Course Interventions to Promote Diversity, Equity, and Inclusion in Engineering Curricula

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Introduction/Background

When framing the importance of the Grand Challenges for Engineering, the National Academy of Engineering states, "The challenges facing engineering today are not those of isolated locales, but of the planet as a whole and all the planet's people" [1]. These challenges will require diverse engineering teams. The literature shows that diverse engineering teams are better problem solvers [2] and more innovative [3].

Unfortunately, white males continue to dominate engineering professions. For example, the percentage of women earning bachelor's degrees in engineering has increased in the last decade; however, the growth has been slow, increasing from 17.8% in 2010 to 22.5% in 2019 [4]. Additionally, the percentage of Blacks or African Americans earning bachelor's degrees in engineering has remained around 4.2% since 2011. With women making up 50.8% of the population and Blacks or African Americans making up 13.4% of the population [5], the severity of the underrepresentation is clear. Since it is not reasonable to expect to build demographically diverse teams, engineering educators must work to build capacity for diversity by cultivating inclusive cultures and curricula [6], [7].

Building inclusive classrooms is one component of building culture [8]. Efforts toward more inclusive classrooms which are focused on student team dynamics are well documented [3], [9] [10], [11]. However, it is critical to provide guidance on the value and importance of leveraging the benefits of diverse teams [12]. When the benefits of diverse teams are not pointedly addressed, the effectiveness of a diverse team can be diminished. One prime example of this is inequitable distribution of work and tasks due to gender bias [9], [10], [12],

Similar to [12], this work focuses on the integration of activities designed to help students see the value and importance of diverse perspectives in engineering design. The engineering program at the investigator's institution was launched in Fall 2018. The program was built with ABET accreditation standards in mind and the faculty prioritized ensuring that our students have "an ability to…create a collaborative and inclusive environment" upon graduation. Our approach to introducing DEI pedagogy was to focus on a first-year course, Grand Challenges in Engineering (GCE), and a second-year course, Engineering Mechanics: Statics (Statics). GCE is the first foundational design course in the program, where ABET Student Outcomes (SOs) 2-6 are introduced. This was a natural fit for introducing DEI concepts, since they tie well with SOs 3 (effective communication) and 5 (function effectively on a team). While Statics is a less obvious choice to integrate DEI instruction, it was an opportunity to explore innovative ways to emphasize the importance of DEI in engineering in a course that focus primarily on disciplinary concepts, and to reinforce content students saw in GCE.

Methods

DEI pedagogy was introduced in GCE and Statics in 2018, and included in those courses the years that have followed. Each course ran 100 minutes twice a week during the Fall semester,

with DEI instruction included in all course section offerings. All students in the engineering program are required to take these courses. We note the number of students in the courses ranged from ~10-30, with 1/3 being female, 2/3 male, and at least 1 non-binary student. Female and male students were identified using data provided by the university registrar. Non-binary students were identified by their self-declared pronouns, regardless of their gender on record. The Elon undergraduate population was represented by an average of 17.8% students of color from 2017-2020; these demographic statistics were unavailable for each course [13].

Details of that instruction and the improvements made are divided in the GCE and Statics sections below:

EGR 121: Grand Challenges in Engineering

GCE is where students learn foundational engineering concepts, and where our program's student outcomes, rooted in the ABET Student Outcomes, are introduced. In 2018, the first iteration of this course's DEI module, the instructor spent a class period solely on the importance of Diversity and Inclusion in Engineering. Students read the article "The Importance of Diversity in Engineering" by WM. A. Wolf [14] to recognize the need for diversity in Engineering before being guided through an exercise to identify inclusive practices they could establish to promote diversity.

In 2019, The DEI instructor did not teach this course but instead guest-lectured in the two sections that were offered. The course instructor for each of those sections was asked to assign the Wolf article as a reading exercise for homework. The next day, the DEI instructor gave a short lesson on the need for diversity in engineering. Students were guided through an exercise to first identify engineering projects that would benefit from a diverse perspective, then to identify the unique perspectives they bring to the table, and finally to identify inclusive practices they could start now that would promote diversity. Due to time constraints, the module had to be trimmed to only 15 minutes. This haste was reflected in the feedback from students, described in more detail in the Results and Discussion section below. As a result of this feedback, DEI instruction was tied to ABET SO 5 as part of the program's continuous improvement plan. Tying this instruction to student outcome assessment does two important things: 1) it makes DEI in engineering a permanent feature in the program so that all students see the content and 2) it will be assessed and improved upon each year as a part of ongoing improvements to the institution's engineering program.

