Student Definitions of DEI in First-Year Engineering and Capstone Design

Dr. Bridget M. Smyser, Northeastern University

Dr. Smyser is a Teaching Professor in the department of Mechanical and Industrial Engineering. Her research interests include DEI in STEM, lab and design course pedagogy, and information literacy.

Dr. Susan F. Freeman, Northeastern University

Susan Freeman, is a member of Northeastern University's first-year engineering facutly, a group of teaching faculty expressly devoted to the first-year Engineering Program at Northeastern University. The focus of this team is on providing a consistent, engaging and hands-on experience for first-year students, hoping to excite and inspire them in the first step of their journey. There is a strong team, continuously improving on project-based curriculum for the first-year and beyond. Sudan Freeman is also the Associate Dean, Undergraduate Education.

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Like many universities, Northeastern University has several initiatives to improve diversity, equity, and inclusion (DEI) in its various programs. The authors have received an internal grant to develop the "New Engineering Toolbox", which will be a resource to help instructors bring DEI concepts into engineering courses. As part of this project, students were surveyed at the beginning and end of their first-year engineering (FYE) cornerstone course and at the beginning and end of their capstone design course. This allowed the authors to measure the impact of DEI materials that had been incorporated into courses. The intent of the survey was to examine student perceptions of the diversity of the program and the college/university to determine if they were satisfied with the present level of diversity and productive discourse between students of different backgrounds. These perceptions were investigated using a series of Likert scale questions. Additionally, students were asked open-ended questions about how they defined inclusion, equity, diversity, and inclusive design. They were also asked to provide examples of inclusive and non-inclusive design. Finally, they were asked whether they felt DEI topics should be covered in engineering courses. Open-response responses were analyzed to find common themes. The survey resulted in a total of 409 responses from FYE students representing all engineering disciplines. Only mechanical engineering capstone design students were surveyed, resulting in 30 responses. The surveys were anonymous, although a non-identifying marker was used to match before and after surveys from the same respondents. A total of 9 capstone students and 13 FYE students responded to both surveys. Results showed that incoming FYE students generally understand the concept of diversity, as do capstone design students. However, many FYE students conflate inclusion and diversity. Moreover, they struggle to define inclusive *design* and cannot generate many examples of inclusive designs. Capstone design students were better able to separate diversity and inclusion and were able to provide definitions and examples of inclusive and equitable designs. Both groups struggled to identify non-inclusive designs. Additionally, FYE students tended to be more satisfied with the diversity of the college and the university than capstone design students. Encouragingly, both groups reported refining their definitions of these concepts over the course of the term and several students reported altering their original design ideas to make them more inclusive. Based on these results, more specific examples of inclusive design are required, particularly at the freshman level. Students should also be required to specifically address DEI issues in their projects and should document their efforts in this vein. Future work involves expanding the survey to sophomore and junior-level classes to map the evolution of these concepts over time, as well as to generate course-specific examples of DEI concepts used to enhance learning in engineering courses.

Introduction

Universities are increasing their programming around diversity, equity, and inclusion (DEI) to make their campuses more welcoming places and to give students skills to work in a global

environment. For this programming to be effective, it is necessary to know students' views on these concepts and assess what they know about the intersection of engineering and DEI. Additionally, the authors wanted to know how students' ideas around this topic changed between their first and final years. Surveys and analysis of open responses have been used by previous researchers to study different cohorts in higher education, but few have attempted to assess the evolution of student thought during their studies.

Before discussing the size and significance of the issue of DEI in STEM, it is important to understand the working definitions of key terms as referred to in this paper. The Inclusive STEM Teaching Project is a MOOC supported by an NSF grant which aims to improve educators' skills in designing courses that are welcoming and effective for all students [1]. A definition of diversity from The Inclusive STEM Teaching Project course material is given as:

"Individual differences (e.g., personality, prior knowledge, and life experiences) and group/social differences (e.g., race/ethnicity, class, gender, sexual orientation, country of origin, and ability as well as cultural, political, religious, or other affiliations)."

This same source defines inclusion as:

"The active, intentional, and ongoing engagement with diversity—in the curriculum, in the co-curricular, and in communities (intellectual, social, cultural, geographical) with which individuals might connect—in ways that increase awareness, content knowledge, cognitive sophistication, and empathic understanding of the complex ways individuals interact within systems and institutions."

Finally, this work will use the following definition of equity:

"The fair treatment, access, opportunity, and advancement for all people, while at the same time striving to identify and eliminate barriers that have prevented the full participation of some groups. Improving equity involves increasing justice and fairness within the procedures and processes of institutions or systems, as well as in their distribution of resources. Tackling equity issues requires an understanding of the root causes of outcome disparities within our society."

These definitions are important as they will be used as the basis to assess student-generated definitions of these terms.

Magnitude and significance of the problem

According to a 2017 NSF report, 49% of those employed in science and engineering occupations are White men [2]. Women of all ethnicities make up 29% of this population. Asian men and women make up 21% of individuals in these occupations, with Black individuals at 5% and Hispanic individuals at 6%. Increasing diversity in STEM fields is important in the work environment to solve customer problems more effectively and promote a healthier work environment [3]. Today's problems are complex and global and cannot be solved without

changing the traditional culture of engineering [4]. Additionally, as the demographics of the U.S. continue to progress toward a minority-majority culture, it will become increasingly more difficult to find enough workers for STEM jobs unless higher education becomes more diverse and inclusive.

Many studies are based on gender differences. Women are 50% of the global population but range from 10-25% of engineers in most of the world. Even when underrepresented groups enter college to study STEM subjects, a lack of inclusion pushes these groups out of engineering at an alarming rate [5]. Gender equality in engineering is linked to both economic development and political ideology. For example, many women leave engineering in the U.S. due to health care and childcare concerns, which are centralized and subsidized more effectively in other parts of the world. Other countries have fluctuated in terms of the number of women studying engineering. Former Soviet bloc countries had approximately 50% woman engineers during the cold war and although the percentage declined a bit afterward, it is still higher than the U.S. in many of those countries. In the Middle East, 70% of Iranian engineering students are female. Women are not kept back by intellectual ability but by socio-cultural factors and national policies. [6]

Many companies such as Google and Microsoft are developing their own DEI initiatives to retain diverse employees, as more diverse organizations have better market growth. This is particularly true if a human-machine interaction is required [5]. A lack of inclusion can have other effects in addition to people leaving the profession or the field. Minority students who experience bias, discrimination, and exclusion tend to have lower GPAs than their majority peers. High-impact role models can help overcome some of these difficulties, but that can be difficult if the faculty itself is not diverse. Financial need also prevents people from joining or completing engineering programs. Financial aid tends to cover tuition. If a student's laptop is underpowered or broken, it can become a decision between fixing the laptop or food and rent. Many diversity-related problems have been identified, but few solutions have been offered. Some of the common solutions, such as active and project-based learning, can decrease confidence if minoritized students are isolated on teams. Despite efforts to date, the system still favors White, cis, affluent males [7].

Engineering culture

The field of engineering was historically developed by White, cis-gendered men from affluent backgrounds, and in many ways, engineering education is still optimized for that demographic. DEI programming that comes from the top down is not always effective, as it provides information without attempting to change the culture [8]. It is often easier to teach students teamwork skills than it is to teach them how to confront racism and systems of oppression [9]. Diversity workshops can be effective when they recognize both the commonalities between groups and the value of their differences. However, for students to develop empathy the

differences need to be made clearly visible and multiply-minoritized students should have opportunities to share their stories and form supportive bonds with other minoritized students [8].

Engineering culture tends to be laser-focused on technical knowledge. It prefers competition to collaboration and tends toward deficit model thinking where a person in some minority category is not in STEM because of some fault of theirs [10]. Engineers tend to be resistant to DEI efforts. Faculty are used to thinking of engineering as technical and objective, outside of any social or political factors. They want a general equation rather than to deal with messy people problems. However, technical content is always wrapped in some societal or cultural context. Culturally relevant pedagogy is needed but not always easy to implement [11].

Student attitudes and resistance can also be a barrier to reform. The prevailing attitude is still one of lecture-style learning and closed-form problems and they often fail to see how DEI concepts can mesh with the stereotypical teaching style. Students don't agree on the value of diversity instruction and what diversity really means. Their impression is that diversity doesn't immediately match with existing engineering culture. They agree that lecturing isn't the best way to learn DEI, but don't always have alternative ideas. [12]

The engineering ideal is still narrow and doesn't embrace diversity. Even administrators trying to improve DEI can see the topic as a marketing strategy rather than an inherent good. Another problem is that diversity is 'easy' to talk about, but inclusion and equity are not. Some view inclusion as a tool wielded by those in authority. Inclusion requires the group to include the individual, rather than for the individual to take on that burden. An ideal DEI environment encourages and hears authentic selves. People who want to improve DEI should engage in repeated reflection to allow their ideas to evolve over time. Those at the top of the hierarchy, who are often not from minoritized groups, particularly need to reflect on their privileges and positionalities in order to enact effective change [10].

