize these LGBTQ biases. Despite these limitations, this research makes important strides in understanding an often-ignored axis of disadvantage.

Implications

This study raises the question of how engineering programs can best support LGBTQ students. Engineering program administrators and faculty can take a number of approaches to improve the climate of their programs for LGBTQ students, including Safe Zone trainings that educate students and faculty on appropriate language and inclusionary behavior toward LGBTQ members of the college or university. In addition, fostering a zero-tolerance policy for homophobic and transphobic jokes and commentary may mitigate some of the most blatant anti-LGBTQ sentiments that students encounter. Similarly, thinking carefully about language use in formal engineering program communication and information structures is important. For example, using partner instead of spouse or husband/wife and allowing students and faculty to designate and be referred to by their preferred gender pronouns are important steps in making LGBTQ persons feel more welcome. Changes to the built environment, such as gender-neutral bathrooms in campus buildings, can further support transgender and gender nonbinary students.

Second, ensuring that a variety of underrepresented demographic categories, including LGBTQ status, are included in the nondiscrimination statements on college and graduate school application materials, engineering course syllabi, and departmental websites can be an important step signaling support for LGBTQ students. Similarly, it would be impactful to make visible openly LGBTQ engineering graduates and professionals who have been successful in the profession by, for example, including them in colloquia and speaker series in engineering departments or profiling the work of LGBTQ engineering alumni on departmental websites, brochures, and recruiting materials. The representation in these capacities of LGBTQ persons who have been successful in engineering sends a message to LGBTQ students (and their peers) that they, too, belong in the profession. Furthermore, collaborating with and supporting membership in organizations for LGBTQ-identifying individuals in engineering such as the Out in Science, Technology, Engineering, and Math (oSTEM) organization and partnering with campus LGBTQ student centers can help foster a more positive school climate for LGBTQ engineering students. Like Yoder and Mattheis (2016), we recommend working to increase the visibility of LGBTQ programs and advocacy efforts in engineering education programs so that students feel comfortable developing beneficial connections with students and professionals who share similar identity characteristics.

In addition, our results suggest that LGBTQ students report more negative health and wellness outcomes due in part to the devaluation and marginalization they experience within their engineering education programs. These findings highlight the potentially serious impact that negative engineering program climates can have on members of marginalized groups. Persistent experiences of stigmatization and devaluation within engineering education programs can personally affect students, impacting not only their quality of life within their engineering programs but also their very health and wellness. These are serious outcomes that demand administrative attention and resources and collective effort by faculty and student allies.

Future Research

Our findings underscore the need to better understand the mechanisms of LGBTQ inequality: how it is perpetuated in informal departmental interactions and through the engineering culture and curriculum, and how best to address these patterns of inequality. More research is needed to explicate the long-term impacts that disadvantageous engineering cultures have on the retention and representation of LGBTQ individuals in the engineering profession. Research that develops and tests quantitative measures of heteronormativity, heterosexism, and transphobia within engineering contexts is also needed to advance survey-based research, and qualitative and ethnographic work is required to precisely document how these patterns of bias are enacted by students and faculty on a day-to-day basis.

As with scholarship on other axes of disadvantage, it is imperative that researchers are sensitive to the sociodemographic and identity complexities of the LGBTQ population even if, as in our case, these complexities sometimes cannot be disaggregated in published scholarship to ensure the confidentiality of respondents. Like all research on marginalized populations, studies of LGBTQ persons should not be conducted simply as a desire to fill "broader impact" requirements on substantively unrelated research grants and projects, but as deliberate efforts that pay careful attention to relevant theoretical and empirical work in social science and queer theory on heterosexism, homophobia, and transphobia. The potential invisibility of students' LGBTQ status also means that researchers should take care to protect participants from breaches of confidentiality in data collection, analysis, and reporting. LGBTQ-inclusive engineering education research, such as inclusive engineering pedagogy, must start from respect for and attention to voices and perspectives of disadvantaged group members themselves.