In 2020, the DEI instructor was again the course instructor, and the module extended over a period of three days. The extension of the module enabled ample time for discussion in class on the various aspects of DEI in engineering. Importantly, it provided more opportunities for students to make a personal connection to the material so that they left knowing the importance of practicing inclusivity, the need for diversity in engineering, and what their role is in these efforts. This resulted in each student being able to at least partly articulate the relationship between inclusive practices and diversity on the midterm exam, whereas only a few students were able to do so when the module was first introduced in 2018. Table 1 outlines the latest version of the 3-day DEI module that is currently used in the course, which includes having

students complete a value systems assessment that has been shown to reduce achievement gaps for underrepresented students [15], [16].

Table 1. 2020 Lesson plan for DEI in engineering intervention for Grand Challenges

Day	Description of	Activity	Homework
1	Students will explore tools for characterizing personality types, and use that to identify their personal strengths and weaknesses. Students will then be led through a conversation on the limitations of personality assessments, why they are used, and fixed- vs. growth-mindsets	Complete online personality test [17] (similar to Myers-Briggs or Keirsey Temperament Sorter)	Complete Value systems Assessment [18]
2	Students are introduced to teamwork and team structures, including the stages of team development and what to expect at each stage. Students are then guided through a discussion on ways to make all team members feel that their contributions are valued	Think-pair-share: Identify ways other teammates might make you feel included on a team, then ways that may make you feel excluded	Read "The Importance of Diversity in Engineering" by W.M. Wolf [14]
3	Students engage in a discussion about why diversity is important for engineering, and motivation to promote diversity in engineering. Students then engage in a discussion tying together how inclusive practices promote diversity in the field.	Find examples of engineering solutions that would have benefited from more diverse team perspectives	None

EGR 206: Statics

Beginning in Fall 2018, students enrolled in Statics completed a project which asked them to consider whether they and/or their experiences are reflected in textbook problems. Note that the textbook primarily features white males and athletic themed images and we have used it for several years. The assignment asked students to create a mechanics problem that reflected who they are in the broadest sense. It included an example from an old edition of the textbook: a problem which required calculation of the force a high heel exerts on the ground.

Unfortunately, the first run of this diversity module demonstrated that students were not adequately prepared for the assignment. While the specific details about what happened are

discussed in the Results and Discussion section, it is important to note that the Fall 2018 experience led to a revision of the diversity module in 2019. The revision focused on devising different ways to scaffold the introduction to the project. In the revision, students are introduced to the project with the TED talk "The Danger of a Single Story" by novelist Chimamanda Ngozi Adichie. In the talk, Ms. Adichie explains that single stories about individuals most often lead to misrepresentation. Next, students are asked to conduct a quick content analysis of their textbook by flipping through the pages of their textbooks while considering who is and is not represented in the images. Finally, students are asked to write their own Statics problem that reflects their identity. The example presented in the assignment was updated to a photo containing an example of Statics in real life and a handwritten solution to an authentic Statics problem created from the photo.

The full revised intervention was attempted in Fall 2019, but complicated by external factors discussed later in the Results and Discussion section. The lesson was fully implemented in 2020 without disruption.

Assessment

Each year, improvements made to the DEI instruction were informed by feedback from students using formative assessments, such as in-class quizzes/assignments/exams asking students to articulate inclusive practices and the need for DEI in engineering, and cumulative assessments such as end-of-year student perceptions of teaching (administered by the institution) and a survey on the perception of DEI in the engineering program. The survey on DEI perceptions in the program was vetted and approved by the institution's internal review board to be presented and published in this forum. The survey was administered by a 3rd party, and all identifying information removed before being provided to the instructors. In 2018 and 2019, the survey was administered in person. In 2020, the survey was administered online due to COVID-19. Students were asked to rank their response to each prompt from Strongly Agree (1) to Strongly Disagree (5). The negatively-worded/positively-worded questions were reverse coded and the new scores were plotted to observe trends. For example, students agreeing with the statement "my instructors talked about DEI" would be a positive score, and students agreeing with the statement "my instructors did not talk about DEI" would be a negative score.