Engineers are still viewed by society as oblivious and antisocial, which lessens the appeal of engineering to some. Others see engineering as heavily aligned with military and corporate interests rather than social justice problems. Engineers want to solve problems and are persistent about it, but they are resistant to change and rely on tradition. They learn to think analytically rather than critically which gets in the way of incorporating diverse social viewpoints into their solutions [13]. Students need to develop the concept of an engineering identity that is as concerned about the social context of the problem as the technical problem to be solved.

Some programs have had limited success in helping students develop inclusive engineering identities. Targeted programs may help some individuals and minority groups, but they don't change the culture. Faculty may be trained in creating inclusive classrooms, but this doesn't always translate to the students valuing DEI. Students need to have their own clear understanding of DEI before they can incorporate it into their engineering identity. The current study is attempting to determine student understanding of DEI at different levels [4].

Current studies of DEI attitudes and knowledge

One of the goals of this study is to assess the current knowledge of students at different points in their educational journey and to determine their attitudes toward DEI ideas. Many researchers have used a variety of methods to pursue these questions. In one study, researchers conducted interviews to determine students' views on the intersection of DEI and engineering education. In their responses, students focused a lot on cultural issues and recognized it is hard to teach this information. Like the current study, older students had a more nuanced understanding of the definitions of diversity, inclusion, and equity. The students agreed that working with diverse teams is an essential professional skill. Yet although they value DEI, they value technical knowledge more and don't want to take time away from the technical engineering content [12].

Survey-based studies are very common in research on this topic. However, the difficulty in assessing the outcomes of DEI interventions has been noted by researchers. Rambo-Hernandez et.al. were moved to develop a new scale to assess students' attitudes toward the value of DEI concepts in engineering and their intention to enact inclusive behaviors. Initial testing seemed to validate their scale, but their results did not indicate many significant changes in attitudes or intentions after various classroom interventions [3].

Baseline diversity surveys to assess climate are a necessary and often-used method for assessing student and faculty attitudes. Hartman et.al. discovered patterns of feeling othered for women, racial minorities, sexual minorities, and non-Christian students, with similar but less extensive patterns reported for faculty. In addition to student results, the researchers found that faculty in minoritized groups felt uncomfortable discussing or disclosing religious and sexual identities. Students indicated problems with being isolated in groups. Faculty need to be aware of non-technical issues as problems cannot be solved without considering the societal context [14].

Proposed solutions and assessments of their effectiveness

A wide variety of solutions have been proposed to develop more DEI awareness in STEM fields, particularly in an engineering context. Several authors focused their attention on first-year or introductory engineering courses. One author sought to improve diversity in a computer science class by including gender perspective as one of the course outcomes, linking course content with badges related to diversity concepts, and requiring inclusive language in documentation and diagrams [15]. The outcomes of this study did not seem to be systematically measured. Another group reported adding several interventions and activities in the first-year program. While these activities were somewhat effective at changing attitudes, the students noticed that DEI was included nowhere else in the curriculum. This signals to them that the topic is not really that important. DEI instruction was most effective when paired with intentional reflective activities and active teamwork. Working across cultures in teams is important, but this can slow down the work if scaffolding and guidance for effective cross-cultural interactions are not included.

Student feedback indicates that DEI needs to be a core value woven throughout the curriculum [16].

An extended NSF-funded study focused on interventions during the first-year experience. The researchers tried to improve students' DEI awareness in terms of understanding how this information can help fulfill a greater purpose, serve customers better, challenge discriminatory behavior, and promote healthy work environments and team behavior. They did this using interactive theater, reflection, and classroom instruction. It was only slightly effective at promoting healthy team behavior and had no effect on the other three points of awareness [3]. Findings showed that if students are not taught the importance of team diversity for generating radical innovations, then marginalization of underrepresented students can occur. This means teams may assign knowledge tasks inequitably, due to preconceived biases about the ability of different minoritized groups. Although the students showed gains in the ability to create healthy team environments in the intervention course, the control group showed decreased ability to create these environments over the course of the term. The researchers acknowledged that an improved method of assessment was needed and that their survey data could be flawed due to students rating themselves highly in various DEI skills [9]. It was interesting to note that their interventions were not overtly connected to engineering practice, which may explain the lack of success.

Another study looked at the need to consider both visible and invisible diversity at the college level. The college of engineering at Rowan University revised its admissions requirements to move to optional SAT scores, along with considering high school inequity factors. This intervention increased the number of underrepresented minorities in the college. They also developed mentoring programs for first-year students to help them identify more with engineering and assimilate into the engineering culture. Although this seems promising, caution is required to prevent 'assimilation' from becoming a need to suppress one's authentic self [14].

Another common theme discussed in the literature and the current study is the need to tie DEI concepts directly to engineering content. Without this clear connection, DEI topics can be seen as unimportant or 'other' [4]. One researcher discussed their efforts to infuse a civil engineering fluids course with DEI concepts. Their method for improving the course involved instructor training, a systematic review of course materials, and weekly faculty discussions on DEI topics. Several interventions encouraged students to consider engineering accomplishments from different social viewpoints. For example, engineers see the construction of a dam as a technological marvel, but Native Americans see it as destroying their land and culture [11]. As in the current study, researchers are attempting to find ways to add DEI concepts without decreasing the time spent on technical tasks and without requiring the instructor to change course content substantially [4]. Although [11] completely reconsidered the entire course, this may not be possible in all courses or departments due to a lack of resources. Tying DEI concepts to engineering with overt and intentional activities, along with opportunities for reflection, can generate the largest impact [4].

Finally, students themselves are a valuable source for identifying problems and offering recommendations. Often the students are not aware of college or university-level initiatives and assume that nothing is being done. In one study, students took the initiative to create their own forum and report on what they saw as diversity and inclusion-related difficulties. They perceived poor faculty-student relationships, biased student-student relationships, issues with advising, and poor communication of DEI policies and initiatives. They noted that student cultural organizations were beneficial in creating inclusive relationships, but that these organizations were expected to do the work to improve inclusion. The students recommended the creation of a Center for Engineering Diversity, structured project and lab teams to prevent isolation, stronger alumni/ae relationships, more formal mandatory training for faculty and TAs, teaching empathy and ethics in the first year, and altering syllabi to underline the value of DEI thinking. The students, without faculty intervention, came up with many of the same solutions as have been seen in the literature [17].

Methods

The complete survey administered to each class at the beginning of the term can be found in Appendix A. This will be referred to as the Before survey for the remainder of the paper. Surveys were distributed via campus email at the beginning of the Fall 2021 semester. Students surveyed included those in the Cornerstone of Engineering course in the First Year Engineering (FYE) program and those in the Capstone Design course (Capstone). Students were asked to provide the name of the street they grew up on as an identifier, in order to match before and after survey information. A similar but not identical set of surveys, found in Appendix B, was administered to both groups near the end of the term. This will be referred to as the After survey.

Survey data was compiled, and Pearson's product-moment correlation analysis was used to determine any significant relations between the responses to the Likert questions. Answers to the open-response questions were examined for common themes. After themes were developed, the responses were read a second time to code which responses fell under the themes. Finally, the responses were examined to find students who had answered both the before and after surveys. Their Likert and open responses were examined to discover any changes in their responses.

Results

The results include average scores for the Likert scale questions, significant correlations, and themes determined by textural analysis. Demographic information was extensive and therefore will not be presented in full, but any unexpected results will be discussed. In total 409 responses were received from the FYE students and 30 responses were received from Capstone students. Additionally, comparisons between the two groups are presented, along with comparisons of before and after results for the 13 FYE students and the 9 Capstone students who responded to both surveys.

First Year Engineering – Demographics and Likert Responses

The demographic data for the FYE students indicated several interesting results. Students who identify as queer or something other than heterosexual represent a very small percentage of the FYE class, which may indicate that these students are still exploring their gender identities. Latinx and Black students are very much a minority. Students reported more chronic mental health issues in the After survey, which may reflect either a poor reaction to the stress of their first year or more students seeking help and receiving diagnoses of these conditions. Most students in both surveys indicated no particular religion or identify as atheists. Students appeared to become more engaged in politics during the term, with fewer students reporting that they haven't considered politics in the After survey. The percentage of first-generation students was smaller in the After survey, which may indicate academic difficulties, although more information would be needed to verify this. Similarly, the percentage of working-class and low-income students decreased in the second survey, again potentially a sign of academic difficulties.

