Perceptions of the Engineering Curricula from Women and LGBTQIA+ Students

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Gender and Sexual Minority Students' Perceptions of the Engineering Curriculum

Abstract
This study analyzes climate survey responses in an engineering college to understand gender/sexual minority students' perceptions of the inclusivity of the engineering curriculum. Crosstabs were conducted to determine differences between these groups and their non-minority counterparts. We found that students' status as 'minority' made them more attuned to exclusionary course experiences for other minority identities.

Study Objectives
The National Science Foundation's Revolutionizing Engineering and computer science Departments (RED) grant was awarded to the Civil and Environmental Engineering Department at midsized mid-Atlantic university in 2016. The RED grant has worked to broaden access and improve the climate of inclusion for underrepresented and underserved engineering students. In 2016 and 2018, the RED research team distributed climate surveys to all engineering students. While extensive research has been done on gender and sexual minority students' perceptions of *belongingness* in engineering, fewer studies have examined their perceptions of the engineering curriculum. To add to this gap in literature, this paper analyzes quantitative responses of gender and sexual minority students' perceptions of the engineering curricula from the survey conducted in 2018.

Relevant Literature
The predominant normative marker of science and scientists in the U.S. has historically and continues to be based on White cisgender male perspectives [1]–[7]. Not surprisingly, this homogenous and heterogenous perspective leads to pedagogical practices in which minoritized students underperform compared to when innovative pedagogical models are used, such as flipped classrooms [8], [9]. This long-standing conceptualization of science and scientists also results in an engineering curriculum that deems "issues of communication, justice, politics, social consciousness, and identity" as "irrelevant" [10, p. 11].

Consequences of this normative 'ideal' affect engineering gender and sexual minority students in various ways. These students generally have lower confidence in engineering and their abilities to succeed [11], recognize that those who exhibit 'feminine' traits are perceived as less competent in STEM [12], and are less certain that they will persist in the field [13]. Often, gender and sexual minority students feel pressure to "pass" or "cover" markers of their identity to assimilate into the engineering culture [10], [14, p. 15]. Cech and Waidzunas also highlighted engineering-specific biases against LGB students, including the way technical language is used throughout the field as a separate and opposite binary to language grounded in the social realm [10]. The exclusion of gender non-conforming students from professional opportunities, camps, groups, and women-specific spaces [15] and increased levels of harassment and discrimination further marginalize gender and sexual minority engineering students [16]. Despite having to navigate an exclusionary engineering curriculum and culture, classroom peers rated female students as having better listening skills, contribution of valuable ideas, reliability, and listening skills [17].

Still, not much is known about how gender and sexual minority students perceive the engineering curriculum. A large deal of literature about engineering classroom experiences discusses how they navigate group work, which often reinforces traditional gender-based roles [18]–[21]. An additional body of literature examines these students' perceptions of engineering experiences, including how intersectionality affects these perceptions [22]–[25]. Likewise, there is already a body of research from diverse scholars focused on disrupting dominant narratives across curricula and educational disciplines [26]–[30]. Disrupting predominant curriculum (and pedagogy) is particularly relevant in order to diversify the field of engineering. For example, Knight et al. found that engineering curricula that emphasized interdisciplinary connections were viewed more favorably by women students [31]. This is not a surprising finding, as additional research supports the idea that women and students of color favor socially relevant engineering content and contexts [32], [33]. However, such an approach has been met with resistance due to the overreliance on technical subject matter in the engineering curriculum [32], [34], [35]. Many engineering faculty, but certainly not all, resist curricular changes to due to "competing tendencies" rooted within the technical/social dualism [36, p. 238].

Methodology

This paper uses a quantitative approach to analyze engineering climate survey responses among gender and sexual minority students. The survey was conducted in spring 2018 at a Mid-Atlantic university as one component of a National Science Foundation grant that was awarded to the Civil and Environmental Engineering Department. The grant program, Revolutionizing Engineering and computer science Departments, aims to broaden access and improve the climate of inclusion for underrepresented and underserved engineering students. Data were analyzed throughout 2019.