Results and Discussion

Students in both GCE and Statics were surveyed at the end of the semester. While formative assessments were made throughout the semester, these surveys serve as our formal cumulative assessment for the DEI modules. Plotted in Figure 1 are the survey scores from students in 2018, 2019, and 2020. Table 2 follows with each statement students were asked to agree or disagree with, along with a short summary of the score over 2018-2020. The results show that there was a general improvement in the perception of DEI in Elon Engineering in 2020. We drew several main conclusions from this data that are being used to inform future implementation of DEI in Engineering course content, both in the courses described here and courses throughout the program.

First, we found that it is imperative that the inclusion of DEI content be meaningful, relevant, and reinforced throughout the semester and by instructors throughout the program. This is evidenced in part by the survey score to statement 6 in 2019 that shows students did not believe they were instructed on DEI content in their course. DEI instruction was done as a module by a guest-lecturer for part of the class in GCE that year. Student comments that were received included statements such as "This was a fun class and I learned a lot. There should be more like it. This being said, the diversity presentation was pointless and not memorable. Maybe include a hands-on example project that emphasizes the importance of diversity." The module for that course evolved to the three-day instruction described in the Methods section the following year, with results to statement 6 being much more positive. Qualitatively, the DEI instructor noted the conversations students had around DEI in class were much more engaging. For example, instead of simply having students read the Wulf article, students were asked to respond to it during the discussion and talk about how they believe their own lived experience can uniquely contribute to the development of innovative designs. The personal connection students made in class to the content led to most students being successful on formative assessments, such as a quiz on the definition of "diversity" and "inclusion," as opposed to most students failing those same formative assessments in the first run of the lesson. Additionally, students noted the need for guest lectures given by members of underrepresented communities. This motivated both DEI instructors to highlight their lived experiences as a woman of color and a gay male during DEI conversations. In Statics, a student noted that faculty in engineering need to do more to think about how DEI conversations can be included in their technical engineering courses. This, in part, motivated the use of these DEI modules for introducing ABET SO 5. In 2021, two new faculty members taught the course and have included the lessons in their courses, which will be assessed as a part of accreditation requirements at the end of the semester.

Second, we found that relevant and up-to-date context is needed for students. The main evidence for this is the stark contrast in positive scores from students in 2020 compared to previous years. The 2020 civil rights protests put a spotlight on the need for DEI in broad aspects of society. Connecting instruction to what students were seeing and experiencing resulted in class conversation being more engaging, and students connecting more personally and deeply with the content. Additionally, the first attempt at executing these lesson plans illustrated the need for this context with how the students responded to assignments. For example, in Statics, despite students expressing excitement about a problem featuring a woman, student questions focused on logistics of when and how to submit. There were also several questions seeking approval to use published problems like the one including the high heeled shoe. The quality of submissions ranged widely. It turns out that the latter point about using existing problems was the primary takeaway for many students; therefore, several copied a problem from Chegg.com without making changes or citing the source. The following years this lesson plan was executed included the broader context that resulted in students taking more seriously the assignment, and not attempting to use disappointing shortcuts to deliver what they thought was expected of them.

Third, the iterative process of including these modules as a part of the continuous improvement of the program resulted in marked improvement in student perceptions and a more meaningful execution of lesson plans. For example, in GCE, a student in 2019 noted "Including more

diversity and inclusion projects and examples in class would raise more awareness. It is helpful to fill out this survey; however, doing it at the end of the semester is pointless because the class is already over, and there is no time to implement change." This resulted in the inclusion of more formative assessments throughout the semester, such as requiring students to submit a memo after a group project to articulate the inclusive practices the team uses, and the perception of inclusivity among team members. Qualitative evidence in 2020 showed a significant improvement in team performance in GCE, with fewer students not contributing to teamwork and an overall improved attitude among team members compared to previous years, as evidenced by ABET course assessments and results from the DEI perceptions survey.

