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Work In Progress: Implementation of a Skills Based Approach to Diversity, Equity, and Inclusion in Senior Undergraduate Aerospace Capstones

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Abstract

In 2019, the Accreditation Board for Engineering and Technology (ABET) updated their student outcome accreditation standards to specifically address team collaboration, leadership, and inclusivity. While Penn State's 2016-2020 University-wide Strategic Plan clearly highlights diversity as one of its core foundations, the College of Engineering 2020-2025 Strategic Plan reaffirmed and clarified this commitment by making one of its unit objectives the integration of ethics, inclusivity, and sustainability into undergraduate programs throughout the college. In the Aerospace Engineering Department, senior undergraduate capstone courses offer ideal conditions for exploring Diversity, Equity, and Inclusion (DEI) issues since these classes are team-based experiential learning environments intended to mirror the engineering workplace.

While Penn State's year-long Aerospace Engineering capstone courses have historically included a unit on DEI presented at the beginning of the Fall semester, these concepts were introduced in a lecture-based format and embedded within the broader context of professional behavior and team dynamics. With the addition of 2-3 team peer review surveys throughout the Fall and Spring semesters to assess team communication, collaboration, and student perceptions of team productivity, this approach satisfies the ABET student outcome accreditation criteria. However, a wealth of research into DEI training over the last decade has indicated that lecture-based approaches are the least effective pedagogical method for ensuring concept retention, changes in empathetic thinking, and recognition of personal implicit biases. In addition, the majority of senior engineering undergraduates have limited experience navigating professional norms, team conflict, and diverse team environments. The combination of these factors created a capstone environment in which students were aware of DEI in the context of professional behavior, but lacked the deeper appreciation of DEI issues resulting from workplace/team culture and other barriers to STEM equity and inclusivity within teams. Furthermore, even when students recognized these issues, they were unfamiliar with methods to mitigate them.

To bridge this knowledge gap, the Penn State Aerospace Engineering Department has implemented a skills-based approach to its DEI learning modules within all capstone courses. This approach combines a variety of pedagogical techniques including interactive video-based bystander training; self reflections on microaggressions and implicit bias; and in-class team exercises and discussions on the intersection of power dynamics, team interactions, and discrimination, as well as strengthening empathy though a recognition of societal privilege and economics factors. Throughout these trainings, activities, and discussions, an emphasis is placed on development of concrete actions that students can take within their current and future teams to promote an inclusive, collaborative, and psychologically safe environment for all members. As implementation of these active learning techniques to DEI concepts within the senior undergraduate aerospace capstones is a relatively new update to the curriculum, development of metrics to gauge effectiveness is ongoing. Planned assessment options include in-class and senior exit surveys, as well as CATME-based or customized evaluation models containing

questions related to psychological safety, communication, collaboration, productivity, team climate, and team interdependence.

Introduction

For the 2019-2020 academic year, the Accreditation Board for Engineering and Technology (ABET) updated their student outcome accreditation standards to specifically address team collaboration, leadership, and inclusivity through Student Outcomes Criterion 3.5: "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives" [1]. The emphasis on inclusivity and collaboration within this outcome is noteworthy, as its language implies recognition of the growing body of research indicating that team climates promoting diversity, psychological safety, and inclusivity perform more effectively and creatively than those that do not [2]-[6]. In addition, retention of engineers from underrepresented demographics continues to be a concern at all levels – undergraduate, graduate, and professional - with multiple studies indicating that departures from STEM fields are directly influenced by experiences stemming from unwelcoming, exclusionary, and biased climates [7]-[10].

Recognizing the need to directly address both the ABET Student Outcomes and the "leaky pipeline" issue, Penn State's College of Engineering 2020-2025 Strategic Plan identified the integration of ethics, inclusivity, and sustainability into undergraduate programs throughout the college as one of its primary unit objectives [11]. This emphasis updates and directly implements Penn State's 2016-2020 University-wide Strategic Plan, which clearly highlights diversity as one of its core foundations [12]. In the Aerospace Engineering Department, senior undergraduate capstone courses offer ideal conditions for exploring, learning about, and practicing Diversity, Equity, Inclusion (DEI) skills that promote inclusive and collaborative climates since these classes are team-based experiential learning environments intended to mirror the engineering workplace.

