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Creating Inclusivity in Engineering Teaching and Learning Contexts: Adapting the Aspire Summer Institute Model for Engineering Stakeholders

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Introduction

There have been many initiatives to improve the experiences of underrepresented students designed to increase their desire to pursue the field of engineering. Programs include K-12 outreach initiatives as well as STEM interventions to address issues related to interest, self-efficacy, and retention [1], [2]. However, despite these efforts, the number of underrepresented populations in the engineering workforce indicates lingering disparities. For instance, within the 2021 engineering workforce, women and underrepresented minorities (e.g., Black, Hispanic, and American Indian/Alaskan Native) comprised only 16% of those in science and engineering occupations [3].

Engineering has historically held cultural values that exclude underrepresented populations based on beliefs around meritocracy, the notion that intelligence is solely based on performance, while not considering structural advantages that contribute to performance, as well as the desire to “weed out” students in courses who are viewed as having lesser abilities and skills [4], [5], [6], [7]. As a result, structural inequities such as those based on race, gender, and socioeconomic status can place individuals at a disadvantage in engineering compared to those with more privileged backgrounds [8]. Meritocratic ideologies can substantially affect the persistence of both women and people of color, populations historically excluded in engineering, because their cultural backgrounds are not validated by instructors and other peers, which reproduces inequity.

Improving student-faculty interactions through engineering professional development is one way to counteract harmful cultural ideologies to positively impact and increase the participation and persistence of underrepresented engineering students [9]. The Eddie Bernice Johnson NSF INCLUDES Aspire Alliance (Aspire) has developed the Inclusive Professional Framework (IPF) with an overall goal of developing an equity mindset among faculty in STEM so they can be more inclusive in their student-focused roles (e.g., mentoring in research settings, advising, and teaching). The Aspire Summer Institute (ASI) is an immersive professional development opportunity that is designed to educate faculty in STEM, institutional leaders, and faculty developers about how to utilize the IPF to create a more inclusive environment for underrepresented STEM students.

The IPF and the ASI are focused on reflexivity and creating an opportunity for participants to understand how their own social and cultural identities interact with others' identities, and how to be aware of and respond to others' differences. In contrast to other summer institute models [e.g., 10] that focus on a specific skill set (e.g., teaching), the ASI focuses on self-awareness, knowledge, and skills applicable across multiple faculty roles. We argue that adapting the IPF and the ASI to address cultural aspects unique to engineering as a discipline, and creating activities that address specific scenarios in engineering, such as team-based interactions, could improve faculty/student interactions within engineering. This can be accomplished by nuancing the intercultural domain of the framework to include a focus on "engineering culture" and adapting activities presented in the ASI to address common scenarios that occur within engineering contexts.

Building inclusive relationships is a key outcome for the IPF and the ASI. This differs from other teaching and learning professional development experiences in that it is not focused on an inclusive practices toolkit but instead builds an understanding of self and others to prepare one to engage in inclusive behaviors. In this paper we first discuss the importance of inclusive teaching and learning and faculty/student interactions in STEM that not only improve student academic outcomes but can improve student socioemotional outcomes such as sense of belonging and persistence. Then, we argue that facets of engineering culture are unique relative to other STEM disciplines, and thus require nuancing the intercultural domain of the IPF to include a focus on engineering culture. Finally, we discuss how adapting the IPF and ASI to fit engineering contexts, through adapted activities focused on culture and engineering scenarios, would improve upon the current ASI professional development which is done for a broader STEM audience. We conclude by arguing that the comprehensive nature of the IPF and its focus on developing an equity mindset can be a valuable tool for engineering faculty and administrators as they navigate the facets of faculty life and seek to improve the experiences of diverse student populations.

Teaching and Learning Contexts in Engineering

Teaching and learning contexts in engineering have been adapted over time to meet the needs of students. As engineering adapted its teaching to fit the demands of the workforce, the need for diverse viewpoints also emerged to contribute positively to the global engineering workforce. Although engineering adapted its teaching and curriculum, more needs to be done to promote equity. Achieving equity through work with faculty can potentially have a broad impact on diverse students. First, it is important to understand how curricular changes first entered the engineering discipline, as well as the emergence of active learning to achieve equitable outcomes.