While we want to best execute these lesson plans, we have found that the challenges faced in their execution have led to improvement as well. For example, comments such as "This class was by far my favorite class. [The course instructor] was a great teacher and I hope to have him again in the future!" in GCE in 2019 illustrated that students were not paying attention to the guest-lecture module, since they were commenting on the course instructor and not the DEI instructor as though this were a course evaluation. This was heavily reflected in the scores from that year, which, as mentioned, resulted in the extended lesson plan described above. In the second iteration of the Statics lesson plan, class was disrupted by a power outage on the day the instructor planned to show the TED talk. After doing her best to give the students a preview of the talk without spoiling it for them, the instructor promised to post the link on the course Moodle site as soon as power was restored and asked the students to watch it. The instructor tried to salvage the remaining moments in class by facilitating the exercise asking students to flip through the pages of their textbooks. At first, the students flipped mindlessly, showing few signs of connecting the TED Talk to what they were being asked to do. After a few pointed questions, some students gave audible responses (verbal and non-verbal) indicating their newfound discovery that the images in their textbook were not fully representative of society. To drive the point home, the instructor drew attention to herself, a woman of color in engineering, explaining her good fortune to have risen above this one-dimensional messaging. Although the instructor was not willing to sacrifice more class time to show the TED Talk and none of the students actually took the time to watch the TED Talk on their own, the Fall 2019 results were better than 2018 and even better in the 2020 execution where the talk was shown in class. Students were more engaged in designing problems based on personal experience as evidenced by the number of questions raised about the project after class and during office hours. The lesson learned here is that we do not need to be perfect with our delivery, as long as we are genuine and work to continuously improve moving forward.

Even though we have seen great progress in DEI perceptions among students over the three-year execution of these lesson plans, there is still much work to be done. For example, student scores from the DEI perceptions survey indicate that many students are unaware of resources available to underrepresented groups. This is also evidenced by student comments, such as "A bit off topic, but I went to [the career center] for help applying to internships for the summer, and they admitted that Elon students seemed to have trouble landing positions in SAAS and hi-tech companies. It worries me that if my white counterpart at Elon has this [trouble], how will I, as a person of color, fare after graduation? (They did suggest applying for research positions to gain

more experience).” We also have feedback from non-white students that they feel isolated at the university, and have difficulty with finding friend and study groups. This has been addressed in part by including a list of demographic-specific engineering societies on the engineering program’s webpage, which is referenced during conversations on professional development in GCE. It has also been addressed with the development of a student organization led peer-mentorship program. However, more work needs to be done to better provide and highlight engineering-specific resources to underrepresented groups in the program.