Respondents self-identified from among these gender identity categories: male, female, cisgender, transgender, gender queer/gender fluid/gender nonconforming, and other. Students also self-identified from among these sexual orientation categories: asexual, bisexual, gay, straight, lesbian pansexual, queer, questioning/unsure, and other. Because this study was conducted at a Predominantly White Institution, there were not sufficient responses to disaggregate race and ethnicity from gender identity or sexual orientation, nor could we disaggregate specific gender or sexual minority identities. Thus, for the purposes of this paper, we have relied on binary identity constructions (male versus female and heterosexual versus non-heterosexual). We understand these artificial categories are unable to capture important nuances in identity as emphasized in critical studies. We therefore acknowledge this as one study limitation and a critical area for future research.

The survey asked operationalized findings from previous research [31]-[33], [37], that women and other underrepresented minorities prefer disciplines that emphasize broad systems perspectives as opposed to narrow technical orientations, integrates non-technical professional skills, encourages connection between individual experiences and context, does not assume prior informal or formal knowledge or experience in order to understand the material presented, and provides an assortment of assessment methods which do not privilege one strength over another (a staple emphasis for inclusive learning). Students were asked their perceptions of the engineering curriculum, theoretical and practical content, interdisciplinary content, acceptance of experiential knowledge, the need for prior lab or machine experience, available assistance and support, and how the interests, experiences, and achievements of various groups are integrated into the curriculum. We conducted crosstabs in SPSS to examine if there are statistically significant differences among versus female and non heterosexual students and their counterparts. Statistical significance was predetermined at chi square <0.05.

Findings

A total of 205 engineering students took the survey in 2018. Fifty-three were women (26% of the sample). Almost a majority of the female students were seniors (42%) and all studied full-time. Female students were predominantly biomedical engineering majors (57%) and White (80%). Ten percent of females identified as non-heterosexual.

Only twelve students who responded to the survey identified as non-heterosexual (2.6% of the sample). A majority of non-heterosexual students were between their first and third years of studies (25%-33%) and all studied full-time. Non heterosexual students were primarily mechanical (33%) and biomedical (25%) engineering majors and all identified as White. Fifty-five percent of non-heterosexual students identified as male and 45% identified as female.

For most of the curriculum questions, we asked students to rate the curriculum between 1 and 5, according to statements we provided for 1 (the least inclusive), 3 (partial inclusivity), and 5 (most inclusive) (see the Appendix for options offered for each question). In Tables 1 and 2 we present the percentage answering the most inclusive option (5). The final question in the tables refers to a question whereby students were asked how strongly they agreed that their engineering coursework would prepare them for a job in engineering.

Table 1 indicates that females agreed with their male counterparts that the skills needed to succeed in engineering were taught in the curriculum (i.e. no prior knowledge was required) and that ongoing assistance and support was offered to all students who wanted to build skills or confidence. Like their male counterparts, females strongly agreed that the engineering coursework would prepare them for a job in engineering. However, females were more likely to disagree that theoretical problems were presented with practical applications and that their work was evaluated on a broad range of technical and non-technical professional skills (Figure 1). None of those findings were statistically significant, however, and perceptions of inclusive pedagogy were more similar than perceptions of comfort in the classroom and perception that minority interests, experiences and achievements were well represented in the curriculum.

Statistically significant findings include the fact that female students are less comfortable sharing in most/all of their engineering classes, and that they are less likely to feel that the engineering curriculum fully integrated the interests, experiences and achievements of women, racial/ethnic minorities, LGBTQ+, disabled, or low-income individuals (Figure 2).

Table 2 indicates that non-heterosexual students agreed with heterosexual students that ongoing assistance and support was offered to all students who wanted to build skills or confidence. Like their heterosexual peers, non-heterosexual students strongly agreed that the engineering coursework would prepare them for a job in engineering (Figure 3). They felt more strongly than their counterparts that their work was evaluated on a broad range of technical and non-technical professional skills. However, these students were more likely to disagree that theoretical problems were presented with practical applications and that skills needed to succeed in engineering were taught in the curriculum (i.e., no prior knowledge was required). (also Figure 3).

Like females, non-heterosexual students were also less likely to feel comfortable sharing in most or all of their classes and felt that the engineering curriculum did not fully integrate the interests, experiences and achievements of women, minorities, LGBTQ+ or low-income individuals. (Figure 4) While the only statistically significant finding includes the fact that sexual minority students are less likely to express that the engineering curriculum does not fully integrate the interests, experiences, and achievements of racial/ethnic minorities, there is a clear pattern of non-heterosexual students perceiving less inclusivity and being less comfortable in the classroom than their heterosexual counterparts.