Tables 1-3 compare the average Likert scale results for the Before and After surveys. The results for each survey were compared using two sample t-tests assuming unequal variances, with the resulting P value for each item provided in the tables. Table 1 provides the result for the first seven questions, which inquired about the students' satisfaction with various measures for the College of Engineering (COE) and the entire university (NU). Only two questions yielded significant or near-significant differences. Satisfaction with gender diversity in COE decreased, while satisfaction with the diversity of points of view in their classes increased. Note that a larger score indicates a greater level of dissatisfaction.

Table 1: Results for satisfaction questions: average Likert scale responses for FYE students from Before and After surveys.

How satisfied are you with (1 = Very Satisfied, 4 = Very Dissatisfied)	Average Before Survey	Average After Survey	P at $\alpha = 0.05$
Sense of community in COE	1.82	1.62	0.22
Sense of community at NU	1.77	1.66	0.52
Ethnic/Racial Diversity in COE	1.67	1.6	0.39
Ethnic/Racial Diversity at NU	1.57	1.51	0.63
Gender Diversity in COE	1.6	1.66	0.03
Gender Diversity at NU	1.29	1.31	0.13
Diversity of points of view in your classes	1.69	1.42	0.05

Table 2 provides the results for questions related to social interactions. All but one of the questions yielded statistically significant differences. In this table, a lower score indicates that the given interaction occurred more often. Students reported studying with peers more often in

the After survey, had more discussions about inter-group relations, and felt more comfortable sharing their experiences with others. However, there were also an increased number of instances of students feeling threatened or insulted based on aspects of their identity as well as an increase in the number of such incidents witnessed by bystanders.

Table 2: Results for social interaction questions: average Likert scale responses for FYE students from Before and After surveys.

Since you arrived at NU, how often have you (1 = Very Often, 5 = Never)	Average Before Survey	Average After Survey	P at $\alpha = 0.05$
Studied or prepared for a class together	2.16	1.77	0.004
Socialized or shared a meal	1.84	1.66	0.26
Had meaningful and honest discussions about inter-group relations	2.76	2.14	<0.001
Felt comfortable sharing your own experiences	2.1	1.82	0.04
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	4.43	3.75	<0.001
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	4.49	3.73	<0.001

The final set of questions asked students about how they fit in on campus and whether they experienced any mental or financial stresses. As shown in Table 3, two of the four questions had significant differences between the two surveys. For these questions, a lower value indicates that the item occurred more often. There was a statistically significant increase in the number of students who recorded skipping meals due to financial difficulties. Additionally, there was an increase in students who felt that their social identity made things artificially more difficult for them.

Table 3: Results for campus fit questions: average Likert scale responses for FYE students from Before and After surveys.

Since you arrived at NU, how often have you (1 = Very Often, 4 = Rarely or Never)	Average Before Survey	Average After Survey	P at α = 0.05
Felt out of place or that you just didn't fit in at NU	3.33	3.12	0.34
Felt overwhelmed by all you had to do	2.45	2.18	0.07
Skipped meals or not had enough to eat because of financial constraints	3.67	3.32	0.04
Felt that aspects of your social identity made things artificially more difficult for you in U	3.55	3.12	0.009

Capstone Design – Demographics and Likert Responses

The surveys of the Capstone students had a rather low yield, with N = 17 for the Before survey and N=13 for the After survey. Additionally, 29% of the respondents did not provide demographic information in the Before survey. Despite the low yield, there were some interesting observations. Compared to the FYE students, the Capstone students were much more likely to have gender identities and sexual orientations that differ from the heteronormative and gender binary majority. More Capstone students identified as genderqueer, gender fluid, or questioning. The percentage of bisexual, queer, and asexual students in both Capstone surveys exceeded that of the FYE surveys. This may indicate students who are more secure in their gender and sexual identity compared to the FYE students. However, the Capstone respondents were less diverse, with no Black or Latinx students, several multiracial White/Latinx or White/Asian students, and a maximum of 8% Asian students. Although the sample size is too small to make any clear conclusions, the data could represent a lack of retention in underrepresented groups. The number of students reporting chronic mental health conditions was similar to the FYE students, but students also reported chronic medical conditions and learning disabilities. The Capstone students reported much more diversity in religious affiliation than the FYE students. Although most of the students identified with no religion or as atheists, the Capstone sample had identified Jewish, Muslim, and Protestant students. There were also a noticeable number of students who reported multiple religious groups. Only one student identified as having conservative political views and no one identified as very conservative. Compared to the FYE students, there was only one student who responded that they hadn't considered political views. Nearly a quarter of the students reported having parents who had not attended college. Finally, Capstone students primarily identified as middle- or upper-middle class, with no low-income students and only one wealthy student.

Tables 4-6 present the average scores for the Likert scale questions for the Before and After surveys for the Capstone students. No P values are presented as there were no statistically significant differences. Additionally, since all the students were in the Mechanical and Industrial Engineering Department (MIE), the students were asked about their satisfaction with the department rather than the college. Table 4 shows that although the differences were not significant, it was interesting that feelings of satisfaction in the measures of sense of community were higher after Capstone was over. Satisfaction also increased in terms of gender diversity, although interestingly more so in the department than in the university. Average scores for all other measures showed lower satisfaction. Given that the diversity of the Capstone sample seemed less than the FYE sample, it is not entirely surprising that satisfaction on that measure decreased.

Table 4: Results for satisfaction questions: average Likert scale responses for Capstone students from Before and After surveys. No statistically significant differences were found.

How satisfied are you with (1 = Very Satisfied, 4 = Very Dissatisfied)	Average Before Survey	Average After Survey
Sense of community in MIE	2.19	1.82
Sense of community at NU	2.00	1.65
Ethnic/Racial Diversity in MIE	2.06	2.18
Ethnic/Racial Diversity at NU	2.06	2.37
Gender Diversity in MIE	2.69	2.31
Gender Diversity at NU	2.69	2.55
Diversity of points of view in your classes	2.13	2.42

Table 5 shows the results for the social interaction questions. Once again, any differences were not statistically significant. Students reported fewer instances of studying or sharing a meal with their peers, having meaningful discussions, and feeling comfortable sharing experiences. Sadly, they also indicated an increase in events where either they or another student was harassed or insulted based on their social identity. These results may be due to a larger number of dissatisfied students taking the time to fill out the survey, but it is something that invites further study.

Table 5: Results for social interaction questions: average Likert scale responses for Capstone students from Before and After surveys. No statistically significant differences were found.

Since you arrived at NU, how often have you (1 = Very Often, 5 = Never)	Average Before Survey	Average After Survey
Studied or prepared for a class together	1.88	2.24
Socialized or shared a meal	1.88	2.43
Had meaningful and honest discussions about inter-group relations	2.44	2.89
Felt comfortable sharing your own experiences	2.13	2.35
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	4.00	3.78
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	3.94	3.79

The questions regarding campus fit, mental health, and financial stresses are discussed in Table 6. Interestingly, although there were no statistically significant differences, all four of these measures worsened between the beginning and end of Capstone. There was nearly no change in how the students felt about their fit at the university. However, there were more instances of feeling overwhelmed, skipping meals, and feeling that things were artificially difficult for them. Capstone design is extremely intensive and stressful, so feeling overwhelmed and having less time for paid work is typical. But the fact that students feel that things are more difficult because of their social identities warrants further examination.

Table 6: Results for campus fit questions: average Likert scale responses for Capstone students from Before and After surveys. No statistically significant differences were found.

Since you arrived at NU, how often have you (1 = Very Often, 4 = Rarely or Never)	Average Before Survey	Average After Survey
Felt out of place or that you just didn't fit in at NU	3.06	3.01
Felt overwhelmed by all you had to do	2.31	1.82
Skipped meals or not had enough to eat because of financial constraints	3.75	3.68
Felt that aspects of your social identity made things artificially more difficult for you at NU	3.44	3.35

Correlation Analysis

Table 7 shows the results of a Pearson's product-moment correlation analysis of answers to the Likert scale survey questions. Answers were coded to allow for computations. All significant correlations were positive but that does not mean that they were all beneficial. For instance, there was a strong positive correlation between the perception of ethnic and racial diversity in COE and that in Northeastern University as a whole. However, there was also a strong positive correlation between being insulted or threatened based on social identity and witnessing someone else being insulted or threatened based on social identity. There was also a positive correlation between feeling out of place and feeling that one's social identity made things artificially more difficult. There was a slight positive correlation between a higher social class and having parents who had graduated from college. Feeling out of place and feeling all overwhelmed also had a positive correlation although it was rather low.

