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Removing Invisible Barriers and Changing Mindsets to Improve and Diversify Pathways in Engineering

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ABSTRACT

Supporting diverse students in engineering education is considered a critical unsolved issue facing engineering education. The field continues to suffer from a lack of diversity and struggles to recruit and retain underrepresented students. We argue that structural barriers prevent equitable participation. In this paper, we examine structural barriers - specifically racism and sexism - experienced by underrepresented students in engineering education and highlight useful interventions. We then call for action to improve and diversify educational pathways in engineering. Specifically, we call for and highlight examples of rethinking mindsets for research and instruction. Lastly, we call for the engineering education community to work together in changing the culture of engineering education while highlighting the key role of the allies.

Key words: Sexism; racism; underrepresented students; allies.

INTRODUCTION

The challenge for universities in preparing 21st century engineers is to design programs with depth in engineering disciplines while broadening the curriculum to address other professional skills and values such as diversity and inclusion, communication across cultures, management within and across organizations, business acumen, inventiveness, ethical decision-making, and teamwork. It is



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impossible to begin to resolve these challenges without first examining the pathways and experiences of our students as they matriculate through the university and considering which students have access and are able to navigate these pathways. In an effort to name and untangle the most critical and unresolved issues facing engineering education research, a Delphi study was conducted within the engineering education community (Besterfield-Sacre and Shuman, 2016; 2019). The study found that the issues included learning in and out of the classroom (Finelli and Froyd, 2016; 2019), improving and diversifying pathways (Simmons and Lord, 2016), and using technology for enhancing learning and engagement (Koretsky and Magana, 2016; 2019). This paper focuses on the theme of improving and diversifying pathways.

Pathways for engineering students might start in prekindergarten and advance through primary and secondary schools into post-secondary institutions and then the workplace. This paper, however, focuses on post-secondary education, specifically four-year colleges. We acknowledge that the other settings are critically important, but believe the four-year college setting is appropriate here because the primary audience for this paper includes engineering faculty (practitioners of education), engineering administrators (deans, department chairs), classroom innovators, and engineering education researchers.

In thinking about issues related to pathways, we focused on the difficulties of transferring research to practice and barriers to achieving widespread propagation. In this paper, we posit that many of these difficulties and barriers are inherent in the underlying systemic problems in engineering education. Such systemic problems are often difficult to identify and even more difficult to address since they require changing the system from its status quo. For example, as a profession, engineering has not necessarily embraced the value of diversity and inclusion and embedded the requirement for developing skills in this area. One hopeful sign is that “creating a collaborative and inclusive environment” is one of the 2019-2020 ABET student outcomes (<http://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/#proposed>). The recommendations in this paper aim to help engineering educators and administrators identify best practices to sincerely meet this new outcome.

We begin this paper by considering systemic or structural issues that contribute barriers to student success, focusing on racism and sexism, and highlighting some useful interventions. Then we call for action in rethinking research and instructional mindsets and the engagement of allies in promoting diversity and inclusion. While we acknowledge the importance of considering barriers for many underrepresented groups in engineering (e.g., generation in college status; socioeconomic status; veteran status; disability; neurodiversity including being on the autism spectrum; lesbian, gay, bi-sexual, transgender, queer or questioning, and ally or asexual (LGBTQA)), we recognize and emphasize that all issues have not been solved for groups such



as African Americans and Latinx¹, therefore, we should not forget that continued research and action are necessary for these students.

STRUCTURAL ISSUES

Some of the most important influences on engineering students' persistence through four-year colleges are structural: curriculum (e.g., sequencing and scheduling of classes, credit hours), faculty (e.g., pedagogy, diversity), environment (e.g., classroom climate, sense of belonging), and university policies and processes (e.g., admissions). The persistently low representation of White women and people of color points to the pervasiveness of issues such as racism and sexism in engineering education. In our experience, engineering educators are reluctant to address these issues head on, fearful of even accessing the literature and discussing such topics to improve their understanding of the ways that, for example, sociologists and psychologists approach these topics. However, by not naming racism and sexism, the engineering community allows these prejudices to persist in engineering.