Conclusion

In detailing the experiences of marginalization and devaluation that LGBTQ students face, this study advances scholarly understanding of an often-ignored axis of difference. We show that these inequalities for LGBTQ students not only impact their day-to-day interactions with their classmates but influence whether they are perceived as competent engineering trainees and even reach into their personal lives to negatively impact their health and wellness. This study also draws attention to engineering education as a site that helps reproduce professional cultures that disadvantage LGBTQ individuals in engineering more broadly. Through the process of professional socialization, anti-LGBTQ biases may become entrenched in students' understanding of what makes "good" engineers and what concerns are tangential to "real" engineering work—understandings that students take with them into the engineering workforce. Furthermore, because the perpetuation of these anti-LGBTQ biases in engineering education and beyond do not necessarily rely on purposeful, overt displays of bias—for example, non-LGBTQ students may not exclude LGBTQ students in an overt or blatant way—the processes that reproduce these LGBTQ inequalities may be difficult to recognize and, thus, particularly difficult to challenge. Reflexive and theoretically anchored research, combined with serious commitments from engineering faculty and program leaders for institutional and cultural change, is necessary to begin to address these inequalities.

APPENDIX A

Table A1 Operationalization of Dependent Variables

Experiences of Marginalization Measures

How accepted do you feel by your classmates? (1 = not at all; 5 = very)

I am invited when my classmates get together after class (1 = strongly disagree; 5 = strongly agree)

How often in the past year have you avoided a social event? (1 = never; 5 = almost every day)

How often in the past year have you felt the need to lie about your personal life? (1 = never; 5 = almost every day)

How often in the past year have you stayed home from school because you felt unwelcome? (1 = never; 5 = almost every day)

Feelings of Devaluation

My peers respect me for the work that I do (1 = strongly disagree; 5 = strongly agree)

In this engineering college, my work is respected (1 = strongly disagree; 5 = strongly agree)

Thinking about the past 12 months, have you avoided working on a certain school project or team? (1 = never; 5 = almost every day)

Health and Wellness Measures

Over the past 12 months, have you experienced feeling exhausted from keeping your personal and professional life separate? (1 = never; 5 = almost every day)

Over the past 12 months, have you experienced sleep issues that affected your performance? (1 = never; 5 = almost every day)

Over the past 12 months, have you felt nervous or stressed? (1 = never; 5 = almost every day)

Over the past 12 months, have you felt unhappy or stressed at school? (1 = never; 5 = almost every day)

Engineering Program Climate Measures

To what extent do you agree with the following statement: LGBTQ students are met with thinly veiled hostility (1 = strongly disagree; 5 = strongly agree)

To what extent do you agree with the following statement: Some faculty seem condescending toward colleagues who are lesbian, gay, bisexual transgender, or queer (1 = strongly disagree; 5 = strongly agree)

Overall, in the last 3 years, have you been aware of instances in which students in your engineering/engineering technology classes have been treated negatively due to their sexual identity, gender expression, or transgender status? (1 = yes; 0 = no)

Table A2 Effect Sizes and Power Values of Mean Differences Between LGBT vs. Non-LGBT Respondents

	LGBT vs. non-LGBT	Power
Marginalization Measures		
Accepted by students in department	.391	.962
Avoided social event	.525	.993
Feel included in social gatherings	.353	.901
Hide personal life	.789	.999
Stayed home because did not feel welcome	.476	.967
Offensive comments	.416	.993
Devaluation Measures		
Treated as equally skilled student	.317	.928
Students respect engineering work	.314	.869
Avoided team or project	.518	.998

(Continued)

Table A2 Continued

	LGBT vs. non-LGBT	Power
Health and Wellness Measures	.346	.961
Exhausted from compartmentalization	.346	.961
Nervous	.370	.996
Depressed or sat at school	.518	.999
Sleeping troubles	.283	.999

Note. columns represent Cohen's *d* effect sizes [*d* = difference in means/pooled standard deviation] on differences in means on each outcome measure between LGBTQ and non-LGBTQ respondents.

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