Background

Senior year capstone courses have become a standard feature within most undergraduate engineering curricula. Although these classes tend to vary in duration (1-2 semesters) and product outcome (design-analyze-report vs. design-build-demonstrate), their intent is the same: to serve as a design-focused culmination of a student's degree experience that requires collective application of the multidisciplinary engineering concepts acquired up to that point and being learned concurrently. In addition, most capstones tend to be team-based, making them ideal environments for students to practice "professional" skills related to communication, leadership, collaboration, global awareness, ethics, and respect that directly impact their future success within their careers [13]. In fact, there is a growing awareness that, in addition to application of technical knowledge, capstone courses' primary efficacy is their role in allowing students to hone and practice teamwork skills while simultaneously fostering proficiency in other non-technical areas like independent learning and critical thinking [14]-[15]. In a 2021 study surveying 489 companies who employed engineers, Hirudayaraj et. al. [16] found that, of 26 "soft" skills linked to career success, industry firms rated entry level engineers as being proficient in only two of them ("global and cultural awareness" and "social responsibility"). In

addition, employers rated "the ability to communicate effectively with diverse groups of people" as having the largest discrepancy between the level of importance they attributed to that skill and the skill proficiency demonstrated by entry-level engineers.

Based on this data, it appears that capstone instructors and developers have some work to do in implementing effective strategies for fostering professional skills. It is particularly telling that the paired difference mean of the importance vs. proficiency rating of entry-level engineers' "ability to communicate effectively with diverse groups of people" was 0.90, while their "social responsibility" and "global and cultural awareness" paired difference mean values were -0.10 and -0.03, respectively [16]. Perhaps these data indicate that students are aware of diversity issues, but lack the communication and conflict resolution strategies necessary to effectively promote an equitable and inclusive climate.

At Penn State, the Aerospace Engineering Department offers four primary capstone courses in the areas of spacecraft, aircraft, rotorcraft, and autonomous vehicle design. The courses each span a full year, with topics in the Fall semester focusing on the systems engineering process and conceptual/preliminary design technical topics, while the Spring semester concentrates on detailed design, analysis, and modeling verification. Of the four courses offered, the majority follow a Design-Analyze-Report process with a paper study produced as the end product. The autonomous vehicle capstone course is a relatively new addition to the curriculum and implements a Design-Build-Fly method with a flight competition at the end of April. Undergraduate aerospace engineering students must take at least 5 credits of capstone to meet their degree requirements.

Prior to the 2021-2022 academic year, all aerospace engineering capstone courses included a lecture-based unit on DEI that was embedded within the broader context of professional behavior and team dynamics. With the addition of 2-3 CATME-based team peer review surveys throughout the Fall and Spring semesters to assess team communication, collaboration, and student perceptions of team productivity, this approach satisfied the ABET student outcome accreditation criteria, but did not offer a consistent experience or set of learning objectives across capstones since lecture materials were developed separately for each of the courses. In addition, a wealth of research into DEI training over the last decade has indicated that lecture-based approaches are the least effective pedagogical method for ensuring concept retention, changes in empathetic thinking, and recognition of personal implicit biases [17].

Discussions with students and review of anonymous peer review survey results from capstone teams within the 2020-2021 academic year highlighted the fact that the majority of senior engineering undergraduates have limited experience navigating professional norms, team conflict, and diverse team environments. The combination of these factors created a capstone environment in which students were aware of DEI in the context of professional behavior through the existing lecture-based unit but lacked the deeper appreciation of DEI issues resulting from workplace/team culture and other barriers to STEM equity and inclusivity within teams. Furthermore, even when students recognized these issues, they were unfamiliar with methods to mitigate them. The need to create a new DEI module focused not just on awareness, but also emphasizing concrete skills development and use, was evident.

DEI Module Goals & Development

Diversity workshops, trainings, and educational units have been delivered in a variety of ways. Lectures, videos, interactive role-playing scenarios, discussions, seminars, and self-reflections are all methods that have been implemented with varying success. [17]-[18] (In this context, the term "success" is used to describe the degree to which a participant's DEI awareness, skill set, or understanding increased following their engagement with the material, often evaluated using pre- and post-participation surveys.) Online and in-person trainings have both been found to be effective, but a broad review of existing DEI training techniques by Alemeo in 2022 [17] indicated that use of multiple instruction methods, longer training, and a combination of active and passive formats resulted in the highest knowledge and skills capture.