In this section, we consider how racism and sexism are manifested in engineering education including through the curriculum, policies, and other university structures. We provide some examples of efforts that creatively address these structural barriers. Again, we emphasize these issues will not be addressed exhaustively but instead highlight some examples.

Sexism

Documentation of a “chilly climate” for women in education began in the 1980s (Hall and Sandler, 1982). Academic departments that express these unfavorable environments have been shown to decrease student engagement and increase student attrition (Seymour and Hewitt, 1997). The low numbers of women in engineering exacerbate these problems. Women's experiences in engineering have been described as a series of microaggressions (Camacho and Lord, 2011). “Microaggressions arise from subtle and covert racist and sexist acts which occur frequently in the lives of marginalized groups” (Camacho and Lord, 2011). These seemingly small actions or interactions are perceived as offensive whether intentional or not. In some examples from that study, researchers found that

¹Throughout this paper, we use the terminology employed by the authors when referring to their research. In general, we use the terms Latino, Latina, or the more inclusive Latinx rather than Hispanic. Hispanic is a term invented by the U.S. Census and refers to persons of Spanish-speaking origin or ancestry. Latino (for males) and Latina (for females) is often preferred as it “more directly refers to Latin American origins and suggest a shared heritage of indigenous peoples and colonizers shaped by conquest.” (Camacho and Lord, 2013, p. 39).



microaggressions occurred at the interpersonal level as comments about women needing to take on the secretarial role in a group and at the institutional level in faculty comments or policies that assume women are outsiders or tokens. Engineering students described jokes relating to sex or denigrating women as making them feel invisible and excluded.

While fields such as law and medicine have made gains in the percentages of women in the field, engineering still lags behind with 20.9% of bachelor of science degrees in engineering being awarded in the United States to women (Yoder, 2016). In examining the literature further, research has uncovered characteristics of the engineering culture and curriculum that contribute to the “chilly climate” for women. The *sexist* nature of engineering culture has been shown to increase from first to fourth year of engineering study (Tonso, 2007). Scholars have pointed to the *gendered nature* of engineering itself (Faulkner, 2007; Ayre, Mills, and Gill, 2013; Pawley, 2007; Stonyer, 2002; Riley, 2008) and features of the culture that discourage or repel women such as *curved grading* and *the meritocracy of difficulty* (Stevens, Amos, Jocus, and Garrison, 2007). Hacker describes the *rigidity* of engineering education curriculum as a legacy of its beginnings in French military schools (Hacker, 1989). From the perspective of a historian, Bix examines the outright *resistance* to women engineers calling them “engineeresses” in the 1950s (Bix, 2004).

Examples of Interventions

Sometimes it is difficult to recognize a structural barrier until an intervention addresses an issue that results in a change in the status quo. It requires a creative perspective to recognize a problem, develop a solution, gain support for implementation, and then facilitate the intervention and, if successful, champion the institutional change. The following examples highlight such interventions that removed structural barriers and ushered in changes for women.

Learning Experiences

Sexism often presents itself in the curriculum. Using both qualitative and quantitative methods to investigate gender in engineering education in Denmark, Du and Kolmos (2009) advocated for the adoption of a less rigid approach to learning as well as specialization options to help support women students. The researchers found that learning experiences in arts and design engineering are different from those in other engineering disciplines. Student projects in arts and design engineering foster a more interdisciplinary and creative approach, focusing on societal and human impact and relationships, and multiple methods of assessment. This discipline included more than a purely technical focus. The women engineering students in this study were more motivated and engaged when their values and contributions were recognized and appreciated. Furthermore, women students also favored a learning approach that included collaborative-learning rather than



just a lecture-based curriculum and group projects. Women students cited both mixed and women only groups as a supportive way to keep women who had a strong wish to study engineering from dropping out. In another example, the alternative pedagogy of pair programming has been found to significantly improve the retention of women in computer science (McDowell, Werner, Bullock, and Ferald, 2006).