Table 7:Significant Strong and Moderate Pearson's R values for related factors in FYE Before and After survey. Asterisks indicate correlations between undesirable factors

FYE Before Survey			FYE After Survey		
Factor 1	Factor 2	R	Factor 1	Factor 2	R
Ethnic/Racial Diversity in COE	Ethnic/Racial Diversity at NU	0.76	Ethnic/Racial Diversity in NU	Ethnic/Racial Diversity in COE	0.82
Ethnic/Racial Diversity at NU	Gender Diversity at NU	0.48	Ethnic/Racial Diversity in NU	Sense of community in NU	0.45
Ethnic/Racial Diversity in COE	Gender Diversity at NU	0.43	Gender Diversity in NU	Gender Diversity in COE	0.46
Gender Diversity in COE	Gender Diversity at NU	0.52	Gender Diversity in COE	Ethnic/Racial Diversity in COE	0.73
			Gender Diversity in COE/NU	Ethnic/Racial Diversity in COE/NU	0.58-0.64
Sense of community in COE	Sense of community at NU	0.48	Sense of community in NU	Sense of community in COE	0.64
Sense of community at NU	Ethnic/Racial Diversity in COE	0.40	Gender Diversity in COE/NU	Sense of community in COE/NU	0.51-0.54
Studied or prepared for a class together	Socialized or shared a meal	0.62	Socialized or shared a meal	Studied or prepared for a class together	0.65

Studied or prepared for a class together	Felt comfortable sharing your own experiences	0.48	Felt comfortable sharing your own experiences	Socialized or shared a meal	0.66*
Socialized or shared a meal	Felt comfortable sharing your own experiences	0.48	Had meaningful and honest discussions about inter-group relations	Socialized or shared a meal	0.60
Had meaningful and honest discussions about inter-group relations	Studied or prepared for a class together	0.47	Felt comfortable sharing your own experiences	Had meaningful and honest discussions about inter-group relations	0.64
Had meaningful and honest discussions about inter-group relations	Felt comfortable sharing your own experiences	0.55	Diversity of points of view in your classes	Gender and Ethnic/Racial Diversity in COE/NU	0.50-0.59
Had meaningful and honest discussions about inter-group relations	Socialized or shared a meal	0.48	Felt comfortable sharing your own experiences	Ethnic/Racial Diversity in NU	0.5
			Had meaningful and honest discussions about inter-group relations	Studied or prepared for a class together	0.49
			Felt comfortable sharing your own experiences	Studied or prepared for a class together	0.47
Did any of your parents a college degree	Which best describes your social class?	0.44	Social class	Did your parents or guardians complete a college degree?	0.69
Felt out of place or that you just didn't fit in NU	Felt social identity made things artificially more difficult	0.53	Felt out of place or that you just didn't fit at NU	Felt insulted or threatened based on your social identity	0.64*
Felt insulted or threatened based on your social identity	Witnessed someone else being insulted or threatened	0.76	Felt that aspects of your social identity made it difficult for	Felt insulted or threatened based on your social identity	0.66*
Felt out of place or that you just didn't fit in NU	Felt overwhelmed by all you had to do	0.43	Felt overwhelmed by all you had to do	Felt out of place or that you just didn't fit at NU	0.47*

			Felt out of place or that you just didn't fit at NU	Witnessed someone else being insulted	0.56*
			Felt that aspects of your social identity made things more difficult for you	Witnessed someone else being insulted	0.59*
			Felt that aspects of your social identity made things artificially more difficult for you at NU	Felt out of place or that you just didn't fit at NU	0.76*
			Skipped meals because of financial constraints	Felt insulted or threatened based on your social identity	0.60*
			Skipped meals or because of financial constraints	Felt out of place or that you just didn't fit at NU	0.56*
			Skipped meals or not had enough to eat because of financial constraints	Witnessed someone else being insulted	0.55*

Although many of these correlations show the overlap between desirable aspects of diversity, the correlations with asterisks show overlap of less desirable aspects. For example, there was a strong correlation between feeling that one's social identity made things artificially difficult and feeling out of place at NU. Feeling that things are artificially difficult is moderately correlated with feeling insulted or threatened based on social identity. Given the large number of white, straight, liberal, and male students, it would be very easy for underrepresented groups to become targets for discriminatory behavior. Two items showed moderate correlations with skipping meals due to financial considerations: feeling insulted or threatened based on social identity and feeling out of place at NU. Given the large majority of middle, upper-middle, and wealthy-class students, students with lower incomes with parents who are also struggling tend to feel left out. This is particularly an issue because socializing and sharing meals is positively correlated with feeling comfortable sharing experiences and having meaningful and honest discussions about inter-group relations. The students with the most to offer in these conversations may be left out because they cannot afford to socialize or eat out as frequently as other students. Skipping meals

was also correlated with witnessing threatening and insulting behavior, which may also point to minoritized students feeling less connected and more vulnerable and also more aware of micro- and macro-aggressions than the average student. Average students would most likely benefit from more contact with these minoritized students, provided tokenism could be avoided.

Table 8 shows the correlations for the Capstone before and after surveys. There were no strong positive correlations for the before survey, and the after survey had a number of significant negative correlations. Negative correlations and correlations between undesired factors are marked with asterisks. In the before survey there were five positive correlations between satisfaction factors and other factors. The strongest correlation was between being satisfied by gender diversity in the department and being satisfied with the ethnic/racial diversity in the department. In the after survey, only three of the correlations with satisfaction items were significant. The largest correlation was between satisfaction about the sense of community in the department and the college. There were two negative correlations in the before survey between satisfaction with ethnic/racial diversity in MIE and either feeling comfortable sharing experiences or socializing/sharing a meal. This indicates that students who were dissatisfied with the diversity in MIE seemed to socialize and share experiences more. This could be a case of minoritized students joining forces for support in a department they perceived as not supportive. In the after survey there were no negative correlations. Positive correlations in both surveys showed many correlations with feeling comfortable sharing their experiences. Students who had witnessed someone else being insulted or threatened were more likely to have meaningful discussions, feel comfortable sharing their own experiences, studied together, or socialized or shared a meal together. One possible reason might be that students who witness others being mistreated develop empathy which then could result in more constructive interactions. However, those who witnessed other students being insulted or threatened were also likely to report having skipped meals due to lack of funds, feeling overwhelmed, and feeling like aspects of their identities made their lives artificially difficult. This may indicate that students who witness others being mistreated are themselves at a disadvantage. Students who felt insulted and threatened themselves reported having meaningful and honest conversations, studying and socializing with others, and feeling comfortable sharing experiences. These students also reported skipping meals due to financial reasons. Satisfaction with gender diversity, both at the college and the department level was positively correlated with satisfaction with ethnic and racial diversity and with the sense of community in COE.

Table 8: Statistically significant correlations for the Capstone before and after surveys. Asterisks indicate correlations between undesirable factors

Capstone Design Before Survey			Capstone Design After Survey		
Factor 1	**Factor 2**	**R**	**Factor 1**	**Factor 2**	**R**
Diversity of points of view in your classes	Ethnic/Racial Diversity in MIE	0.41	Ethnic/Racial Diversity in COE	Sense of community in MIE	0.45
Gender Diversity in COE	Ethnic/Racial Diversity in MIE/COE	0.49-45	Gender Diversity in COE	Sense of community in MIE	0.51
Gender Diversity in COE	Sense of community in MIE/COE	0.58-0.53	Sense of community in MIE	Sense of community in COE	0.62
Gender Diversity in MIE	Ethnic/Racial Diversity in MIE/COE	0.60-0.42			
Gender Diversity in MIE	Sense of community in COE	0.46	Felt comfortable sharing your own experiences	Socialized or shared a meal	0.49
			Felt comfortable sharing your own experiences	Sense of community in MIE	0.42
Felt comfortable sharing your own experiences	Ethnic/Racial Diversity in MIE	-0.48	Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	Had meaningful and honest discussions about inter-group relations	0.55
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	Had meaningful and honest discussions about inter-group relations	0.61	Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	Socialized or shared a meal	0.42
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	Studied or prepared for a class together	0.60	Had meaningful and honest discussions about inter-group relations	Socialized or shared a meal	0.61
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	Socialized or shared a meal	0.54	Studied or prepared for a class together	Ethnic/Racial Diversity in MIE	0.45
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	Felt comfortable sharing your own experiences	0.53	Studied or prepared for a class together	Gender Diversity in MIE	0.43