The history of engineering as a professional versus a liberal arts discipline has caused many institutions to focus teaching and learning on providing students with the necessary practical skills to be successful in engineering. The notion of creating environments where students could put theory to practice and engage in team-based learning became more prominent in engineering programs of the 1990s [11]. During this time, engineering faculty and administrators recognized a need to infuse design and more active learning strategies into the curriculum to graduate engineers that could find solutions to increasingly complex societal problems [12]. Dym et al. [12] explain that a report in 1997 by the National Science Foundation outlined the need for engineering curricula to place more emphasis on teamwork, project-based learning, and industry connections, which influence retention, student learning, and diversity. Although these changes had a positive effect on students, a disconnect still lingered in the area of diversity.

Active learning, a form of interactive teaching, emerged as a method to center students in the learning process, have them engage in activities to foster critical thinking, develop active participation through hands-on activities, mentor students in the learning process, and utilize teaching tools to sustain students' attention [13]. Hernandez-de-Menendez et al. [13], argue that active learning leads to lower failure rates and promotes skills that engineers need to be successful in their professions such as teamwork, communication, and collaboration.

However, although active learning can improve the experiences for students within engineering, the impact of active learning on students of color and women are mixed [e.g., 14]. Studies of the general college population have demonstrated positive effects of active learning on students' self-confidence and persistence toward graduate school [15]. However, for some students, active learning practices such as volunteering to answer a question and being called on to answer a question in class can be anxiety inducing [16]. In a biology course Aguillon et al. [14] found that women's participation and academic performance in an active learning course did not improve. This reveals that active learning alone may not go far enough in achieving equitable outcomes. Therefore, active learning used in the context of inclusive teaching, which is specifically designed to support underrepresented populations, may be a way to enhance the current teaching models in engineering classrooms [17], [18].

Inclusive teaching, which emphasizes the importance of recognizing the complex identities and needs of diverse students, can positively influence self-confidence, academic performance, and academic engagement [19], [20], [21]. Hockings et al. [22], [20] found that inclusive teaching methods can enhance student learning and engagement, especially for underrepresented populations such as women and students of color. Hockings et al. [22] also found that students appreciated instructors that recognized their academic and social identities. Tanner [23] further explains that inclusive teaching practices include ensuring fairness in classrooms by allowing opportunities for students to participate and have time to process and present ideas. Equitable methods also facilitate a personal connection to the subject and explicitly welcome students into class discussions.

According to Dewsbury [24], creating inclusive classrooms can help mediate the challenges underrepresented students encounter because of traditional exclusionary STEM methods of teaching. He contends that instructors' self-awareness, (i.e., understanding their social position and the personal histories they bring to the classroom) and empathy (i.e., listening to and understanding the needs of students) combined with pedagogy (i.e., incorporating strategies to maximize "deep learning") contribute to the development of a positive classroom climate.

In summary, although active learning has benefits to students in engineering, inclusive teaching which values equity and fairness may be another layer that enhances underrepresented students' experiences in the classroom. For example, inclusive teaching has shown to both increase women's sense of belonging as well as their self-efficacy in engineering classrooms [25]. By creating inclusive environments through a combination of active learning and inclusive teaching, underrepresented students can be more successful thus broadening their participation and increasing their persistence.

Faculty/Student Interactions in Engineering

Besides teaching, faculty also have a role in affecting the experiences of women and people of color in the ways they interact with students. Research indicates that women and people of color's interactions with STEM instructors can contribute to academic performance, self-efficacy, and sense of belonging in different ways [e.g., 26], [27], [28], [29].

Positive faculty interactions can also contribute to underrepresented students' desires to continue in engineering. Riegle-Crumb et al. [30], in a survey of 229 Asian and White women at two universities in chemistry and chemical engineering, measured women's future commitment to working in STEM, perceptions of agentic (being able to use skills to do enjoying work) and communal opportunities in STEM fields, and faculty/student interactions. They found that agentic occupational affordances were a strong predictor of students committing to pursuing a STEM career. They also found that White women who had higher satisfaction with faculty interactions had higher commitment to pursuing STEM.