Study Significance

This study shows that when it comes to their perceptions of the engineering curricula, gender and sexual minority students are less comfortable sharing in class and felt that experiences and interests related to their identities are excluded from the engineering curriculum. Interestingly, not only do they feel their own identity's interests are excluded, they view the exclusionary curricula more broadly – they felt the curriculum also excluded the interests, experiences, and achievements of racial/ethnic groups, disabled groups, and low-income groups (with the exception of sexual minority students, who felt more strongly than their heterosexual peers that disability interests were fully integrated into the curriculum). In other words, these students were more attuned to exclusionary coursework for other minoritized identities as well as their own.

While extensive research has been done on female and sexual minority students' perceptions of belongingness in engineering, fewer studies have looked at how these students view the engineering curricula. Our findings support research that indicates that the need to support engineering faculty in curriculum development efforts so that all identities are represented and fully integrated into the engineering curriculum, assignments, and assessments [33], [37], [38]. This is critical because students who have minoritized identities are able to recognize that not only is their own identity excluded from the curriculum, but also other minoritized identities, which can amplify these students' sense of isolation and lack of belonging in the engineering major and career. Designing curricula, assignments, and assessments that reflect diverse perceptions of engineers and engineering work can help cultivate the professional formation of engineering identity and encourage students with minoritized identities to persist in the engineering major and career.

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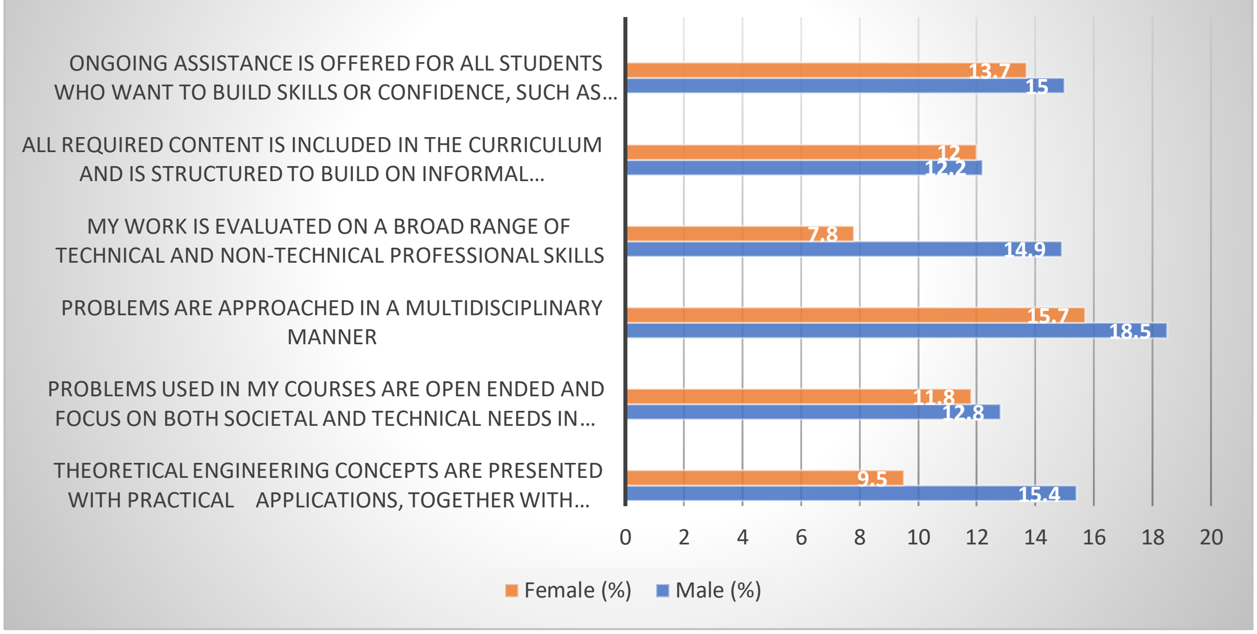
Table 1
Perceptions of the engineering curriculum by gender identity (% answering the option listed)*