Felt overwhelmed by all you had to do	Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	0.42*	Studied or prepared for a class together	Ethnic/Racial Diversity in COE	0.42
Socialized or shared a meal	Ethnic/Racial Diversity in MIE	-0.42*	Studied or prepared for a class together	Gender Diversity in COE	0.41
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	Had meaningful and honest discussions about inter-group relations	0.67	Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	Had meaningful and honest discussions about inter-group relations	0.63
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	Felt comfortable sharing your own experiences	0.64	Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	Socialized or shared a meal	0.40
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	Studied or prepared for a class together	0.62			
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	Socialized or shared a meal	0.59	Felt out of place or that you just didn't fit in MIE	Sense of community in MIE/COE	-0.75--0.54*
			Felt out of place or that you just didn't fit in MIE	Gender Diversity in COE	-0.52*
Felt out of place or that you just didn't fit in MIE	Studied or prepared for a class together	0.54	Felt out of place or that you just didn't fit in MIE	Felt comfortable sharing your own experiences	-0.52*
Felt out of place or that you just didn't fit in MIE	Had meaningful and honest discussions about inter-group relations	0.45	Felt out of place or that you just didn't fit in MIE	Ethnic/Racial Diversity in COE	-0.49*
Felt overwhelmed by all you had to do	Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	0.42*	Felt out of place or that you just didn't fit in MIE	Diversity of points of view in your classes	-0.42*
Felt that aspects of your social identity made things artificially more difficult for you in MIE	Felt overwhelmed by all you had to do	0.53*	Felt overwhelmed by all you had to do	Ethnic/Racial Diversity in MIE	-0.43*

Felt that aspects of your social identity made things artificially more difficult for you in MIE	Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	0.49*	Felt that aspects of your social identity made things artificially more difficult for you in MIE	Felt out of place or that you just didn't fit in MIE	0.53*
Skipped meals or not had enough to eat because of financial constraints	Ethnic/Racial Diversity in COE	0.62	Felt that aspects of your social identity made things artificially more difficult for you in MIE	Socialized or shared a meal	0.45
Skipped meals or not had enough to eat because of financial constraints	Sense of community in COE	0.57	Felt that aspects of your social identity made things artificially more difficult for you in MIE	Sense of community in COE/MIE	-0.65 - 0.52*
Skipped meals or not had enough to eat because of financial constraints	Gender Diversity in COE	0.54	Felt that aspects of your social identity made things artificially more difficult for you in MIE	Ethnic/Racial Diversity in COE	-0.54*
Skipped meals or not had enough to eat because of financial constraints	Ethnic/Racial Diversity in MIE	0.47	Felt that aspects of your social identity made things artificially more difficult for you in MIE	Diversity of points of view in your classes	-0.47*
Skipped meals or not had enough to eat because of financial constraints	Sense of community in MIE	0.45	Felt that aspects of your social identity made things artificially more difficult for you in MIE	Ethnic/Racial Diversity in MIE	-0.46*
Skipped meals or not had enough to eat because of financial constraints	Felt out of place or that you just didn't fit in MIE	0.56*	Felt that aspects of your social identity made things artificially more difficult for you in MIE	Gender Diversity in COE/MIE	-0.43 - 0.41*
Skipped meals or not had enough to eat because of financial constraints	Diversity of points of view in your classes	0.56	Skipped meals or not had enough to eat because of financial constraints	Felt out of place or that you just didn't fit in MIE	0.58*
Skipped meals or not had enough to eat because of financial constraints	Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	0.48*	Skipped meals or not had enough to eat because of financial constraints	Felt comfortable sharing your own experiences	-0.51*

Skipped meals or not had enough to eat because of financial constraints	Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	0.53*
Did any of your parents or guardians complete a college degree (Bachelor's or higher)?	Gender Diversity in MIE	-0.47*
Which of the following best describes your social class when you were growing up?	Ethnic/Racial Diversity in COE	-0.40*

The negative correlations in Table 8 reveal several interesting observations that warrant additional discussion. In the before survey, the lower the satisfaction with ethnic/racial diversity in COE, the higher the reported social class of the respondent. Given that most of the respondents were white, this desire for ethnic and racial diversity may reflect increased awareness of the need for this diversity among the students. People who socialized or shared a meal with someone of a different background were negatively correlated with satisfaction with ethnic and racial diversity in MIE. A desire to socialize with more diverse peers may be thwarted by a lack of diversity. Students whose parents had attended college were less likely to be satisfied with the gender diversity in MIE. Assuming many of the students have both male and female-identifying parents, it may be that they expect more or less equal numbers of different genders based on their parents' experiences. When this turns out not to be true, it may lead to dissatisfaction. Finally, students who felt comfortable sharing their own experiences were likely dissatisfied with ethnic and racial diversity in MIE. It is not immediately clear why this is the case. It could be that students who are comfortable sharing experiences recognize that the reason they feel comfortable is that they see a lot of peers who share the same race. Students who are this aware may be calling for more diversity in the department and college.

In the after survey, one strong negative correlation was between the sense of community in MIE and feeling out of place in MIE. This makes sense as it is hard to see a sense of community if one feels out of place. The sense of community in either COE or MIE was also negatively correlated with the feeling that one's social identity made things artificially difficult. Students who felt that aspects of their social identity made things difficult for them had lower satisfaction with ethnic/racial/gender diversity as well as a lower satisfaction with the diversity of viewpoints in classes. As the demographic data showed, most of the respondents were straight, white, middle to upper-middle-class males. Students who did not fit this heteronormative mold seem to feel the differences in a significant way. There were a few correlations that seem a bit more difficult to explain. One is the negative correlation between skipping meals due to financial difficulties and feeling comfortable sharing experiences. This could be indicating a sense of embarrassment at not being as financially stable as their classmates or spending less time socializing with them due to financial constraints. The other negative correlation that stood out was between feeling

overwhelmed and the satisfaction with ethnic/racial diversity in MIE. This was a weaker correlation that does not seem to have a ready explanation.

Analysis of Open Responses

The open-ended questions on the first-year survey and the before capstone survey are the most comparable, as the questions changed for the after capstone survey. The question “In your own words, provide your definition of diversity” was answered by both ‘before’ cohorts. A comparison of the themes identified in the responses is shown in Table 9. Both cohorts had similar themes, however, 8% of the first-year responses seemed to equate diversity with inclusion, which is a different concept. Both groups had roughly the same percentage of responses that mentioned race or ethnicity in their responses, however,r a higher percentage of capstone students mentioned gender diversity and sexual orientation. The first-year students were more likely to mention diversity of origins and/or religions in their responses.

Table 9: Comparison of themes in responses to the question 'Provide your definition of diversity

First-year 'Before' Survey	**Percentage of Responses**	**Capstone 'Before' Survey**	**Percentage of Responses**
Race/Ethnicity	37	Race/Ethnicity	33
Gender	16	Gender	33
Sexual Orientation	14	Sexual Orientation	22
Ideas	26	Ideas	11
Backgrounds/Origins/Religions	54	Backgrounds/Origins/Religions	44
Coexist/Are represented	21	Coexist/Are represented	33
Other	20	Variety	56
Variety	20	Other	33
Inclusion	8		

The definitions of inclusion and diversity discussed in the introduction were used to evaluate the student responses. Many first-year students were unable to define diversity without using the word inclusion. An example is:

“Diversity is inclusion that is not based on race, gender, or any other feature. Diversity is inclusion of all people, regardless of the aforementioned attributes.”

Senior students generally have a definition closer to the accepted definition such as:

"Diversity is a mixture of different people with different races, ethnicities, genders, sexual orientations, etc that can feel safe and heard in their experiences."

Both groups listed similar examples of diversity in terms of different social identities, but the senior students tended to have more sophisticated and mature answers overall.

Themes found in the answers to the question "In your own words, provide your definition of equity in design" are compared in Table 10. One very noticeable difference between the first-year students and the seniors is how few of the first-year students used the word 'Design' in their responses. They discussed equity in terms of fairness and equality, or opening new opportunities for disadvantaged groups, or providing accessibility, but very few of them linked it to design in any clear way. When the first-year students did discuss design, the result was a rather narrow answer that showed an incomplete understanding of the question:

"Equity means that everyone is capable and have the ability to use the new design. For instance, equity in the design of a bicycle entails a design where all people are able to pedal and operate the bike regardless of their age."