Instructors may also have a role in the development of a sense of belonging, either positive or negative, through their interactions with students. Sense of belonging, or the connectedness a student has to their community, can contribute to positive outcomes such as persistence for students in the STEM classroom [31]. Verdín's [32] study of women in engineering (n=373) across nine institutions in the United States offers further evidence of the influence of instructors on a sense of belonging for minoritized women. She found that for minoritized women, receiving outside recognition from instructors contributed to their sense of belonging in the major and the classroom. Minoritized women also reported receiving lower levels of recognition from instructors compared to majority women thus suggesting the importance of instructor support for women of color in engineering.

In her study of eight undergraduate first-generation Latinx students in engineering, Espinoza [33] found that most participants viewed their engineering professors as caring more about their research than their teaching and appeared to avoid them. Yet, one student discussed feeling positive when a professor showed interest in her personal life. Another student, who had received a compliment from a professor, felt more confident. The few positive interactions that some of the students encountered with their engineering professors appeared to influence their self-efficacy. According to Espinoza, receiving validation from professors appeared important to the Latinos in the study.

The previous studies discussed reveal that faculty interactions with students, particularly underrepresented students, can influence their sense of belonging and self-efficacy. Since these interactions contribute to the experiences of underrepresented students, it is important to engage engineering faculty in understanding the effects they can have on students. By having instructors participate in self-reflexive work that helps them build an intercultural awareness and assists them in developing positive relationships with their students, the overall experiences of underrepresented students in engineering can be improved.

Engineering Culture

Understanding engineering culture is critical in determining the cultural norms that exist within engineering contexts and how faculty and students operate within those contexts. By understanding culture, more impactful professional development can be developed to support more inclusive practices in engineering.

According to Grayson [34], engineering education in the United States was founded in the military to address a pressing need for surveying and construction skills. By World War II, engineering schools in the US enrolled a large number of men and trained them in technical skills needed for the war. There were very few women or people of color enrolled in engineering schools, particularly since the military was only composed of White men during this time period. These historical exclusionary roots contributed to the formation of an engineering culture that was reflected in its disciplinary norms. Tonso's [35] work in engineering classrooms in the 1990s revealed how masculinity within engineering culture led to sexist behaviors by men instructors and peers toward women. More recent work has also highlighted the effects of racial microaggressions on students of color in engineering [36], [37].

Holland and Lave [38] explain that culture socializes individuals within an environment through the social processes by which they participate in their personal lives, work, and relationships. The socialization process that people experience within engineering culture emphasizes aspects of meritocracy. Meritocracy values achievement and performance while ignoring sociocultural systems such as racism and sexism which privilege certain populations over others. According to Cech [5], engineering also promotes depoliticization, the idea that engineering should maintain objectivity and that social justice does not belong. These aspects of engineering culture are reinforced in spaces such as engineering classrooms and can have a negative effect on women and people of color [39], [6], [40], [41].

Tonso's [35] research in engineering classrooms revealed how gendered discourses occurred between instructors and students and between students. She argued that people within engineering become enculturated in a system of masculine practices and beliefs historically rooted in the military. Tonso [35] believed that the weed-out system, or the process of being "objectively" filtered out of the engineering discipline, reflected historical military practices where men had to "prove" to their fellow men that they had the abilities to continue in the military. Those that could not overcome challenges faced in the military were eventually dismissed much like how "weeding out" in engineering occurs, where students are told to find another major if they cannot achieve the necessary grades.

Besides a "weed out" engineering culture, Tonso [35] also found that gendered discourse occurred in design teams where men engaged in sexist behaviors toward women using sexually suggestive language and questioning women's skills. Beverly [25], in her study of engineering courses, found evidence of men engaging in behaviors toward women such as co-opting women's ideas, mansplaining, and ignoring them. Black women in Beverly's [25] study also indicated both racial and gendered experiences in sharing that White men and women engaged in negative treatment toward them in group projects. Therefore, engineering culture perpetuates embedded practices that are exclusive toward both women and people of color. It is important to consider how this culture influences engineering teaching and learning environments and the faculty's role in shaping the experiences for students. By improving teaching and learning environments by educating faculty in engineering on how to create more inclusive spaces for students, we can further broaden participation in engineering and improve retention rates.