University Policy Admission

Standard university policies can have a negative impact on admission. For example, in a study by Holloway et al. (2014), the authors explain how an admissions policy that unintentionally reduced the number of women admitted to a midwestern public university's engineering education program was corrected. The study examined and found statistically significant evidence of admission decision gender bias for engineering applicants when considering standardized test scores (i.e., SAT math score). By changing the admissions requirement to focus more on leadership and academic motivation and less on standardized math test scores, the number of women admitted to engineering at the university increased.

The School of Computer Science at Carnegie Mellon implemented the following curricular, admission, and cultural changes that helped create a more welcoming culture and improved the recruitment and retention of women students:

- Added four different ways for first year students to enter the curriculum depending on the student's level of experience,
- Removed strong preference for prior experience in the university's admission criteria to complement the above curriculum change,
- Assigned better, more experienced and more senior instructors in the earliest courses in the curriculum,
- Trained graduate teaching assistants on gender equality,
- Redesigned courses to place technology in the context of its real world uses and impact in computer science,
- Raised faculty awareness of the difficulties women face, the myth that prior experience equals success and different motivations for entering computer science,
- Started an advisory council composed of undergraduate and graduate women in computer science who have introduced curricular and policy initiatives,
- Sponsored outreach to high school teachers (Margolis and Fisher, 2002).

As a result of these changes, the proportion of incoming women students increased from 7 percent in 1995, the first year of the study, to 42 percent in 2000. Retention of women also improved during that period (Margolis and Fisher, 2002).



While this section focused on women in engineering, researchers have sought to explain why women are missing from science, technology, engineering, and mathematics (STEM) fields and offer practical ways to increase educational and employment opportunities. As a useful starting point, the reader is referred to the American Association of University Women (AAUW) report “Why So Few? Women in Science, Technology, Engineering, and Mathematics” which summarizes some key literature on women in STEM (Hill, Corbett, and St. Rose, 2010).

Racism

Structural barriers impeding entry to, persistence in, and belonging for African Americans in engineering has deep roots in the legacy of racism and racial segregation that persist today. Slaton (2010) presents a sociohistorical example where Harry Clifton Byrd, President of University of Maryland from 1935-1954, argued that African Americans should not be allowed entry into the University including into engineering. As a result, Whites gained the advantage of entering the field of study at well-resourced, prestigious institutions while African Americans experienced an accumulated disadvantage. Slaton concludes that the policies at the University of Maryland and others in that region resulted in African American absences from engineering education and technical occupations that have yet fully to reverse themselves. Continued evidence of this perspective in the United States continues to discourage African Americans (Slaton, 2010).

Although such overtly public racist statements are less common today, African American students continue to feel unwelcome in engineering decades later. For example, in a study by McGee and Martin (2011), student participants described experiences of subtle and blatant racism including a constant state of awareness that being African American is an indicator of inferiority in engineering contexts. The authors suggest that stereotypes or the threat of being stereotyped at predominantly White colleges and universities are ubiquitous. Participants in the study indicated that they worked extremely hard to prove the stereotype wrong, yet received no reward or vindication. They perceived they were continually viewed as not smart enough or just affirmative action students. An electrical engineering student in this study commented on his encounters with everyday racism as “What the hell are you doing here?” experiences. Entering high-level course classrooms, he felt as if he stood out but at the same time, felt invisible. White students withdrew from him and he was called an “affirmative action student.” The authors concluded that the devaluing of students’ academic abilities made them keenly aware of their otherness.

Whereas the above discussion focused on the experience of African Americans, we recognize that racism is not limited to this population. Researchers found that other groups experience racism in engineering differently. Recent work has considered Latinas (Camacho and Lord, 2013) and Asian Americans (Trytten, Lowe, and Walden, 2012).



Examples of Interventions

As discussed, the roots of unequal access are tied in part to the legacy of racism and reluctance to name it as such. Therefore, one key to addressing racism is to purposely disrupt the system and support marginalized populations. Here we highlight some examples of interventions that have helped African American engineering students to succeed, thereby removing some structural barriers. Some of these interventions are at the institutional level, in the form of support programs or faculty actions, while others are at the individual level, in the form of peer-led social and professional societies.