At the same time, it is important to recognize the limitations associated with DEI teaching, especially in the context of capstone courses. Pfluger et. al [14] theorized that capstone faculty may lack the background necessary to promote teamwork and interpersonal skills due to their own prior negative team experiences, a lack of training, or because of the silo nature of academia, in which independent, solitary activities are often rewarded. When developing workshops embedded into a Civil and Environmental Engineering capstone design course at the University of Wisconsin-Madison, Hanus and Russell [15] pointed out that, although team-based capstone settings require students to *use* teamwork, diversity, leadership, and communication skills, the need for use doesn't necessarily result in *development or practice* of the skills. In other words, students need to be given the tools and strategies to implement DEI practices within their teams and in their future careers. Instructors can not assume that the identification of the need will magically result in the development of the solution.

DEI module development for the Penn State Aerospace Engineering capstone courses was therefore based upon the Learn-Practice-Assess framework proposed by Hanus and Russell [15] and approached from the need to address multiple aspects of DEI in a relatively short timeframe due to course content requirement constraints and limited contact hours (2.5 hrs/week). In keeping with the intent of capstone courses to both mirror a real-life industry setting and focus on concept application vs. theory, goals of the DEI module development were as follows:

- *Goal 1:* Introduce students to DEI issues and the myriad ways in which they can manifest in the workplace, including microaggressions, macroaggressions/microassaults, microinvalidations, implicit bias, institutional bias, and stereotypes
- *Goal 2:* Present concrete actions and steps that students can take in their teams and workplaces to create an equitable and inclusive climate, as well as advocate for themselves and their peers
- *Goal 3:* Reflect realistic workplace climates that may include both subtle and overt exclusionary and bias cues. In representing the sometimes insidious nature of these interactions, demonstrate an appreciation for how team dynamics, coworker/teammate relationships, and power discrepancies may impact individual responses, agency, and psychological safety.
- *Goal 4:* Heighten awareness about privilege, inequality, inequity, and how personal experience can influence individual perceptions of communication and team climate

- *Goal 5:* Deliver the DEI module in a range of mediums and approaches in order to maximize knowledge capture and skills development.

To meet the five goals outlined within the 2.5 contact hours/week allotted, a sequence that includes an initial lecture, video-based bystander training, a role-playing scenario, an individual self-reflection, and an interactive team "game" were all integrated to develop the new week-long DEI module (Figure 1). Each of the in-class elements placed emphasis on initial capstone team interaction and discussion, followed by full class discussion facilitated by the instructor.