The IPF and Aspire Summer Institute

Conceptual models like the IPF and the ASI, a form of professional development, can promote inclusive practices in engineering. STEM reform initiatives focused on faculty professional development, such as the Aspire Alliance (Aspire), seek to diversify STEM faculty in part by preparing and educating faculty to integrate inclusive practices across their various student-focused (e.g., teaching, advising, research mentoring) and peer-focused (e.g., collegiality, and leadership) campus roles and responsibilities. This work is grounded in Aspire's Inclusive Professional Framework (IPF) [42], [43], [44]. This research-informed, holistic professional development framework involves three domains that operate together when engaging in inclusive practices. *Identity* involves understanding not only your social and cultural identities, but also that of students, and the impact of identity in learning spaces. *Intercultural awareness* involves instructors being able to navigate cultural interactions in a positive way as they consider the diverse backgrounds of students, while recognizing their own privileges and biases. The *Relational* domain involves creating trusting relationships and a positive communication between instructors and students. These core domains of identity, intercultural awareness and relational skills are common across faculty's student and peer-focused institutional roles.

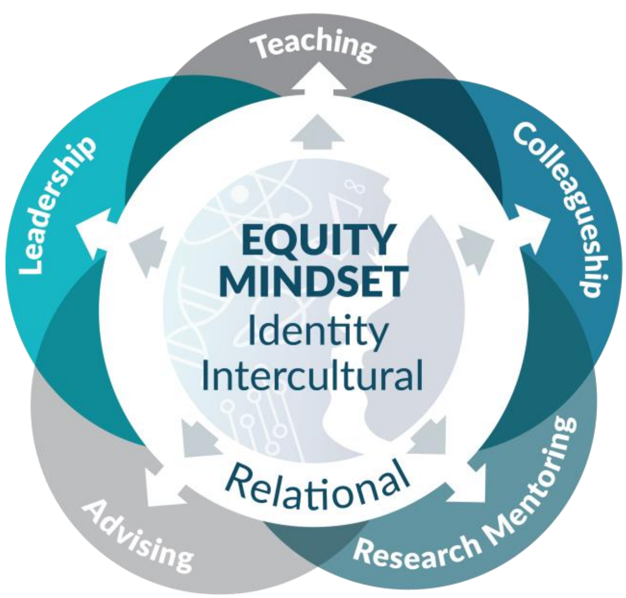

Fig. 1: Aspire’s Inclusive Professional Framework

The Aspire Summer Institute (ASI) has been one of Aspire’s most successful programs. The ASI is an intensive and immersive, week-long professional development program focused on educating institutional teams of faculty, campus leadership and faculty developers about the Inclusive Professional Framework and how to integrate its components, individually and as teams, to improve STEM faculty inclusive behaviors. During the Institute, participants explore the IPF by engaging in a mix of expert presentations, discussions, case-based scenarios, role plays, as well as individual and group reflection. Teams action plan to operationalize learning in both their individual roles and at an organizational level. In addition, participants can engage with an ongoing Community of Practice.

To gauge the impact of participation in the ASI, participants were invited to complete linked pre- and post-Institute surveys. Respondents indicated gains in IPF-based knowledge and confidence. These results are based on comparing mean differences and no statistical tests were conducted on the data. For example, for the 2021 ASI, respondents indicated pre-post knowledge gains (pre-survey response rate of 76% (n=37 of 49 total participants)) and post-survey response rate of 71% (n=35) in example categories (6pt Likert scale): (a) The role that identity plays in creating effective learning environments (m=3.68 to m=5.06); (b) Key elements of an equity mindset (m=3.56 to m=4.88); and (c) Ways to support the persistence of undergraduate students from underrepresented groups in STEM disciplines (m=3.47 to m=4.59). Respondents reported pre-post gains in confidence in the following example categories: (a) Engage my students’ individual identities, experiences, and values in support of their personal, developmental, and academic growth (m=3.93 to m=4.80); and (b) Recognize how cultural diversity can benefit my student and collegial relationships (m=4.19 to 5.16) [44].