Institutional Support Programs and Role of Faculty

Among other objectives, engineering support programs seek to promote belonging, persistence and academic achievement of engineering students. In a study of African American engineering students, an engineering support program was able to promote academic achievement during the first year (Good, Halpin, and Halpin, 2002). Lee and Cross (2013) found that African American engineering undergraduate students gained academic support, social support, professional development and a community of practice through participating in a mentorship program managed by an engineering support program.

Faculty play a significant role in the college experience of all students. A study by Newman (2011) suggests that faculty play an important role in encouraging or dissuading African American engineering students to persist in their respective majors and become involved in research and internships. African American engineers in this study cited examples of both faculty members who were inspiring and those who were barriers to participants' academic and career goals.

Individual Support: Social and Professional Societies

Peer-led, social and professional societies can play a role in dismantling structures and improving access for African American, Latinx, and Native American engineering undergraduate students (e.g. National Society of Black Engineers (NSBE) <http://www.nsbe.org/home.aspx>, Society of Hispanic Professional Engineers (SHPE) <http://www.shpe.org/>, and American Indian Science and Engineering Society (AISES) <http://www.aises.org/>). In a study conducted by Simmons and Martin (2011), involvement in Black Greek Organizations (BGOs) (i.e., fraternities and sororities) was linked to the development of the following six of the ten Engineer of 2020 attributes (NAE, 2005):

- Practical ingenuity,
- Good communication skills,
- Business and management skills,
- Leadership,
- High ethical standards,
- Professionalism.



Additionally, BGO membership was attributed to development of academic and career skills (e.g., interview skills, time management, teamwork, and problem solving) and with achievement and persistence in engineering (Trenor, Grant, and Archer, 2010). Involvement in NSBE was found to contribute to professionalism, business and management, leadership, and communication skills (Simmons et al., 2014). Brown, Morning, and Watkins (2005) focused on the perception of the campus climate and the ways the climate may or may not influence the academic performance and graduation rates of African American engineering students who are members of NSBE. The researchers found that NSBE members who attended Historically Black Colleges and Universities (HBCUs) tended to have higher grade point averages and a more favorable perception of the campus climate than NSBE members who attended other universities.

This section highlighted issues within the college structure and provided examples of how a few of these issues have begun to be addressed. We believe this section also raises questions of what other university policies warrant scrutiny through these lenses of inequality (i.e. racism, sexism etc.)? What other structural barriers should be examined or could be uncovered in engineering education?

CALL FOR ACTION

Rethinking Mindsets for Research

Data driven research is crucial to elucidate pathway impediments in engineering, inform the community, and move toward strategies for improvement. We need to rethink our mindsets, our metrics, and the data we collect. This section includes some examples of expanding frameworks, adopting creative methods including conducting different types of studies, developing new metrics, and expanding the categories of data we collect. The note-worthy examples highlighted below are not intended to be an exhaustive review of all such examples. We urge researchers to heed the call of Alice Pawley (2017) to “shift the default” and specify the demographics of all studies to make “diversity the expected condition for engineering education and making Whiteness and maleness visible.”

Frameworks

To realize change in data driven research, we echo the call of current researchers for an increase in and diversity of theories and methodologies to insure a better understanding of the diverse experiences of students in engineering education. For example, Beddoes and Borrego (2011) argued that feminist theory is not utilized enough when developing scholarship addressing engineering education. However, when used, the theory most often focuses on White, Western, middle class women and the White, male, dominant group. This narrow focus usually omits other identity markers



that might be salient for other students and ignores issues that do not concern the dominant group. Following a content analysis of gender-related research, Pawley, Schimpf, and Nelson (2016) found that studies aimed at analyzing and improving women's participation and success in engineering education often conflate participant identities by combining women, men, and racial minorities together. Theories that might be useful to insure a better understanding of the diverse experiences of students in engineering education include social identity theory (Ellemers and Haslam, 2012; Hogg 2006), Black Feminist thought (Collins, 1990), critical race theory (Delgado and Stefancic, 2001), theory of systemic racism (Feagin, 2006), and the colorblind racism paradigm (Bonilla-Silva, 2014). These frameworks would help researchers to critically examine the role of institutions and faculty in their complacency toward addressing structural barriers to persistence.