	Male (%)	Female (%)	Total (%)
Theoretical engineering concepts are presented with practical applications, together with societal, global, environmental, or economic impacts	15.4	9.5	14.0
Problems used in my courses are open ended and focus on both societal and technical needs in their solutions	12.8	11.8	12.5
Problems are approached in a multidisciplinary manner	18.5	15.7	17.6
My work is evaluated on a broad range of technical and non-technical professional skills	14.9	7.8	13.1
All required content is included in the curriculum and is structured to build on informal experiences that will be familiar to a diverse range of students (e.g., household items and technology)	12.2	12.0	12.1
Ongoing assistance is offered for all students who want to build skills or confidence, such as additional familiarization sessions	15.0	13.7	14.6
I feel comfortable sharing in most or all of my classes	36.1**	19.6**	31.8**
Women's interests, experiences and achievements are fully integrated into the curriculum	27.9**	9.8**	23.2**
Interests, experiences, and achievements of low-income individuals are fully are fully integrated into the curriculum	24.5**	5.9**	19.7**
Minority interests, experiences and achievements are fully integrated into the curriculum	23.1**	7.8**	19.2**
Disability interests, experiences and achievements are fully integrated into the curriculum	24.0**	7.8**	19.8**
LQBTQ+ interests, experiences and achievements are fully integrated into the curriculum	21.8**	5.9**	17.7**
I strongly agree that my engineering coursework will prepare me for a job in engineering	76.2	73.4	75.5

* See all options offered for each of these questions in the Appendix table. **Chi-Square<0.5

Figure 1. Perceptions of Inclusive Pedagogy by Undergraduate Engineering Women and Men