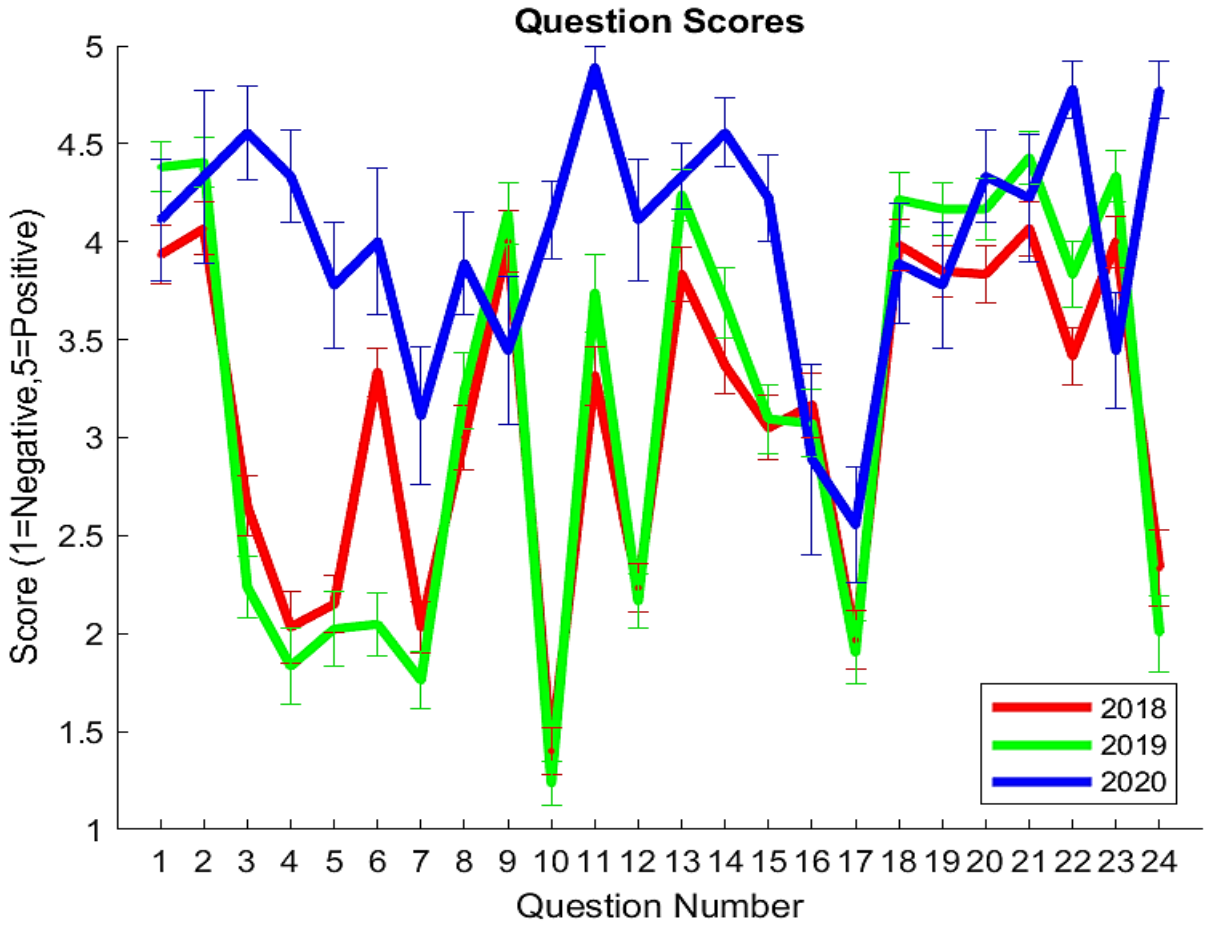

Figure 1. Survey results for assessing DEI interventions in Grand Challenges and Statics

Table 2. Summary of DEI perceptions survey results from 2018-2020

1. Elon Engineering has always promoted diversity and inclusion.	Students generally agreed the program has always promoted diversity and inclusion.
2. Discussions of diversity and inclusion do not belong in the classroom	Students generally agreed that DEI belongs in the classroom.
3. I am unsure of the difference between diversity and inclusion.	Students in 2018 and 2019 generally were unable to articulate the difference between diversity and inclusion. This was addressed in for the 2020 module, and resulted in the majority of students understanding better this difference.
4. Diversity and inclusion activities helped me understand their importance in Engineering.	Students in 2018 and 2019 generally disagreed these activities were helpful. This changed in 2020 with the overhaul of class activities, and the extension of activities over several days.
5. I have experienced or witnessed prejudice from other students in Engineering courses.	Students generally witnessed prejudice from other students in 2018 and 2019, but this improved significantly in 2020. We believe this was largely a result of the protests during Summer 2020.
6. I was instructed on the importance of diversity and inclusion in this course.	Fewer students in 2019 felt they were instructed on the importance of DEI compared to 2018 and 2020. The biggest difference in 2019 was that DEI instruction for most students (GCE) was a part-day guest lecture.
7. Elon Engineering is not doing enough to promote diversity and inclusion	Students generally agreed more in 2020 that Elon Engineering is doing enough to promote DEI, and is more evidence the improvement of modules made a positive impact.
8. I feel that my voice is heard in classroom discussions pertaining to diversity and inclusion.	Students more strongly felt their voices were heard in the classroom in 2020. This could be due to the better clarity around inclusive practices in the 2020 lesson plan.
9. I am aware of resources available to underrepresented Engineering students.	Students were slightly less aware of resources for underrepresented groups in 2020. This could be due to the need to eliminate some career development content from GCE for hybrid courses, which is where some of these resources had been shared with students.
10. My Engineering professors have talked about diversity and inclusion in class.	Students in 2018 and 2019 overwhelmingly felt that their professors did not talk about DEI. This change in 2020 was likely a direct result of conversations in the classroom around the 2020 protests.
11. I have experienced or witnessed prejudice from my instructors of Engineering courses.	Disappointingly, several students noted they saw prejudice from professors in 2018 and 2019. We suspect the events and conversations from the 2020 protests helped improve student perceptions.
12. There is no need for more efforts to promote diversity and inclusion in Elon Engineering.	We aimed to do a better job of articulating the need for DEI in engineering in 2020, though the political climate that Fall likely played a key role in illustrating the need for DEI overall, which resulted in overall improved scores for 2020 compared to 2018 and 2019.