When considering issues related to diversity, it is important to adopt an intersectional approach and consider how multiple identities such as race and gender intersect in the experiences of engineering students. This approach builds on key literature from critical race theory (Delgado and Stefancic, 2001) and Black Feminist thought (Collins, 1990). Intersectionality studies disaggregate categories such as "underrepresented minority" and "women," which hide the experiences and stories of distinct groups such as Latino males and African American females. Recent work in engineering education has begun to use this approach. In *The Borderlands of Education: Latinas in Engineering*, Camacho and Lord offer the first focused consideration of Latinas highlighting the intersection of racism and sexism (Camacho and Lord, 2013). In other research, Ro and Loya (2015) found that Black women, Asian men, and men from other racial/ethnic groups tend to rate their engineering skills lower than their White counterparts. In their study, Charleston et al. (2014) found that African American women in computing believed that computer science culture was not welcoming to women in general and even less so to African American women. Participants reported feeling isolated and a lack of institutional, faculty, and peer support. They described how classmates did not want to work with them and because no other peers looked like them, they had to work alone. One participant recalled a professor making disparaging remarks about her:

"I don't think she has talent. I think White professors gave her grades because of her race and they felt bad about slavery. I don't think there are any real computer scientists who are African American, and maybe she can be the first" (Charleston et al. 2014, p. 172).

While the above research is largely qualitative, there are also examples of quantitative research in engineering education that adopt an intersectional framework. Some of this research also includes the added dimension of engineering discipline. Godfrey (2007) describes differences in disciplinary cultures within engineering underscoring the importance of considering various disciplines within



engineering. Lord et al. (2009) put forth that most studies using quantitative methods combine underrepresented students into one underrepresented group because of the small numbers. As a result, the specific experiences of each group are conflated. In a series of quantitative studies, this research group has shown that outcomes for engineering students vary by race/ethnicity and gender as well as institution (Ohland et al., 2011) and engineering discipline including electrical and computer engineering (Lord, Ohland, and Layton, 2015), chemical engineering (Lord, Layton, Ohland, Brawner, and Long, 2014), and civil engineering (Ohland, Lord, and Layton, 2015). For example, about one-third of Black male engineering students choose electrical engineering, more than any other group or field, but they do not have high graduation rates. Latinas have the highest graduation rates of all populations studied in industrial engineering but much lower in civil engineering. Litzler (2010) conducted a multi-institution study of sex-segregation in engineering fields showing differences for engineering disciplines. In a multi-institutional study, researchers found curricula that emphasize broader system-level approaches, including chemical, industrial and bioengineering, also have more women compared with mechanical and electrical engineering (Knight, Lattuca, Yin, Kremer, York, and Ro, 2012).

Another promising trend in engineering education research is the use of asset-based rather than deficit based approaches. Asset-based frameworks can have profound implications for the tone, recommendations, and impact of the work. Recent, praiseworthy examples of the use of an asset-based framework include exploring Latina/o funds of engineering knowledge (Wilson-Lopez, Mejia, Hasbún, and Kasun, 2016) and using community cultural wealth for examining persistence of Black and Latinx engineering students (Samuelson and Litzler, 2016).

Methodological: Kinds of Studies and Metrics

It is important that engineering education research takes multiple forms: quantitative studies, qualitative investigations, and personal self-reflections. Most engineering educators may be more familiar with large quantitative studies. However, there is value in qualitative work focused on narratives of small numbers of students or even a single individual (e.g., Pawley, 2013; Foor, Walden, and Trytten, 2007). In addition, work on self-reflection (e.g., Turns et al., 2014) offers insights not available in other types of studies.