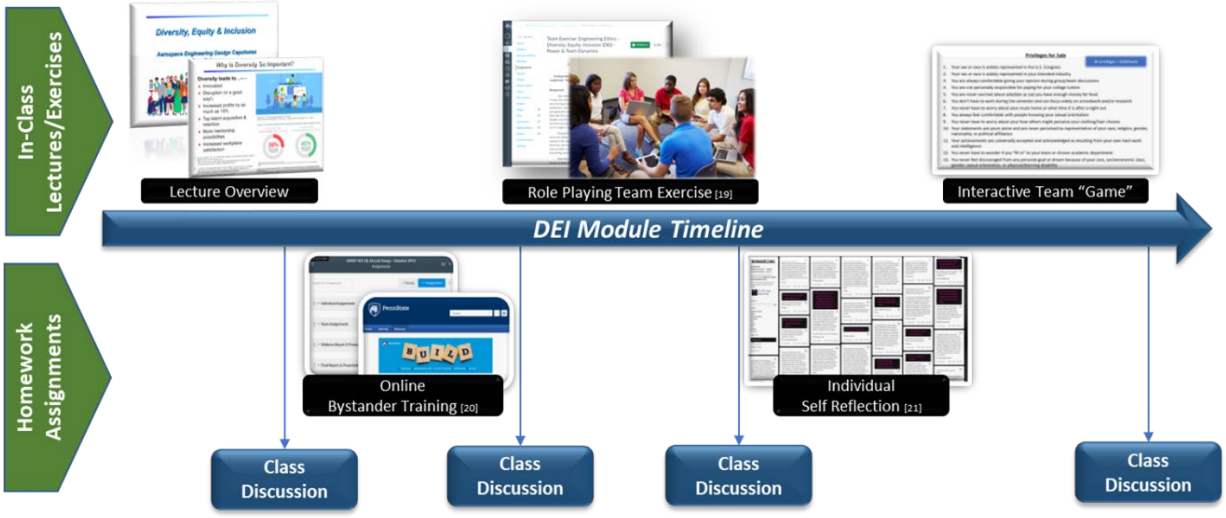

Figure 1: DEI Module Sequence

While discussions about DEI issues are becoming more commonplace in society, especially within University settings, students often reach their senior undergraduate year without having undergone any formal instruction related to diversity, equity, and inclusion concepts, and in general, very few have been exposed to how these issues might impact engineering teams. To ground the DEI module activities that follow, a DEI Overview lecture was developed that is presented in class on the first day of the unit. The lecture establishes the need for creating diverse, equitable, inclusive teams by introducing students to existing research on the positive impact of diversity for company profits, team innovation, and problem-solving creativity [2]-[6]. Terms within the DEI lexicon (e.g. microaggression, microinvalidation, implicit bias, psychological safety) are defined with examples, and a list of initial, actionable steps that students can take to promote inclusive team climates, both within the capstone course and within their future careers, are introduced. Whenever possible, real-world examples of DEI issues from the engineering industry are used and subsequent concrete actions like bystander techniques, non-confrontational responses, or direct interventions are discussed. In addition, resources available in both educational and workplace environments like ethics hotlines, an ombudsman program, and mentorship support are identified as useful ways to seek additional assistance when required.

Following the DEI Overview lecture, students receive an individual homework assignment in which they take an online, video-based, interactive bystander training session developed by SunShower Learning [22]. The "Ouch! That Stereotype Hurts" training is provided by Penn

State's Learning Resource Network (LRN) and is free to University faculty, staff, and students. Through videos and interactive vignettes that address a broad array of identity characteristics (e.g. age, disability, nationality, language, race, gender, religion, and sexual orientation), it provides a clear set of 6 techniques that individuals can use to halt verbalized instances of bias at the micro- and macro- levels in non-confrontational but effective ways. The training materials also include a workbook that allows students to practice the techniques learned and that is used, in part, as an assessment mechanism for the homework grade.

Armed with the techniques presented in both the DEI Overview lecture and the "Ouch! That Stereotype Hurts" bystander training, students enter the next in-class session ready to practice the methods that they have learned. Students are asked to sit together with their capstone teams and are presented with a role-playing scenario in which, collectively, they inhabit a male engineer who has just graduated. "Sam's" first job is at a small, highly desirable, cutting edge start-up company, and he is eager to make a positive technical impact in his new job. During his first week, Sam's direct supervisor invites him out to lunch with a select group of other engineers, giving Sam the opportunity to build team relationships and network within the company. As the scenario proceeds, however, students are given examples of statements made by Sam's supervisor that seem to demonstrate implicit bias or a pattern of microaggresive tendencies towards underrepresented groups within the company. In addition, students are presented with further scenario details possibly indicating that project task and professional development opportunities are distributed inequitably based on gender and race.

Initial discussion within this exercise is team-based, and teams are asked to determine the degree to which DEI issues appear to be present, what actions the Sam character might take based on the techniques they have learned, and whether or not the comments Sam is hearing from his supervisor warrant action at all since they occur outside of the physical workplace at lunch. Following role playing and subsequent discussion within this first scenario, Sam's gender is then flipped to female ("Samantha"), and students are asked to reassess the situation with the same questions, first within their capstone teams, and then through a class-wide discussion.

The purpose of the role-playing scenario within the larger context of the DEI module is to address the often nuanced nature of implicit bias and microaggressions in the workplace as experienced by underrepresented groups ("Samantha") and witnessed by their widely represented colleagues ("Sam"). It's been well documented that marginalized individuals within STEM can encounter a wide range of microaggressions that directly impact their decisions to stay within engineering, but allyship can be an effective tool for mitigating these negative experiences [8]-[10][23]. Asking students to view the same scenario through the lens of two different genders confronts participants with the disparity that can exist in how either "Sam" or "Samantha" experience the situation at hand, which may potentially impact the actions the teams choose to recommend. Instead of focusing on the ethically "correct" action, the exercise seeks to confront students with the often difficult and conflicting issues at play: existing team dynamics, personal career advancement, fear of retribution within a small team or company, and power discrepancies, all while asking them to apply information acquired in the previous module lessons.