13. I know what I can do as a future professional to promote inclusion in the workplace.	Students generally understood their professional roles across the three years, with marginal improvements in scores through 2020.
14. I have noticed efforts this year to promote diversity and inclusion in Elon Engineering.	Students noticed more the efforts to promote DEI in 2020 compared to previous years, likely due to the extension of lesson plans over several days in 2020.
15. There is a need for initiatives to promote diversity and inclusion outside of the classroom.	Students were neutral in 2018 and 2019 on the need for DEI initiatives, but much more strongly agreed there is a need in 2020. This again is attributed to the events of Summer 2020.
16. I know about demographic-specific Engineering societies.	The histograms of responses to this question exhibit a bi-modal distribution, which implies roughly half our students are unaware of demographic-specific Engineering societies.
17. Traditionally UR groups are not represented in course material	Students generally agreed that underrepresented groups are not represented in their course materials across 2018-2020, which is being actively addressed by the instructors.
18. Academic activities with classmates outside of class are inclusive.	Students generally agreed that academic activities outside of class are inclusive. With that said, the university is primarily represented by white students, and we have noted that our students of color do not feel this way.
19. I feel comfortable having conversations about diversity and inclusion in class.	Some students felt discomfort with conversations about DEI in class, but generally felt comfortable, though efforts to improve this are being made at both the program and the university level.
20. I know what I can do as a student to promote inclusion among my peers.	Students generally agreed they know what to do to promote inclusion, with a marginal increase from 2018 to 2019 and 2020.
21. I'm aware that underrepresented groups are disproportionately represented in Engineering.	Most students were aware of the disproportional representation of underrepresented groups in Engineering for all years, with a marginal improvement beyond 2018.
22. I understand why Elon Engineering is making an effort to promote diversity and inclusion.	While several students did not understand why our program was working to promote DEI in 2018 and 2019, most students did understand in 2020. We again attribute this to the events of Summer 2020.
23. Traditionally UR groups ARE represented in my course lectures	Students generally agreed that underrepresented groups are represented in their course materials, in contradiction to their response for question 17.
24. I know how diversity and inclusion relate to each other.	As reflected in question 3, students in 2020 better understood the difference between diversity and inclusion compared to previous years.

Conclusion

From 2018 and onward, we have included lessons to highlight DEI in Elon Engineering in the introductory design course EGR 121: Challenges in Engineering and the second-year course EGR 206: Statics. This manuscript reports student feedback from 2018-2020. We found that 1) DEI instruction needs to be substantive and not just a single assignment or lecture, 2) DEI instruction needs to be put into the context of relevant and up-to-date events that reflect students' lived experiences, and 3) integrating DEI instruction into the engineering curriculum and improving upon it yearly is a powerful way to ensure students are getting meaningful and relevant DEI content that they will use in their careers. While DEI perceptions in the program improved from 2018-2020, several areas of improvement are still needed, such as more visible and impactful resources for underrepresented students in engineering. Overall, we are excited to continue moving forward with improving and promoting DEI in engineering.

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