The metrics used in student persistence should also be examined as they may have unintentional bias. For example, as described by Ohland et al. (2011), although eight-semester persistence appears to also predict six-year graduation, this association is not the case for all students. This approach is methodologically flawed as it is based on the persistence of the White male population. The use of eight-semester persistence may result in systematic majority measurement bias. Ohland et al. (2011) argued that pathways are not linear and vary by gender and race/ethnicity. As such, multiple measures



are needed to describe outcomes in diverse populations. Furthermore, they posited that consistency in the manner institutions treat all students does not guarantee the same outcomes because different populations respond differently to the same conditions. Examining persistence and outcomes by race/ethnicity and gender can positively impact the quality of research in engineering education.

Expanding Categories

We need to expand the categories of data we collect, where possible, including generation in college status, veteran status, disability, neurodiversity, and LGBTQA (lesbian, gay, bi-sexual, transgender, queer or questioning, and ally or asexual). We also need to collect demographic variables aligned with our current understanding of people's experiences and identities. For instance, we need to be mindful of modern definitions of gender identity including gender fluidity and transgender. With our current categories, we are missing many people's experiences and identities. Some examples of recent research expanding categories includes studies of first generation college students (Simmons and Martin, 2014; 2017), military veterans in engineering (Mobley, Brawner, Main, Lord, and Camacho, 2017; Soldan, Gruenbacher, Schulz, Vogt, and Hageman, 2013), LGBTQA students in engineering (Trenshaw, Hetrick, Oswald, Vostral, and Loui, 2013; Cech and Waidzunus, 2011), and students on the autism spectrum in engineering (Pilotte and Bairaktarova, 2016) and STEM (Wei, Yu, Shattuck, McCracken, and Blackorby, 2013).

With detailed, modern categories, we would have the data to analyze through the lens of intersectionality. We realize gathering this data is difficult in engineering given the small populations of some groups, but this small population underscores the need for multi-institutional data sets and qualitative research focused on small numbers. As we broaden the definition of diversity and consider more groups or more dimensions, we should be mindful that we still have much work to do for groups whom we have been failing to remove the structural barriers for years specifically African Americans and Latinx.

Rethinking Instructional Mindsets

Faculty play an important role in shaping the culture of engineering education including whether or not students feel they belong and can be successful. We encourage all engineering instructors to use more effective and creative pedagogies to enhance student learning and sense of belonging. Some practical actions that faculty can take include becoming informed about and mitigating stereotype threat and using resources to promote an inclusive climate.

For example, considerable research exists on stereotype threat - "a term used by social scientists to describe the anxiety one feels when he or she fears the potential to confirm a negative stereotype about his or her own group. This anxiety impairs the ability to think and reduces motivation to try. Even



if an individual consciously rejects a negative stereotype, performance outcomes may still be affected” (Eschenbach, Virnoche, Cashman, Lord, and Camacho, 2014). One of the first studies documenting stereotype threat showed that the performance of African American college students on the verbal Graduate Record Exam (GRE) was lower when they were told that the test is “diagnostic of intellectual ability” rather than “a laboratory problem-solving task that was nondiagnostic of ability” (Steele and Aronson, 1995). Stereotype threat has been shown to be invoked for women taking difficult math exams (Spencer, Steele, and Quinn, 1999). This finding is particularly important for engineering given the low percentage of women and high number of mathematical tasks. In these studies, students not under the stereotype threat condition do not show a change in performance for the different test conditions. Hundreds of studies have verified the impact of stereotype threat in various situations including classrooms. For a discussion of the development of stereotype threat concepts, see Steele (2010) and, for a review of stereotype threat research, see Spencer, Logel, and Davies, (2016).

Engineering educators should be aware of this research and adopt practices that mitigate it in their classroom. The “Reducing Stereotype Threat: Resources for Instructors” website is an excellent resource (<https://teachingcenter.wustl.edu/resources/inclusive-teaching-learning/reducing-stereotype-threat/>). A summary of research on stereotype threat, its implications for engineering education, and suggestions for engineering faculty to mitigate it is found in Eschenbach, Virnoche, Cashman, Lord, and Camacho (2014). The suggestions include:

- Encourage students to affirm their personal values and remember why they are studying your discipline,
- Communicate high standards to students as well as strong belief in students’ ability to meet standards,
- Help students develop attitude that successful engineers are not born, but developed through persistent commitment to their work,
- Use exams that are fair and measure learning and not innate ability,
- Remove any cues that may trigger stereotype threat,
- Help students develop a sense of belonging,
- Help students learn to manage feelings of stress and stereotype threat,
- Convey diversity is valued in the classroom.