A second homework assignment completes the individual segment of the DEI module. Students are directed to a tumblr social media project in which volunteers have submitted digital "cards" detailing their own experiences with microaggressions [21]. As part of a self-reflection, students are asked to select any three cards with which they feel a connection, describe the reason behind their selection, and then indicate which previously-learned DEI techniques they would use if 1) they were the bystander observing the microaggression, and 2) if they were the recipient of the microaggression. The tumblr site (Figure 2), which began in 2010 and continues to accept volunteer submissions, contains several hundred real-life examples of microaggressions that are tagged based on content topic. This medium allows students to easily search for microaggression cards that echo their own personal experiences or those of their peers, friends, and families. For individuals who have been sheltered from microaggressions, the tumblr site facilitates a visually impactful confrontation with the scale and societal pervasiveness of this manifestation of bias. The result meets the goals of both the tumblr project's intent and the DEI module's goal #4: a heightened awareness of microaggressions "showing how these comments create and enforce uncomfortable, violent and unsafe realities onto peoples' workplace, home, school, childhood/adolescence/adulthood, and public transportation/space environments" [24].

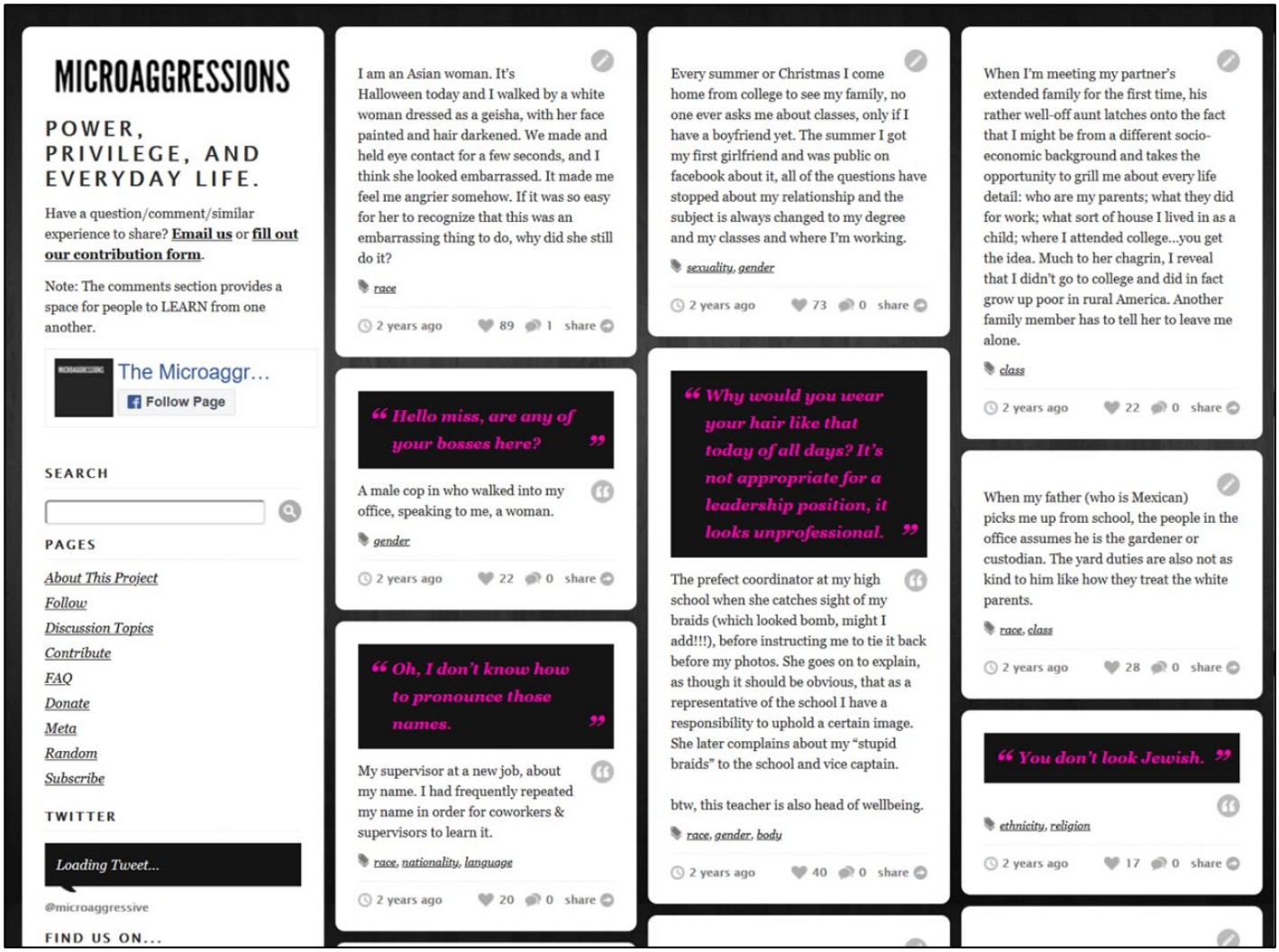

Figure 2: A Snapshot of the Microaggressions Project tumblr Page [21]

To close out the DEI module, an in-class activity called "Privileges for Sale" is conducted. This team-based role-playing scenario evolved from the Privilege Walk, an established DEI training exercise that Magana [25] found to elicit the following response among participants:

- Increased participants' awareness of their own experiences and that of disadvantaged groups;
- Facilitated psychosocial growth in participants' connections with others;
- Prompted a desire for increased action to promote equity; and
- Appreciated the positive impact of the activity and its ability to increase participants' empathy, as well as engendering changes in thoughts and behaviors surrounding DEI issues.

However, despite its successes, the Privilege Walk can be an uncomfortable and fraught exercise to implement as it forces the "walking" volunteers to divulge aspects of their identity and backgrounds to the entire audience. Despite its impact, it places a spotlight on individuals who may not wish to publicly broadcast their private circumstances. By contrast, the Privileges for Sale activity asks teams to "buy" privileges from a list like the one given in Figure 3. Each privilege "costs" $100 each, and each team is allotted a different budget ranging from $300 to $1000. Teams are explicitly told at the start of the activity that any privilege not purchased will not apply to them. In fact, they can assume that the exact opposite circumstance is true for their team members.