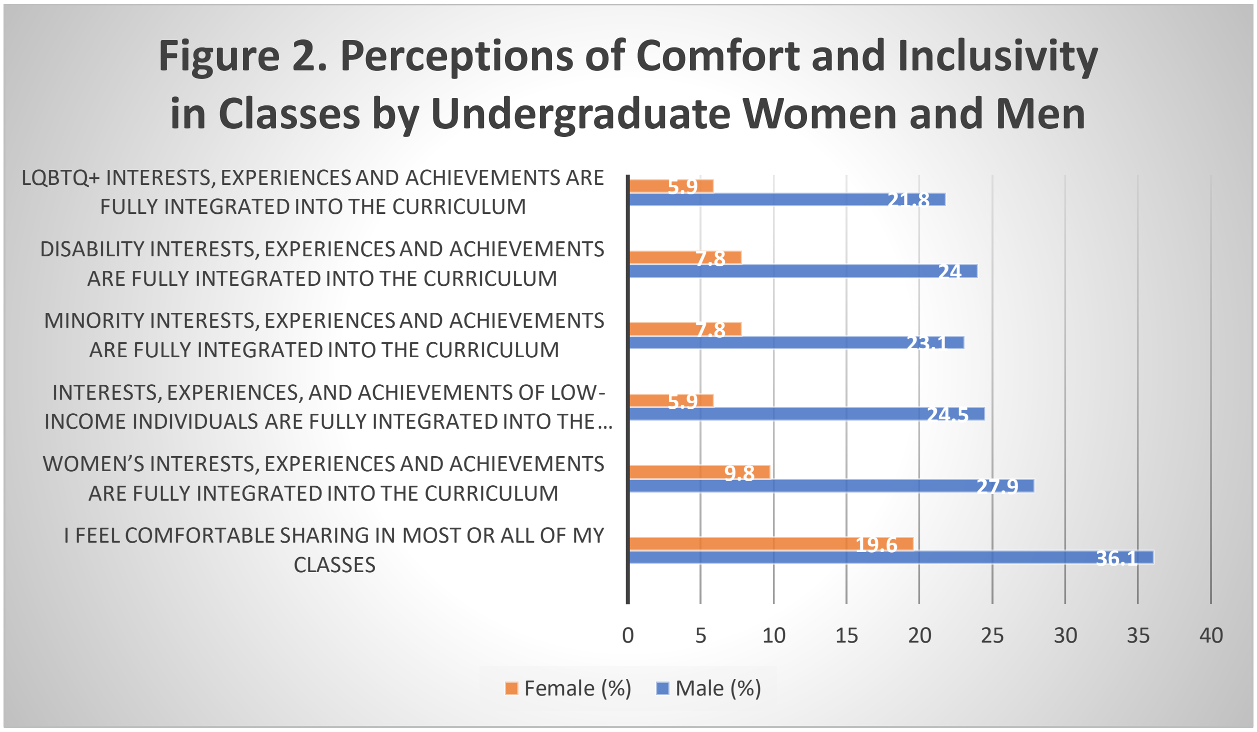


Figure 2. Perceptions of Comfort and Inclusivity in Classes by Undergraduate Women and Men
LQBTQ+ INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
5.9
21.8
DISABILITY INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
7.8
24
MINORITY INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
7.8
23.1
INTERESTS, EXPERIENCES, AND ACHIEVEMENTS OF LOW-INCOME INDIVIDUALS ARE FULLY INTEGRATED INTO THE…
5.9
24.5
WOMEN'S INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
9.8
27.9
I FEEL COMFORTABLE SHARING IN MOST OR ALL OF MY CLASSES
19.6
36.1
0
5
10
15
20
25
30
35
40
Female (%)
Male (%)

Table 2
Perceptions of the engineering curriculum by sexual orientation (% answering the option listed)*

	Hetero sexual (%)	Non-hetero sexual (%)	Total (%)
Theoretical engineering concepts are presented with practical applications, together with societal, global, environmental, or economic impacts	14.3	0.0	13.4
Problems used in my courses are open ended and focus on both societal and technical needs in their solutions	13.2	8.3	12.9
Problems are approached in a multidisciplinary manner	18.6	0.0	17.5
My work is evaluated on a broad range of technical and non-technical professional skills	13.3	16.7	13.5
All required content is included in the curriculum and is structured to build on informal experiences that will be familiar to a diverse range of students (e.g., household items and technology)	12.3	0.0	11.6
Ongoing assistance is offered for all students who want to build skills or confidence, such as additional familiarization sessions	15.5	16.7	15.6
I feel comfortable sharing in most or all of my classes	32.6	16.7	31.7
Women's interests, experiences and achievements are fully integrated into the curriculum	24.6	8.3	23.6
Interests, experiences, and achievements of low-income individuals are fully are fully integrated into the curriculum	19.8	16.7	19.6
Minority interests, experiences and achievements are fully integrated into the curriculum	19.8**	8.3**	19.1**
Disability interests, experiences and achievements are fully integrated into the curriculum	19.4	25.0	19.7
LQBTQ+ interests, experiences and achievements are fully integrated into the curriculum	18.2	8.3	17.6
I strongly agree that my engineering coursework will prepare me for a job in engineering	29.0	25.0	28.7

* See all options offered for each of these questions in the Appendix table. **Chi-Square<0.5