Senior students also mentioned disabilities/accessibility issues in their responses, but many more of their answers emphasized the need to be able to broaden the user range of a design. The largest percentage of responses focused on using design to improve society, provide opportunities to a broad range of individuals, and remedy past inequities. Two of the senior responses embody this more mature understanding of the question:

"Equity, as it pertains to design, is when a design embodies accessibility to a wide array of users, and a thoughtful consideration of the deeply diverse range of abilities present in the world."

"Equity design is a creative process to dismantle systems of oppression and (re)design towards liberation and healing by centering the power of communities historically impacted by the oppressive systems being (re)designed."

The response of the seniors is clearly closer to the definition presented in the introduction than the first-year students, whether that is due to personal maturity or exposure to DEI concepts during their undergraduate career.

Table 10: Open response themes for the question "Provide your definition of equity in design"

First Year 'Before' Survey	**Percentage of responses**	**Capstone 'Before' Survey**	**Percentage of responses**
Fairness	18	Design	33
Equality	32	Disabilities	22
Justice	6	Wide user range	22
Meets Needs	28	Remedy past wrongs/Opportunity	67
Accessibility	6	Other	44
Design	13		
Opportunity	35		
Other	20		

The themes found in the responses to the question "In your own words, provide your definition of inclusive design" are summarized in Table 11. 40% of the first-year students could not answer this question without using the word 'inclusive' or replacing 'inclusive' with some version of 'doesn't exclude'. They often equated it with solving certain problems or accommodating certain needs, but again failed to connect it to design 75% of the time. Those who did connect their definition to design often discussed the design *process* rather than the concept of an inclusively designed product. One example of this type of response is:

"Inclusivity means that each member involved in the design process has equal weight and all ideas are given the same consideration as others before a decision is made."

In this response, inclusivity is within a working group, rather than in the designing of a product that can be used by a wide number of users, particularly those who have previously been excluded from using certain products or services. The senior students once again mentioned design much more often, with 56% of the responses explicitly discussing design. One such comment was:

"Inclusive design is a design for which distinct groups that are often overlooked or ignored when considerations are being made in the design phase are explicitly considered when new designs or innovations are being made."

Other senior students focused more directly on product outcomes:

"Inclusive design is a design process in which a mainstream product, service or environment is designed to be usable by as many people as reasonably possible, without the need for specialized adaptions."

Table 11: Open response themes in answers to the question 'Provide your definition of inclusive design'

First-Year Before	**Percentage of responses**	**Capstone Before**	**Percentage of responses**
Space/Environment	5	Space/Environment	11
Inclusive/ Doesn't Exclude	40	Wide User Range	56
Multiple inputs & ideas	25	Multiple inputs & ideas	22
Accommodation	7	Accommodation	22
Accessibility	13	Participation	33
Participation	16	Design actually mentioned	56
Design actually mentioned	25	Other	33
Other	21		

The next open-response question asked, "From your experience, describe an example of a design that was not inclusive". Table 12 shows the primary themes identified in the responses to this question. Both cohorts had a percentage of students who could not come up with any example of a non-inclusive design. Of the respondents who did come up with an example, 31% of the first-year students and 43% of the capstone students came up with designs that addressed physical disabilities or characteristics. Other first-year responses addressed some sort of discrimination – racial, gender, orientation, or financial. But several first-year students had examples based on social interactions related to high school experiences:

"A design that is not inclusive is the early college program. The early college high schools only accept students were performed exceptionally in their academics. "

The seniors also came up with examples that stemmed from social interactions or that addressed financial inequalities, in similar percentages. However, 57% of the students had responses that discussed specific, concrete products or services. Some responses that did zero in on product design showed clear insight:

"There was a specific component that was colored gray-ish with red components where critical identification was needed. This was not friendly to color-blind individuals."

Overall, both cohorts struggled somewhat to come up with examples of non-inclusive designs and tended to come up with ideas in a rather narrow selection of topics. First-year students additionally struggled with identifying specific examples of products or services, in contrast to the senior students.

Table 12: Open response themes in answers to the question 'Describe a design that was not inclusive'

First-Year Before	**Percentage of responses**	**Capstone Before**	**Percentage of responses**
Physical disabilities/ qualities	31	Physical disabilities/ qualities	43
Can't think of one	8	Can't think of one	14
Discrimination (Race, Gender, Orientation)	29	Product or Service	57
Financial Discrimination	6	Financial Discrimination	14
Skill based	9	Social Aspects	29
Social Aspects	27	Other	29
Other	19		

Table 13 shows the results from the analysis of the question "From your experience, describe an example of a design that was inclusive". For this question, all the senior respondents were able to come up with an example of some kind, whereas 5% of the first-year students could not. As in the previous section, a fairly large percentage of each group focused on designs that addressed physical limitations. The first-year answers also continued to have a strong focus on forms of discrimination being addressed by some intervention, although not necessarily a concrete service or product. However, 21% of the first-year students did identify a particular product or service whereas none of the first-year students were able to do so for a non-inclusive design. This may point to the need for more explicit examples of non-inclusive design in the first-year program to allow students to better recognize and avoid flawed designs.

Senior students, on the other hand, had 75% of their answers focused on products and product design. Like the first-year students, they did have some responses that related to course activities or social experiences. Unlike the first-year students, they did mention the need to appeal to/be

used by a wide range of users. Physical limitations were mentioned in half of the responses, but other forms of discrimination were not. The contrast can be seen between a first-year response:

"Designing everything with wheelchairs in mind, because this can benefit people of all identities."

and a senior response:

"The shoes that pop on and off without using their hands. Their[sic] *super quick, easy, comfy, and cool. They're great for people with disabilities and not."*

Both responses are focused on people with disabilities. However, the first-year response is rather vague, while the senior response addresses a specific product. The senior response also recognizes the importance of appealing to a wide audience, not just a specific narrowly defined group.

Table 13:Open response themes in answers to the question 'Describe a design that was inclusive'

First Year Before	**Percentage of responses**	**Capstone Before**	**Percentage of responses**
Physical disabilities/ qualities	34	Course/Social experience	25
Can't think of one	5	Product Design	75
Race, Gender, Orientation	6	Physical limitations	50
Financial Discrimination	5	Many Users	13
Skill based	2		
Social Aspects	30		
Product or service	21		
Other	19		

The next question asked students to, "Describe an experience (can be hypothetical) where engineering can be used to increase social justice." The results shown in Table 14 show several common themes including housing and financial equity, educational equity, reducing bias, promoting justice in the legal system, and transportation and other infrastructure. The first-year students also specifically addressed healthcare and accessibility as areas where engineers could contribute. The largest percentage of first-year responses were categorized as 'other'. These included answers such as "I don't know" or "I'm not sure", answers which seemed to not understand the question, and answers that were somewhat difficult to follow such as:

"Engineers could volunteer to design and build a building or statue dedicated to helping social justice or for a good cause."

While this is true, it may not be the best use of engineering skills to further social justice by coming up with an engineered solution to a real problem. However, there were first-year answers that showed some maturity and understanding such as:

"Engineers engage in research, teaching, and community engagement. Through these tactics they can look at issues within communities and try to solve them. EX: Clean water."

Senior students also had several comments about education and its impact such as:

"Providing a good engineering education and environment in different communities creates more engineers from those backgrounds, able to address problems that others may not be aware of"

Another answer explored the interactions between innovation and financial inequality:

"Engineering frequently drives innovation. The problem with innovation is that cutting edge technology tends to come with a price tag. That price makes it prohibitively expensive to the majority of people. If all technological progress benefits the wealthy first then progress becomes an engine by which inequality is driven. Using engineering design principals to bring costs down serves to make technologies more egalitarian."

Both of these answers highlight using information from the minority to solve problems for everyone. The second answer further underlines the fact that engineering can both strengthen and weaken social justice, which is not something first-year students typically pick up on.