Adapting the ASI for Engineering

Because the ASI model and the IPF have been successful at educating STEM faculty, institutional leaders, and faculty developers about inclusive practices, we argue that developing an ASI that directly addresses the engineering context would be especially beneficial. We also feel that the domains of the IPF work well in a highly project-based professional discipline to provide faculty with tools to effectively engage with and manage student groups. Further, because engineering is a discipline that has historically excluded women and people of color, the IPF can be a useful tool, as it is broadly used in STEM, to promote a sense of belonging for members of these underrepresented groups.

Two key domains of the framework are identity and intercultural awareness. We argue that adding activities connected to understanding the nuances of engineering culture would be an effective way to help individuals situate their identity in the engineering context. For example, participants could reflect on and discuss their socialization experiences in both the field of engineering and in their department. They could then identify aspects of the engineering culture within their departments that could potentially create barriers for students historically underrepresented in the discipline. Finally, we would task participants with identifying actionable steps to shift the perceptions of engineering culture with their students both inside and outside of the classroom. Adding exercises related to engineering culture to the institute would allow engineering faculty and administrators to engage in sustained dialogue about their beliefs and understanding of engineering culture, and may impact their understanding of the way engineering operates to include some and exclude others.

A more focused discussion about disciplinary culture will provide a launching point to begin dialogue about the complexities of identity and how it shapes and can be shaped by certain social contexts. Because engineers may be enculturated to believe that social justice does not belong within engineering curriculum [5], this would provide an opportunity for participants to reflect on why the belief exists and how they have participated or gone against such norms. When discussing the identity domain, we would utilize an academic wheel of privilege exercise to have individuals begin to think about how aspects of their identities contribute to their positionality, and how that influences their social roles.

The domains of intercultural awareness and the relational piece of the IPF can be applied to the engineering environment due in part to the use of team-based work in the discipline. For general STEM audiences, the ASI utilizes an activity based on Yosso's Community Cultural Wealth model [45] in which participants begin to consider the different types of cultural capital students, particularly those from underrepresented backgrounds, bring to the classroom. This activity would also apply in an engineering context. To explore the relational domain of the IPF, we would suggest developing case studies that reflect engineering situations with groups working on team projects. These scenarios can promote practice around how to address student-to-student conflicts in group or team settings, while being aware of how identity can contribute to those conflicts. Participants could also bring an intercultural awareness to addressing differences in teams. Further integrating differences connected to race, gender, gender identity, and disability would help participants reflect on the challenges that these particular identity groups encounter in an engineering environment.

Conclusion

The IPF is important in that it encourages instructors to engage in self-reflexive practices to understand that their own identity has an impact in social contexts. This practice goes against the historical roots of engineering culture which claim that engineering is a space that is both objective and neutral. Yet, by engaging in these practices, instructors will gain awareness that engineering culture is indeed not objective or neutral and that much of the culture is Eurocentric and masculine focused. The IPF can be a useful tool within faculty professional development in engineering to begin to chisel away at cultural norms that are exclusive of women and people of color. By doing this, we can create inclusive environments that broaden participation and increase persistence to meet the diverse needs of the world.

Inclusive practices have been shown to have a positive effect on all students, but especially important to creating belonging and increased self-efficacy of those underrepresented in engineering [25]. The Inclusive Professional Framework not only focuses on improving teaching practices but also provides tools to apply an equity mindset through advising and research mentoring interactions. Further, the IPF also provides tools to support equity-minded leadership and collegial interactions. Although there are other professional development opportunities focused on educating STEM faculty on teaching practices [e.g., 46], the focus is on teaching methods and the delivery of those methods rather than engaging instructors in a self-reflexive process. Even inclusivity-focused professional development opportunities, such as the Inclusive STEM Teaching Project [47], often have instructors focus on understanding their identity without the deeper intercultural and relational awareness needed to holistically engage in inclusive practices. The IPF can be a useful tool to begin altering engineering culture that treats students as "objective" numbers. The IPF provides a platform for instructors to understand identity, have intercultural awareness, and be able to develop relationships built on trust. These skills are essential to promoting belonging and overall student success within engineering, particularly for those that are underrepresented.

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