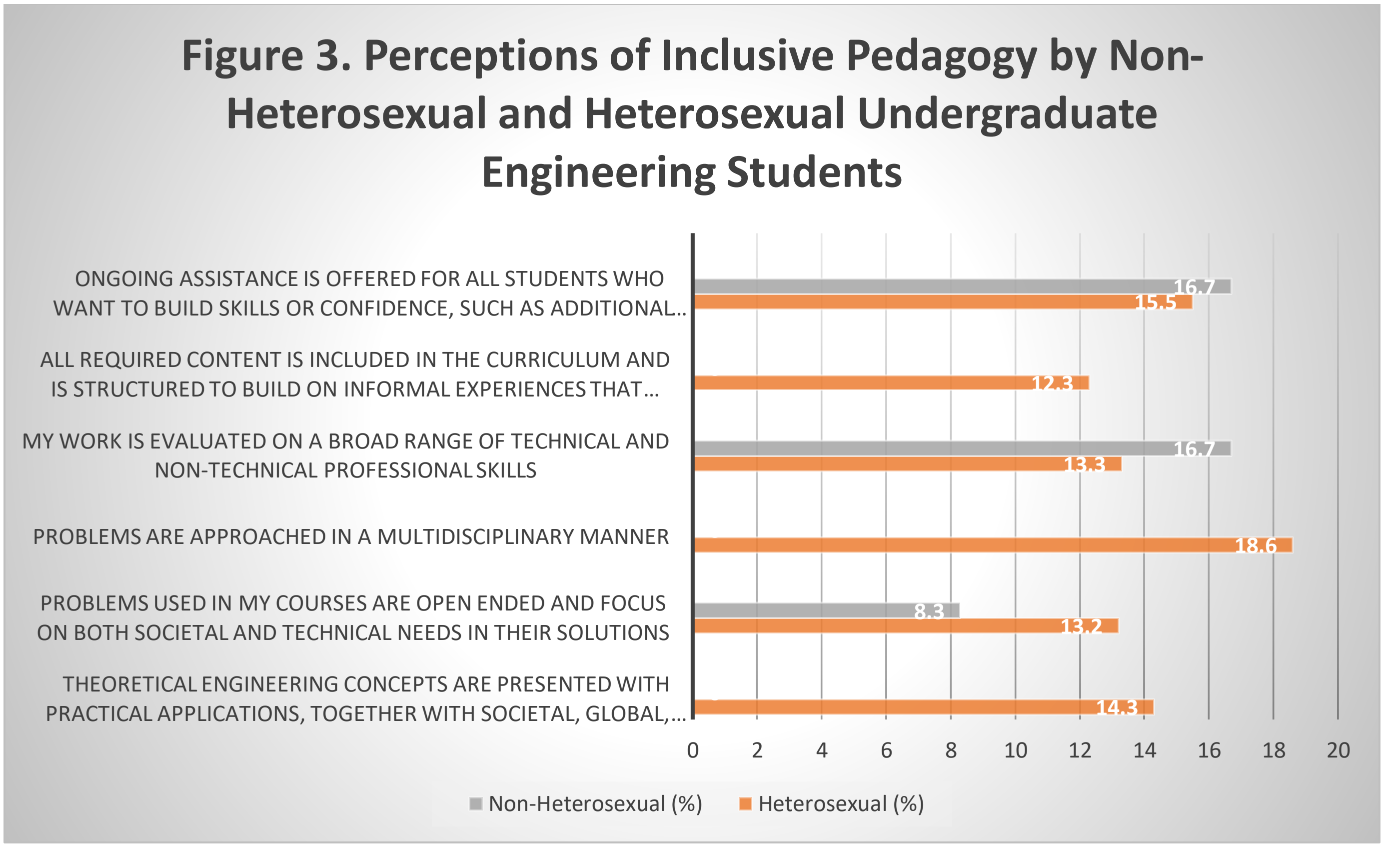


Figure 3. Perceptions of Inclusive Pedagogy by Non-Heterosexual and Heterosexual Undergraduate Engineering Students
ONGOING ASSISTANCE IS OFFERED FOR ALL STUDENTS WHO WANT TO BUILD SKILLS OR CONFIDENCE, SUCH AS ADDITIONAL...
ALL REQUIRED CONTENT IS INCLUDED IN THE CURRICULUM AND IS STRUCTURED TO BUILD ON INFORMAL EXPERIENCES THAT...
MY WORK IS EVALUATED ON A BROAD RANGE OF TECHNICAL AND NON-TECHNICAL PROFESSIONAL SKILLS
PROBLEMS ARE APPROACHED IN A MULTIDISCIPLINARY MANNER
PROBLEMS USED IN MY COURSES ARE OPEN ENDED AND FOCUS ON BOTH SOCIETAL AND TECHNICAL NEEDS IN THEIR SOLUTIONS
THEORETICAL ENGINEERING CONCEPTS ARE PRESENTED WITH PRACTICAL APPLICATIONS, TOGETHER WITH SOCIETAL, GLOBAL,...
16.7
15.5
12.3
16.7
13.3
18.6
8.3
13.2
14.3
0
2
4
6
8
10
12
14
16
18
20
Non-Heterosexual (%)
Heterosexual (%)