Table 14: Open response themes in answers to the question 'Describe how engineering could be used for social justice'

First Year Before	**Percentage of responses**	**Capstone Before**	**Percentage of responses**
Housing/ Homelessness/ Financial Equity	18	Housing/ Homelessness/ Financial Equity	14
Educational Equity	15	Educational Equity	43
Reducing bias	16	Reducing bias	14
Healthcare	2	Transportation/ Infrastructure	14
Transportation/ Infrastructure	18	Legal/ Justice	29
Accessibility	11	Other	14
Legal/ Justice	6		
Other	31		

Finally, the students in both cohorts were asked, “Do you believe diversity, equity, and inclusion should be included in the engineering curriculum? Why or why not?” The results, shown in Table 15 indicate a resounding yes from both sets of students. However, the few ‘no’ votes had different reasons for that response between the two cohorts. The first-year ‘no’ responses included some that said that DEI topics were not relevant to engineering, or that if they were included, they should not be a big focus. In contrast, the senior students who said ‘no’ explained that it should be taught at the university level because all students need this information, not just engineers. The relevance of these topics seemed very obvious to the seniors, but less so to some of the first years. In fact, 100% of the seniors said that DEI topics are fundamental ideas that everyone should learn about, versus 24% of the first-year students. What is interesting, and encouraging, is that the percentage of students who thought that knowledge of these topics leads to better engineering was nearly the same for both cohorts. Although only roughly a quarter of each cohort specifically mentioned the engineering benefits of diversity, there is at least some understanding of the concept from both ends of the curriculum. Both cohorts were also nearly equal in the percentage of students who said something to the effect of, “This is important because this is the way the world is.” The recognition that engineering needs to exist in the world and that the world is inherently diverse seems like the first step in connecting diversity and engineering.

Table 15: Open response themes in answers to the question ‘Should DEI be included in the engineering curriculum?’

First-Year Before	**Percentage of responses**	**Capstone Before**	**Percentage of responses**
Yes	90	Yes	88
No	10	No	13
Said why?	82	Said why?	100
Foundational issue/Everyone needs	24	Foundational issue/Everyone needs	100
World is diverse	23	World is diverse	25
Fixes a personal/Social issue	22	Fixes a personal/Social issue	13
Better Engineering	21	Better Engineering	25
Shouldn't be big focus	13		
Not relevant/taught elsewhere	7		

Discussion and Conclusions

There are several important thematic conclusions from this large amount of data to consider.

- First year students report working together more over the course of that first year, in many ways. They appear to be building a community
- Capstone students have a community but are more attuned to differences and diversity and so report it less positively.
- Studying together, sharing meals together, and other community-type activities correlate with sharing viewpoints more freely.
- There are negative issues that arise over time and increased awareness of injustices, such as witnessing harassment and feeling out of place over the time between the first year and capstone.
- Understanding of equity and inclusion in design increases as it is discussed and over time when the first-year students are in capstone, it will be even more interesting to see if that first-year exposure had a significant effect.

Where does this lead for next steps? These themes suggest some possible continued efforts and work.

1. Provide opportunities, starting in the first year, for students to meet and work together. Possibly provide meals to help those struggling. This will build early that sense of community. Have these events bring larger groups together to not have these be naturally occurring affinity groups, but groups of more diverse backgrounds and thinking.
2. Further work between first-year and capstone to discover if students are witnessing or experiencing harassment. If so, try to dig more deeply into the cause and how to correct any situations.
3. More touchpoints between first year and capstone on equitable and inclusive design and also about inclusive practice, reinforcing the concepts introduced in the first year.
4. Survey after this cohort has reached capstone to see if there has been an effect.

Although the result is not surprising, the number of disenfranchised students that feel isolated is a continued cause for concern. On the other hand, the sense of community and willingness to discuss challenging concepts is also clear. Students have continued to tell us that they want and need to be heard on these topics and that DEI is important to them.

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Appendix A: ‘Before’ Surveys for First Year Engineering and Capstone Design

Note: Several questions (Q4-Q20) were the same for both surveys. As such they will only be shown once.

Before DEI Survey FYE Fall 2021

Start of Block: Default Question Block

Q13 **First Year Engineering Beginning of Term Diversity, Equity, and Inclusion Survey**
This survey is anonymous, voluntary, and confidential. We will ask you to create an identifier to track the responses over time. This research is funded by a Faculty Innovations in Diversity and Academic Excellence Grant from the Unknown University Provost Office.

Q1 How satisfied have you been with the following aspects of your experience at Unnamed University so far this year?

	Very Satisfied (1)	Somewhat Satisfied (2)	Somewhat Dissatisfied (3)	Very Dissatisfied (4)	N/A (5)
Sense of community in COE (1)	○	○	○	○	○
Sense of community at UU (2)	○	○	○	○	○
Ethnic/Racial Diversity in COE (3)	○	○	○	○	○
Ethnic/Racial Diversity at UU (4)	○	○	○	○	○
Gender Diversity in COE (5)	○	○	○	○	○
Gender Diversity at UU (6)	○	○	○	○	○
Diversity of points of view in your classes (7)	○	○	○	○	○

Q2 Since you’ve been at Unnamed University how often have you had the following interactions with students who differed from you in race, national origin, sexual orientation, political views, or religion at Unnamed University?

	Very Often (1)	Often (2)	Occasionally (3)	Rarely (4)	Never (5)
Studied or prepared for a class together (1)	○	○	○	○	○
Socialized or shared a meal (2)	○	○	○	○	○
Had meaningful and honest discussions about inter-group relations (3)	○	○	○	○	○
Felt comfortable sharing your own experiences (4)	○	○	○	○	○
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.) (5)	○	○	○	○	○
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity (6)	○	○	○	○	○

Q3 Since you've been at Unnamed University, how often have you:

	Very Often (1)	Often (2)	Occasionally (3)	Rarely or Never (4)
Felt out of place or that you just didn't fit in UU (1)	○	○	○	○
Felt overwhelmed by all you had to do (2)	○	○	○	○
Skipped meals or not had enough to eat because of financial constraints (3)	○	○	○	○
Felt that aspects of your social identity made things artificially more difficult for you in UU (4)	○	○	○	○

Q4 The following open-ended questions are meant to probe your views about diversity in relationship to engineering and engineering design.

Q5 In your own words, provide your definition of **diversity**.

Q6 In your own words, provide your definition of **equity** in design

Q7 In your own words, provide your definition of **inclusive** design

Q8 From your experience, describe an example of a design that was **not** inclusive

Q9 From your experience, describe an example of a design that **was** inclusive

Q10 Describe an experience (can by hypothetical) where engineering can be used to increase social justice.

Q11 Do you believe diversity, equity, and inclusion should be included in the engineering curriculum? Why or why not?

Q12 Which of the following best describes your gender identity? Mark all that apply.

- [ ] Agender (1)
- [ ] Androgyne (2)
- [ ] Demigender (3)
- [ ] Genderqueer or gender fluid (4)
- [ ] Man (5)
- [ ] Questioning or unsure (6)
- [ ] Trans man (7)
- [ ] Trans woman (8)
- [ ] Woman (9)
- [ ] Prefer not to disclose (10)
- [ ] Other gender identity. Please specify: (11) _____

Q13 What is your sexual orientation? Mark all that apply.

- [ ] Asexual (1)
- [ ] Bisexual (2)
- [ ] Gay (3)
- [ ] Straight (heterosexual) (4)
- [ ] Lesbian (5)
- [ ] Pansexual (6)
- [ ] Queer (7)
- [ ] Questioning or unsure (8)
- [ ] Same-gender loving (9)
- [ ] Prefer not to disclose (10)
- [ ] Other gender identity. Please specify: (11) _____

Q14 What is your race or ethnicity? Mark all that apply

- [ ] American Indian or Alaska Native (1)
- [ ] Asian (2)
- [ ] Black or African American (3)
- [ ] Hispanic or Latino (4)
- [ ] Native Hawaiian or Other Pacific Islander (5)
- [ ] White (6)

Q18 Are you a veteran of the U.S. Armed Forces, Military Reserves, or National Guard?

- ○ Yes (1)
- ○ No (2)

Q15 Do you have any of the following disabilities or chronic conditions?

- [ ] Learning disability or ADHD (1)
- [ ] Mobility or sensory disability (e.g., prosthetic, spinal cord injury, hard of hearing, low vision, etc.) (2)
- [ ] Chronic mental health condition (e.g., depression, PTSD, etc.) (3)
- [ ] Chronic medical condition (e.g., cystic fibrosis, diabetes, chronic pain, etc.) (4)
- [ ] Other disability or chronic condition (please specify): (5) _____
- [ ] None of the above (6)

Q16 Which religious, spiritual, or philosophical tradition do you practice or identify with? Mark all that apply.

- [ ] Protestant (1)
- [ ] Roman Catholic (2)
- [ ] Another type of Christian (e.g., Orthodox, LDS, etc.) (3)
- [ ] Buddhist (4)
- [ ] Hindu (5)
- [ ] Jewish (6)
- [ ] Muslim (7)
- [ ] Atheist (8)
- [ ] Some other religious, spiritual, or philosophical tradition (9)
- [ ] Spiritual but do not identify with a religious tradition or group (10)
- [ ] None (11)

Q17 How would you describe your political views?