There are useful resources available online for engineering educators to enhance student learning and promote an inclusive climate in the classroom. ASEE’s Safe Zone Training website includes training materials and resources for faculty (https://docs.asee.org/public/LGBTQ/Inclusive_Classroom_Strategies.pdf). Their research-based inclusive classroom strategies include:

- Examine your assumptions,
- Avoid stereotypes,



- Model inclusive language,
- Model inclusive behavior. Take an Implicit Biases Test online (<https://implicit.harvard.edu/implicit/selectatest.html>). Reflect on the results with an open mind. Most of us have biases of which we are unaware,
- Create equal opportunities for student participation,
- Use diverse examples,
- Include a diversity statement on your syllabus (see statement below). This simple step might help some students feel more comfortable in the class and raising concerns with the instructor.

“I consider this classroom to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class” (https://docs.asee.org/public/LGBTQ/Diversity_Statement.pdf).

Another useful resource for engineering educators is the NSF/WEPA Engage website (<http://www.engageengineering.org/>), which offers practical examples of engineering topics. These examples appeal to all students but might be particularly important for those who feel marginalized and struggle to see the relevance of the theoretical engineering coursework. In addition, this resource offers materials on promoting faculty-student interaction, which can help improve classroom climate. To more directly address issues related to diverse students, engineering educators could learn from the field of culturally relevant pedagogy or culturally sustaining pedagogy (Ladson-Billings, 2014). Long and Henderson (2017) provide recommendations for faculty in supporting African American male engineering students emphasizing resilience, persistence, and confidence.

Rethinking the Engagement of Allies in Teaching, Policy and Research

“Social justice allies are members of dominant social groups (e.g., men, Whites, heterosexuals) who are working to end the system of oppression that gives them greater privilege and power based upon their social group membership” (Broido, 2000, p. 3). Particularly since there are so many White men in engineering, it is critical that the important work of promoting success for all students be shared. Promoting equity is not just the work of women or people of color. White men can explore and reflect on their own privilege within engineering education (Douglas, 2015).

People may be willing to be allies, but not know what to do. Therefore, training is needed. One useful example of ally training is the National Science Foundation funded GEO Opportunities for



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Leadership in Diversity (GOLD) Institute (https://www.nsf.gov/awardsearch/showAward?AWD_ID=1645430&HistoricalAwards=false). This professional development training helps established scientific leaders in the geosciences to become champions of change for diversity by giving them the content knowledge, tools, and skills. By targeting senior scientists who are already well respected in the field, the project seeks to capitalize on their reputations, networks, and social capital to build them into diversity champions with the power to make significant and swift cultural change in their institutions and the wider field.

Efforts to help engage men as gender equity allies in engineering are powerful examples of the importance of allies. As part of the NSF-funded ADVANCE FORWARD project at North Dakota State University, researchers designed and implemented a male allies program (Bilen-Green et al., 2013). Building on the literature on social justice ally development, they identified several key features of such programs:

- Brings awareness regarding gender inequities,
- Engages men in solution building,
- Provides ongoing training, discussions
- Increases empathy and understanding of impacts,
- Utilizes male role models,
- Provides opportunities for men-only dialogues,
- Encourages reverse mentoring,
- Acknowledges costs men face,
- Intentionally includes male colleagues (Bilen-Green et al., 2013).

This program has expanded beyond that one institution and is part of WEPAN's "Male Allies Moving the Gender Equity Needle" (<http://www.wepan.org/?page=maleallies>). At the 2017 ASEE Annual Conference, workshops were held with one session for males only and one open to anyone.