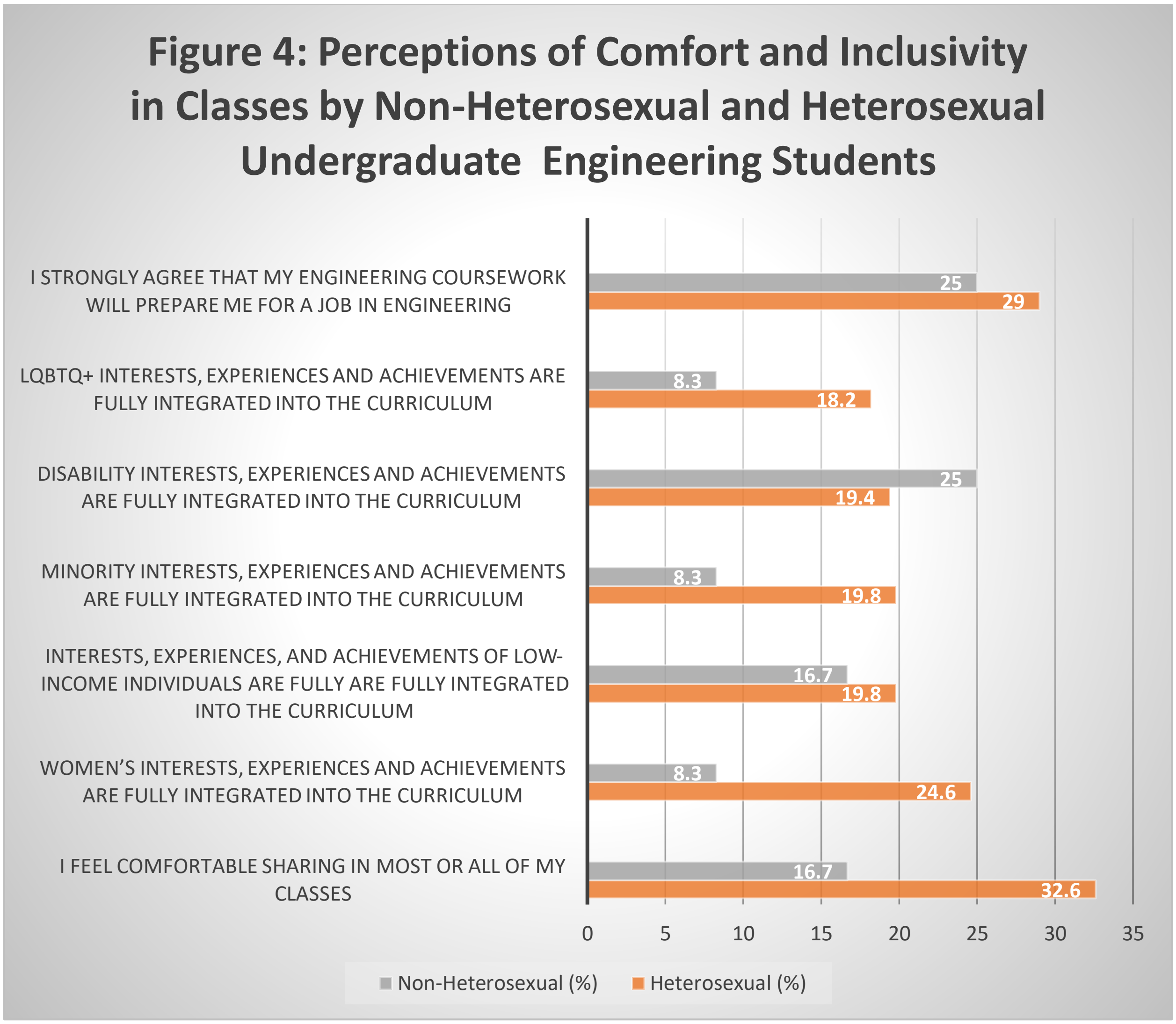


Figure 4: Perceptions of Comfort and Inclusivity in Classes by Non-Heterosexual and Heterosexual Undergraduate Engineering Students
I STRONGLY AGREE THAT MY ENGINEERING COURSEWORK WILL PREPARE ME FOR A JOB IN ENGINEERING
25
29
LQBTQ+ INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
8.3
18.2
DISABILITY INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
25
19.4
MINORITY INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
8.3
19.8
INTERESTS, EXPERIENCES, AND ACHIEVEMENTS OF LOW-INCOME INDIVIDUALS ARE FULLY ARE FULLY INTEGRATED INTO THE CURRICULUM
16.7
19.8
WOMEN'S INTERESTS, EXPERIENCES AND ACHIEVEMENTS ARE FULLY INTEGRATED INTO THE CURRICULUM
8.3
24.6
I FEEL COMFORTABLE SHARING IN MOST OR ALL OF MY CLASSES
16.7
32.6
0
5
10
15
20
25
30
35
Non-Heterosexual (%)
Heterosexual (%)

Appendix – Curriculum Perception Questions and Response Options

Q. 41 How are theoretical engineering concepts taught within your courses?

- Level 1. They are taught largely in isolation
- Level 2. Between 1 and 3
- Level 3. They are typically presented together with industry-related practical applications
- Level 4. Between 3 and 5
- Level 5. They are presented with practical applications, together with societal, global, environmental or economic impacts.

Q43. What kinds of problems are used in your course(s)?

- Level 1. Problems usually require focus on technical detail only.
- Level 2. Between 1 and 3
- Level 3. Problems acknowledge societal needs but are still primarily technically focused.
- Level 4. Between 3 and 5
- Level 5. Problems are open ended and focus on both societal and technical needs in their solution.