- ○ Very liberal (1)
- ○ Liberal (2)
- ○ Moderate/Middle-of-the-road (3)
- ○ Conservative (4)
- ○ Very conservative (5)
- ○ Something else (6)
- ○ Haven't thought that much about it (7)

Q18 Did any of your parents or guardians complete a college degree (Bachelor's or higher)?

- ○ Yes (1)
- ○ No (2)

Q19 Which of the following best describes your social class when you were growing up?

- ○ Low Income (1)
- ○ Working Class (2)
- ○ Middle Class (3)
- ○ Upper-Middle or Professional Class (4)
- ○ Wealthy (5)

Q20 Please enter the name of the street you grew up on. This will be used to match before and after surveys.

Q13

Capstone Beginning of Term Diversity, Equity, and Inclusion Survey

This survey is anonymous, voluntary, and confidential. We will ask you to create an identifier to track the responses over time.

This research is funded by a Faculty Innovations in Diversity and Academic Excellence Grant from the [redacted] University Provost Office.

Q1

How satisfied have you been with the following aspects of your experience at [redacted] during the current academic year?

	Very Satisfied	Somewhat Satisfied	Somewhat Dissatisfied	Very Dissatisfied	N/A
Sense of community in COE	○	○	○	○	○
Sense of community in MIE	○	○	○	○	○
Ethnic/Racial Diversity in COE	○	○	○	○	○
Ethnic/Racial Diversity in MIE	○	○	○	○	○
Gender Diversity in COE	○	○	○	○	○
Gender Diversity in MIE	○	○	○	○	○
Diversity of points of view in your classes	○	○	○	○	○

During this academic year, how often have you had the following interactions with students who differed from you in race, national origin, sexual orientation, political views, or religion at [redacted]

	Very Often	Often	Occasionally	Rarely	Never
Studied or prepared for a class together	○	○	○	○	○
Socialized or shared a meal	○	○	○	○	○
Had meaningful and honest discussions about inter-group relations	○	○	○	○	○
Felt comfortable sharing your own experiences	○	○	○	○	○
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.)	○	○	○	○	○
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity	○	○	○	○	○

Q4

During the current academic year, how often have you:

	Very Often	Often	Occasionally	Rarely or Never
Felt out of place or that you just didn't fit in MIE	○	○	○	○
Felt overwhelmed by all you had to do	○	○	○	○
Skipped meals or not had enough to eat because of financial constraints	○	○	○	○
Felt that aspects of your social identity made things artificially more difficult for you in MIE	○	○	○	○

Appendix B: ‘After’ Surveys for First Year Engineering and Capstone Design

Note: The demographics questions (Q14-Q20) were the same as the ‘Before’ surveys. As such they will not be repeated here.

After DEI Survey FYE

FYE End of Term Diversity, Equity, and Inclusion Survey

This survey is anonymous, voluntary, and confidential. We will ask you to create an identifier to track the responses over time. This research is funded by a Faculty Innovations in Diversity and Academic Excellence Grant from the Northeastern University Provost Office.

Q1 How satisfied have you been with the following aspects of your experience at Northeastern during the current academic **term**?

	Very Satisfied (1)	Somewhat Satisfied (2)	Somewhat Dissatisfied (3)	Very Dissatisfied (4)	N/A (5)
Sense of community in COE (1)	○	○	○	○	○
Sense of community in NU (2)	○	○	○	○	○
Ethnic/Racial Diversity in COE (3)	○	○	○	○	○
Ethnic/Racial Diversity in NU (4)	○	○	○	○	○
Gender Diversity in COE (5)	○	○	○	○	○
Gender Diversity in NU (6)	○	○	○	○	○
Diversity of points of view in your classes (7)	○	○	○	○	○

Q2 During this academic **term**, how often have you had the following interactions with students who differed from you in race, national origin, sexual orientation, political views, or religion at Northeastern?

	Very Often (1)	Often (2)	Occasionally (3)	Rarely (4)	Never (5)
Studied or prepared for a class together (1)	○	○	○	○	○
Socialized or shared a meal (2)	○	○	○	○	○
Had meaningful and honest discussions about inter-group relations (3)	○	○	○	○	○
Felt comfortable sharing your own experiences (4)	○	○	○	○	○
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.) (5)	○	○	○	○	○
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity (6)	○	○	○	○	○

Q3 During the current academic **term**, how often have you:

	Very Often (1)	Often (2)	Occasionally (3)	Rarely or Never (4)
Felt out of place or that you just didn't fit at NU (1)	○	○	○	○
Felt overwhelmed by all you had to do (2)	○	○	○	○
Skipped meals or not had enough to eat because of financial constraints (3)	○	○	○	○
Felt that aspects of your social identity made things artificially more difficult for you at NU (4)	○	○	○	○

Q4 The following open-ended questions are meant to probe your views about diversity in relationship to engineering and engineering design.

Q5 Thinking back to the beginning of term, has your definition of equity in design changed?

Q6 Thinking back to the beginning of term, has your definition of inclusive design changed?

Q7 After the material **on Design for Diversity, Equity, and Inclusion (DEI)** was presented, did you revise or alter your design to consider other points of view or a broader audience? If so, describe what you did.

Q8 Was there any particular case or example presented in class that helped you view your design differently? .

Q9 Can you think of other examples of equity and design after seeing the material on the topic or viewing other students' work?

Q10 Do you believe diversity, equity, and inclusion should be included in the engineering curriculum? Why or why not?

After DEI Survey Capstone Fall 2021

Capstone End of Term Diversity, Equity, and Inclusion Survey

This survey is anonymous, voluntary, and confidential. We will ask you to create an identifier to track the responses over time. This research is funded by a Faculty Innovations in Diversity and Academic Excellence Grant from the Northeastern University Provost Office.Q1 How satisfied have you been with the following aspects of your experience at Northeastern during the current academic **term**?

	Very Satisfied (1)	Somewhat Satisfied (2)	Somewhat Dissatisfied (3)	Very Dissatisfied (4)	N/A (5)
Sense of community in COE (1)	○	○	○	○	○
Sense of community in MIE (2)	○	○	○	○	○
Ethnic/Racial Diversity in COE (3)	○	○	○	○	○
Ethnic/Racial Diversity in MIE (4)	○	○	○	○	○
Gender Diversity in COE (5)	○	○	○	○	○
Gender Diversity in MIE (6)	○	○	○	○	○
Diversity of points of view in your classes (7)	○	○	○	○	○

Q2 During this academic **term**, how often have you had the following interactions with students who differed from you in race, national origin, sexual orientation, political views, or religion at Northeastern?

	Very Often (1)	Often (2)	Occasionally (3)	Rarely (4)	Never (5)
Studied or prepared for a class together (1)	○	○	○	○	○
Socialized or shared a meal (2)	○	○	○	○	○
Had meaningful and honest discussions about inter-group relations (3)	○	○	○	○	○
Felt comfortable sharing your own experiences (4)	○	○	○	○	○
Felt insulted or threatened based on your social identity (gender, race, national origin, values, sexual orientation, etc.) (5)	○	○	○	○	○
Witnessed someone else being insulted or threatened based on some aspect of that person's social identity (6)	○	○	○	○	○

Q3 During the current academic **term**, how often have you:

	Very Often (1)	Often (2)	Occasionally (3)	Rarely or Never (4)
Felt out of place or that you just didn't fit in MIE (1)	○	○	○	○
Felt overwhelmed by all you had to do (2)	○	○	○	○
Skipped meals or not had enough to eat because of financial constraints (3)	○	○	○	○
Felt that aspects of your social identity made things artificially more difficult for you in MIE (4)	○	○	○	○

Q4 The following open-ended questions are meant to probe your views about diversity in relationship to engineering and engineering design.

Q5 Thinking back to the beginning of term, has your definition of equity in design changed?

Q6 Thinking back to the beginning of term, has your definition of inclusive design changed?

Q7 After the lecture on Design for Diversity, Equity, and Inclusion (DEI) did you revise or alter your design to consider other points of view or a broader audience? If so, describe what you did.

Q8 Was there any particular case or example presented in the lecture on DEI that helped you view your design differently?

Q9 Can you think of other examples of equity and design after seeing the material on the topic or viewing other students' work?

Q10 Are there specific MIE courses that should include DEI topics, and if so, which specific topics or discussion areas would you like to see?