In addition to allies from the dominant group and in order to address many underlying issues (e.g., need for role models), it is critical to have representation from diverse groups in the engineering faculty. Since engineering is entwined with innovation, diverse perspectives are critical for success in teaching, research, and engineering practice. In a study of African American and Latino college students attending selective predominantly White institutions (PWI), Baker (2013) found that race is an influential component of student success. Being in classes with professors who are of the same race as students positively influenced academic performance for most African American and Latino students and was most beneficial for African American females, Latinas, and Latinos at selective institutions. However in the United States, the representation of women, African Americans, and Latinx among engineering faculty remain low. "The percentage of faculty members who are women increased by half a percent from 2015 to 16.3 percent in 2016. The representation of



African Americans decreased slightly to 2.3 percent in 2016, while that of Asian faculty increased to 27.5 percent and that of Latinos rose to 3.6 percent” (Yoder, 2016). Academics of all races and ethnicities can be allies in policy development and implementation that result in hiring and retaining faculty of color in engineering education.

A useful strategy to aid in the hiring of diverse faculty is becoming aware of implicit bias and the fact that everyone has bias (Hill, Corbett, and St. Rose, 2010, Chapter 8, pp. 73-79). Combining training with a facilitated discussion of implicit bias may be particularly beneficial. Moving beyond guilt to strategies that result in empowering allies is critical to removing structural barriers to hiring faculty of color. We encourage all involved in faculty hiring to consider and adopt best practices for searches and hiring (University of Michigan, 2016; Guenter-Schlesinger and Ojikutu, 2009) and innovative approaches such as cohort hiring (Sgoutas-Emch, Baird, Myers, Camacho, and Lord, 2016). We also encourage search committees to examine their own mindsets and avoid the false dichotomy of excellence versus equity.

More engineering educators should serve as allies in the retention of women, people of color, and members of other underrepresented groups in faculty positions. If new hires enter “chilly” workplace climates (Cech and Waidzunus, 2011; Fouad and Singh, 2011), then it is unlikely they will stay. Because these work environments do not match their perception of departmental environments that attract individuals to the disciplines and/or support their development as faculty members, they are more likely to change their career. The role of an ally, in this instance, might be to find ways to create an environment where individuals can have positive, formal and informal interactions and work collaboratively (Guenter-Schlesinger and Ojikutu, 2009). Creative strategies are needed for mentoring all faculty including faculty of color (Mack, Watson, and Camacho, 2012). White women can also play important roles as allies for women of color (Dace, 2012). There have been examples of excellent programs aimed at supporting specific groups of faculty (e.g., ADVANCE Women of Color (WOC) Career Coaching Program sponsored by Purdue University, <https://www.purdue.edu/advance-purdue/>; Minority Faculty Development Workshop https://www.nsf.gov/awardsearch/showAward?AWD_ID=1441387; and LATTICE (Launching Academics on the Tenure Track: an Intentional Community in Engineering) <https://advance.washington.edu/lattice>). However, external funding from agencies such as the NSF has typically supported these programs. We call for institutionalizing such initiatives to truly change the structure and culture of engineering.

Another useful resource is the AAUW's, *Solving the Equation: The Variables for Women's Success in Engineering and Computing* (Corbett and Hill, 2015), which provides recommendation targeted for employers, men in engineering and computing, women in engineering and computing, university administrators, government, parents, and policy makers.



CONCLUSIONS

The discussions in this paper lead us to consider a number of questions. Answering these questions could lead to important insights that address the systemic and structural issues in engineering education that we argue impede pathways for students. Careful consideration of these issues can help make a collaborative and inclusive environment a reality for future students in engineering education. Everyone in engineering education should explore how power and privilege are enacted in their own experiences and how they can dismantle these structures. How can you be an ally for all students in teaching, research, and policy? As an instructor, are you implementing inclusive teaching strategies? As a researcher, are you adopting a mindset that allows for inclusivity? As a policy maker, are you considering the experiences of a diverse group of students in developing policies?

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Removing Invisible Barriers and Changing Mindsets to Improve and Diversify Pathways in Engineering



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