



## **Interactive Panel: Improving the Experiences of Marginalized Students on Engineering Design Teams**

### **Dr. Lorelle A Meadows, Michigan Technological University**

Dr. Lorelle A. Meadows is the Dean of the Pavlis Honors College at Michigan Technological University.

### **Prof. Denise Sekaquaptewa, University of Michigan**

Denise Sekaquaptewa, Ph.D., is Professor of Psychology at the University of Michigan, Ann Arbor. Her research in experimental social psychology focuses on stereotyping and intergroup dynamics, in particular how being in the numerical minority in terms of gender or race influences academic outcomes and experiences.

### **Dr. Marie C Parette, Virginia Tech**

Marie C. Parette is an Associate Professor of Engineering Education at Virginia Tech, where she co-directs the Virginia Tech Engineering Communications Center (VTECC). Her research focuses on communication in engineering design, interdisciplinary communication and collaboration, design education, and gender in engineering. She was awarded a CAREER grant from the National Science Foundation to study expert teaching in capstone design courses, and is co-PI on numerous NSF grants exploring communication, design, and identity in engineering. Drawing on theories of situated learning and identity development, her work includes studies on the teaching and learning of communication, effective teaching practices in design education, the effects of differing design pedagogies on retention and motivation, the dynamics of cross-disciplinary collaboration in both academic and industry design environments, and gender and identity in engineering.

### **Dr. Alice L. Pawley, Purdue University, West Lafayette**

Alice Pawley is an Associate Professor in the School of Engineering Education and an affiliate faculty member in the Gender, Women's and Sexuality Studies Program and the Division of Environmental and Ecological Engineering at Purdue University. She was co-PI of Purdue's ADVANCE program from 2008-2014, focusing on the underrepresentation of women in STEM faculty positions. She runs the Feminist Research in Engineering Education (FREE, formerly RIFE, group), whose diverse projects and group members are described at [feministengineering.org](http://feministengineering.org). She received a CAREER award in 2010 and a PECASE award in 2012 for her project researching the stories of undergraduate engineering women and men of color and white women. She received ASEE-ERM's best paper award for her CAREER research, and the Denice Denton Emerging Leader award from the Anita Borg Institute, both in 2013. She helped found, fund, and grow the PEER Collaborative, a peer mentoring group of early career and recently tenured faculty and research staff primarily evaluated based on their engineering education research productivity. She can be contacted by email at [apawley@purdue.edu](mailto:apawley@purdue.edu).

### **Dr. Shawn S Jordan, Arizona State University, Polytechnic campus**

SHAWN JORDAN, Ph.D. is an Assistant Professor of engineering in the Ira A. Fulton Schools of Engineering at Arizona State University. He teaches context-centered electrical engineering and embedded systems design courses, and studies the use of context in both K-12 and undergraduate engineering design education. He received his Ph.D. in Engineering Education (2010) and M.S./B.S. in Electrical and Computer Engineering from Purdue University. Dr. Jordan is PI on several NSF-funded projects related to design, including an NSF Early CAREER Award entitled "CAREER: Engineering Design Across Navajo Culture, Community, and Society" and "Might Young Makers be the Engineers of the Future?" He has also been part of the teaching team for NSF's Innovation Corps for Learning, and was named one of ASEE PRISM's "20 Faculty Under 40" in 2014.

### **Prof. Debbie Chachra, Olin College of Engineering**

### **Dr. Adrienne Minerick, Michigan Technological University**



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Adrienne Minerick received her M.S. and Ph.D. from the University of Notre Dame and B.S. from Michigan Technological University. Adrienne's research interests include electrokinetics, predominantly dielectrophoretic characterizations of cells, and the development of biomedical microdevices. She earned a NSF CAREER award and was nominated for Michigan Professor of the Year in 2014. Research within her Medical micro-Device Engineering Research Laboratory (M.D. – ERL) also inspires the development of Desktop Experiment Modules (DEMOS) for use in chemical engineering classrooms or as outreach activities in area schools (see [www.mderl.org](http://www.mderl.org)). Adrienne is currently co-Chair of ASEE's Diversity Committee and PIC I Chair; she has previously served on WIED, ChED, and NEE leadership teams and contributed to 37 ASEE conference proceedings articles.

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## **Introduction**

It is widely recognized that group-learning approaches such as problem- and project-based learning or collaborative learning benefit students by creating an educational environment in which students achieve higher grades, learn at a deeper level and retain information longer. However, group work is fraught with challenges for students who are inexperienced in managing interpersonal interactions and for faculty who sometimes struggle to guide student teams in achieving successful interactions and learning outcomes.<sup>1-3</sup> One important challenge centers on the interactions between students from groups negatively stereotyped as poor performers in engineering (e.g., women and under-represented racial minorities) and others. A body of research in psychology indicates that students from these marginalized groups may have qualitatively different group work experiences compared to others, which may contribute to their self-selection from engineering and thus their group's under-representation in engineering fields.

Recent research suggests that the negative experiences of people from marginalized groups on engineering student design teams can influence many factors that contribute to persistence and success, such as development of self-efficacy, sense of belonging, identification and identity integration. Often, negative experiences are the result of subtle bias or schemas that all students bring with them into their teams, and occur despite the employment of best practices in team formation.

This paper presents a summary of a contemporary understanding of this phenomenon as presented by several individual researchers covering the fields of stereotype threat, engineering design, teamwork, motivation, and race, gender and their intersections. The content of this paper was generated by collecting the individual responses of each researcher to a set of prompts including:

- examples of how students can be marginalized in engineering teamwork and what governing factors influence this marginalization and how these experiences influence key outcomes;
- promising strategies to reduce or minimize the potential for negative experiences of under-represented students;
- important assumptions that we as researchers, instructors and administrators should challenge.