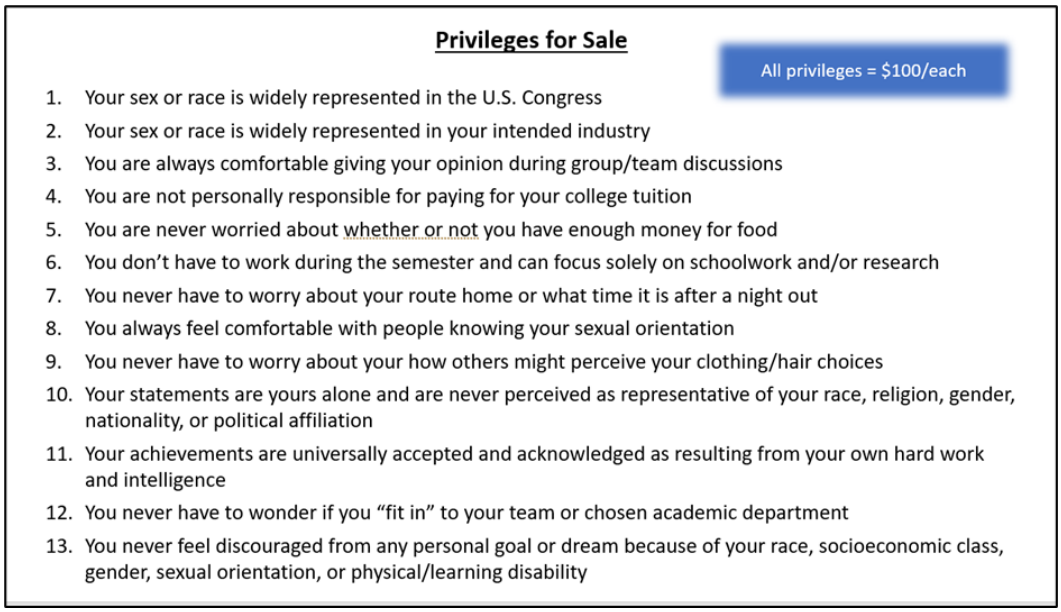

Figure 3: An Example Privileges for Sale List Used within the DEI Module

Based on these parameters, capstone teammates work together to identify the privileges that they propose purchasing as a team. This negotiation period is followed by a short, impromptu presentation by each team detailing their selections and rationale. Class-wide discussions related to economic considerations, identity intersectionality, inclusion, psychological safety, bystander

intervention/support, and mental load evolve both from audience questions asked during the presentations and from additional instructor prompting. The exercise wraps up with a review of the insights gleaned from the list of privileges, the role played by economic hardship/advantage, and the ensuing discussion points. While the Privileges for Sale activity could have been implemented as an individual self-reflection, its inclusion as a team activity reinforces the DEI module's intended goals by opening the privilege selection discussion beyond each team member's own background, identity, and experience. Students who relate strongly to deficiencies within certain privilege categories can share their experiences with others, enhancing appreciation among fellow team members for the lived experiences of disadvantaged and underrepresented groups.

DEI Module Implementation and Initial Observations

Development and implementation of the new DEI module occurred incrementally, with only the DEI Overview Lecture, "Ouch! That Stereotype Hurts" bystander training, and Sam/Samantha team role-playing scenario/discussion incorporated into the Penn State Spacecraft Capstone Design course during the 2020 Spring semester. Due to the pandemic, the module was taught entirely remotely through the use of Zoom lectures, breakout rooms, and class discussions incorporating Zoom's chat feature. Despite the difficulties related to engagement that can occur in the remote environment, discussion was lively and post-course survey comments related to the module were positive. As a result, the module was expanded based on the research presented here and implemented across all four Penn State Aerospace Engineering primary capstone courses starting in Fall 2021. Because the capstone courses are offered with different class patterns (Monday-Wednesday-Friday vs. Tuesday-Thursday), the segments of the DEI module sometimes had to be altered slightly to fit within a week-long unit. (For example, the initial DEI Overview may be assigned as a recorded lecture homework on the Thursday before the DEI module is supposed to formally begin in the Tuesday-Thursday capstones to ensure that adequate in-class discussion time is available for team-based activities.) However, the order and content of the DEI module remained the same for all courses, providing consistency for the concepts and skills presented in the Learn-Practice-Assess framework.

Anecdotally, the new DEI module was successful in meeting its goals. Figure 4 provides a snapshot of Penn State's 2022-2023 Aerospace Engineering undergraduates, and it is clear from inspection that these demographics still do not reflect the racial and gender composition of the national average in engineering, although Penn State does have a 4% greater representation of female undergraduates who have declared aerospace engineering as their major when compared to all United States university programs offering that option [26].