Q44. Are problems approached in a multidisciplinary manner (e.g. do they draw upon or link to a range of other academic areas such as ethics, social justice, or politics?)

- Level 1. Strictly single-discipline approach
- Level 2. Between 1 and 3
- Level 3. Includes awareness raising material and uses content from other disciplines, but this is not necessarily integrated with the rest of the content.
- Level 4. Between 3 and 5
- Level 5. Approach is multidisciplinary

Q46. How is your work evaluated or graded in your course(s)?

- Level 1. Evaluation focuses on technical knowledge
- Level 2. Between 1 and 3
- Level 3. Evaluation focuses mainly on technical knowledge and a small range of non-technical professional skills
- Level 4. Between 3 and 5
- Level 5. Evaluation focuses on a broad range of technical and non-technical professional skills

Q47. In your courses, is it assumed that students already have some informal knowledge (for example, is it assumed that they know how a car engine works?)

- Level 1. At commencement of the course, students are expected to have some degree of knowledge which is not formally taught in prerequisite courses, e.g. previous experience with electrical or mechanical components.
- Level 2. Between 1 and 3
- Level 3. Curriculum content assumes no knowledge outside prerequisite curriculum
- Level 4. Between 3 and 5
- Level 5. All required content is included in the curriculum and is structured to build on informal experiences that will be familiar to a diverse range of students (e.g. household items and technology)

Q48. Is prior knowledge of laboratories and equipment use assumed in your courses?

- Level 1. Students are assumed to be competent in the use of equipment, machinery, apparatus, and computers
- Level 2. Between 1 and 3.
- Level 3. Students receive a basic introduction to equipment, apparatus, etc. relevant to the course
- Level 4. Between 3 and 5.
- Level 5. Ongoing assistance is offered for all students who want to build skills or confidence, such as additional familiarization sessions

Q49. To what extent do you feel comfortable sharing ideas, discussing beliefs, and expressing incomplete or incorrect ideas in the learning environment?

- Level 1.I do not feel comfortable sharing in most of my classes.
- Level 2. between 1 and 3
- Level 3.I feel comfortable in some classes, but not others.
- Level 4. Between 3 and 5
- Level 5. I feel comfortable sharing in most or all of my classes.

Q50. How are women's interests, experiences, and achievements represented within your course(s)?

- Level 1. Women's interests, experiences and achievements are not addressed.
- Level. 2 Between 1 and 3
- Level 3. Content acknowledges women's interests and includes women's experiences and achievements
- Level 4. Between 3 and 5.
- Level 5. Women's interests, experiences and achievements are fully integrated into the curriculum.

Q51. How are the interests, experiences and achievements of low income individuals represented within your course(s)?

- Level 1. Interests, experiences and achievements of low income individuals are not addressed.
- Level. 2 Between 1 and 3
- Level 3. Content acknowledges interests and includes experiences and achievements of low income individuals
- Level 4. Between 3 and 5.
- Level 5. Interests, experiences and achievements of low income individuals are fully integrated into the curriculum.

Q52. How are racial/ethnic minority interests, experiences and achievements represented within your course(s)?

- Level 1. Minority interests, experiences and achievements are not addressed
- Level. 2 Between 1 and 3
- Level 3. Content acknowledges minority interests and includes minority experiences and achievements
- Level 4. Between 3 and 5.
- Level 5. Minority interests, experiences and achievements are fully integrated into the curriculum

Q53. How are interests, experiences and achievements of individuals with disabilities represented within your course(s)?

- Level. 1 Disability interests, experiences and achievements are not addressed
- Level. 2 Between 1 and 3
- Level 3. Content acknowledges disability interests and includes disability experiences and achievements
- Level 4. Between 3 and 5.
- Level 5. Disability interests, experiences and achievements are fully integrated into the curriculum

Q54. How are LGBTQ+ interests, experiences, and achievements represented with your course(s)?

- Level 1. LGBTQ+ interests, experiences, and achievements are not addressed
- Level. 2 Between 1 and 3
- Level 3. Content acknowledges LGBTQ+ interests and includes LGBTQ+ experiences and achievements
- Level 4. Between 3 and 5.
- Level 5. LGBTQ+ interests, experiences and achievements are fully integrated into the curriculum