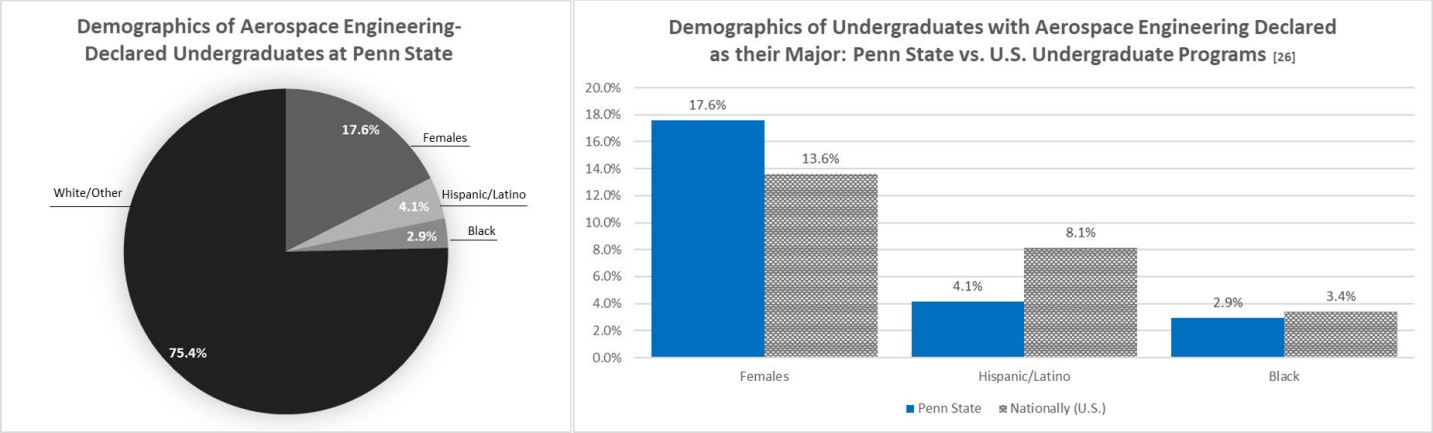

Figure 4: Penn State Aerospace Engineering Demographic Information for the 2022-2023 Academic Year

Based on the numbers, it was unsurprising that many capstone teams showed a distinct lack of racial or gender diversity, although factors related to economic status, sexual orientation, religion, or other identity dimensions may have been represented. Internal team conversations overheard by instructors, class-wide discussions, self-reflection homework content, and comments provided in general post-course surveys all implied that the module heightened awareness about DEI issues and their impact on the individual, team dynamics, and team/workplace climate. Students also appreciated the skills-focused approach in which concepts and techniques were applied to real-world scenarios. Class-wide discussion surrounding the Sam/Samantha in-class role-playing exercise often reflected surprise and consternation at the power dynamics represented, with multiple questions focused on the difficulty in determining what actions would meet criteria satisfying ethics, allyship, job satisfaction, and career advancement. In fact, power dynamics are frequently overlooked in DEI training, despite the fact that individuals in positions of leadership within a team can dramatically impact climate, psychological safety, and productivity [27][28].

In addition to increased awareness, student responses to the microaggression self-reflection were overwhelmingly heartfelt and deeply personal. While indicating which newly acquired non-confrontational and direct techniques they would use in their selected tumblr cards, many students provided conditional responses, demonstrating an appreciation for how the effectiveness and suitability of each technique changed given different conditions and situations. Similarly, discussion during the Sam/Samantha role-playing exercise sometimes included instances when both the instructors and students would voluntarily share their own experiences with bias and discrimination, and the class would actively brainstorm how techniques identified during the module might have been used in those situations. Throughout each segment of the DEI module, students' comments indicated that they completed the unit feeling empowered to apply the tools that they had learned within their capstone teams and within a future workplace setting.

To ensure that continued skills development and an attention to DEI issues occurred throughout the capstone course once the module was completed, teams were asked to create a DEI plan for their "company". Using the knowledge and techniques gained from the module, the assignment required students to develop clear communication and behavior guidelines to foster a climate of inclusivity and psychology safety, as well as an action plan if the team deemed that those

guidelines had been violated. Adherence to this plan was then assessed three times throughout each semester through self- and team peer evaluation surveys that included questions specifically addressing behaviors that promote inclusivity, psychological safety, respectful communication, and conflict resolution. This integration of the DEI skills into an experiential learning environment is a critical component of the Learn-Practice-Assess model's implementation, and represents a potential paradigm shift in the way that DEI concepts and capstone projects can be woven together.

Conclusion & Next Steps

Over the last two years, ~250 Penn State aerospace engineering senior undergraduate students have participated in the DEI Module as part of their capstone design experience. While anecdotal evidence is a valuable early indication of the unit's efficacy in satisfying its goals, data is needed to verify that conclusion. A research study is therefore planned during the 2023-2024 academic year in which capstone students will be asked to participate in a pre- and post-module survey to assess their absorption of DEI concepts, skills development, and awareness surrounding DEI issues. While development of the study and assessment metrics is still a work in progress, criteria may include team perceptions of psychological safety, increased awareness of implicit bias, understanding of actionable steps, application of bystander training techniques, and self-assessment of empowerment. Statistical analysis will be used on survey results to determine the mean and median response for each item on the survey, and the Kolmogorov-Smirnov test will be used to assess the level of statistical significance. A follow-on conference paper detailing these results will be submitted in time for the 2024 ASEE Annual Conference.

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