The individual responses were synthesized into the following document. This summary provides an overview of group-learning environments in engineering education and categories of marginalization within these environments, a theoretical framework for race and gender, key social science research in this domain and promising research-based strategies to improve the educational experience for all students.

## Group-learning Environments in Engineering Education

Before we discuss how students can be marginalized, it's useful to articulate why we use group assignments in engineering courses. Of importance, most engineering work in industry happens in teams, and the use of group projects provides a means to simulate, and thus prepare students for, professional practice including skills such as interpersonal communication, leadership, cultural literacy, conflict negotiation, and project management.<sup>4</sup> At the same time, group-learning models such as problem-based learning and collaborative learning have demonstrated positive student outcomes with respect to life-long learning, problem-solving, and creativity.<sup>5</sup>

Ideally, in these learning environments, we want our students to develop knowledge and skills in the technical space in which they work. We also want them to develop knowledge and skills in the professional and interpersonal domains, including communication, teamwork, leadership, creativity, cultural literacy, and social responsibility. We want their experience to be synergistic, such that each individual learns and accomplishes more as part of a team than they could accomplish on their own. Finally, we want them to develop a level of self-confidence in these skills that is commensurate with what they can accomplish.

Importantly, however, simply placing students in groups does not inherently foster such learning. For effective learning to occur, faculty should play an active role in shaping and supporting students' group-learning experiences.<sup>6</sup> While faculty practices are important in all group-learning approaches, they can be particularly important for supporting under-represented students, who often experience marginalization in such settings. Both faculty and peers can marginalize individual students in a variety of ways, including through assignment of work tasks, validation of work tasks, validation of ideas or perspectives, and the nature of the group task itself.

First, at the onset of an activity, task assignment biases can often result from unconscious expectations about who may be more (or less) suited to certain tasks.<sup>7, 8</sup> While each team is different, with a different set of identities and personalities, there is also (unsurprisingly) a significant interaction between forms of marginalization and demographics. For example, female students may find themselves in the position of scheduling team meetings or organizing final reports because these are viewed as more "social" tasks stereotyped as "women's work."<sup>9</sup> Similarly, women may wind up with fewer opportunities for hands-on construction of prototypes.<sup>10</sup> Students from groups that are racially under-represented in engineering may not get the opportunity to perform mathematically-intensive analyses because expectations, again supported by social schemas and implicit bias, may unconsciously suggest to teachers and/or to teammates from dominant groups that these students are not "good at math." These biases are compounded because under-represented students often enter engineering with lower self-efficacy, and may hesitate to volunteer for technical tasks.<sup>11</sup>

Second, marginalization can occur when an individual's work tasks are not validated or fully recognized by their peers or their instructors.<sup>12-14</sup> These biases can emerge when peers or instructors may simply not acknowledge a student's contributions or when they subsume that student's work under the group as a whole. This bias can manifest as the difference between "we did X" versus "Michael did X" or "we 3-D printed a model" versus "Beth created a CAD drawing so that we could 3D print a model."

Third, team members can also be marginalized intellectually when their attempts to contribute are ignored or their suggestions aren't considered seriously. This marginalization can occur, for example, when students' ideas are not written down during brainstorming sessions<sup>12</sup> or when a pattern develops over time in which an individual's repeated, technically viable suggestions are ignored in favor of ideas from dominant group members. In some cases, validation of ideas only occurs after a more highly valued member of the team also makes the same suggestion. Validation may become attached to the individual with a positively stereotyped identity at the expense of another individual.<sup>15</sup> This intellectual marginalization or elevation can be compounded by gendered speech patterns. For example, ways of speaking that are characteristically feminine (e.g. softening criticism, admitting ignorance) are less respected by both men and women on engineering teams.<sup>16</sup>

Fourth, students of certain racial or cultural identities may feel marginalized because the projects themselves are not relevant or meaningful in their cultural context. For instance, Native American students may feel marginalized in engineering teams due to differences between Western approaches to science and collectivistic culture.<sup>17</sup> Similarly, gender biases can occur when design tasks are perceived as explicitly or implicitly masculine,<sup>18, 19</sup> and these biases can affect both engagement and decision-making.

As a result of being marginalized, students may be denied the opportunity to engage in the full range of tasks and develop these important and diverse skill sets. They may miss the opportunity to collaborate effectively with others and, in the extreme, could be socially excluded. The poor quality of their interactions with teammates may undermine, rather than increase, their comfort and confidence in their chosen field.

## **Theoretical Framework**

To understand alternatives to these kinds of marginalizing practices, we need to first step back and understand their sources. This marginalization of individuals originates in part with the set of social schemas that individuals hold for what it means to be an engineer. Despite the best efforts of many individuals, the field of engineering is biased towards dominant images of white males as successful engineers.<sup>20</sup> This representation is problematic for everyone concerned and reinforces schemas that serve to engender implicit bias and marginalize the diverse contributors needed to solve the challenging problems of the 21<sup>st</sup> century.

Importantly, these biases do not imply that engineering, or all engineering faculty are *racist*, or *sexist* (though both sexism and racism persist). Instead, they point to the ways in which engineering is '*raced*' white and '*gendered*' male. To fully understand these two terms, however, it is valuable to think about gender and race from a more theoretical point of view than what we have come to learn as "common sense."

Connell<sup>21</sup> provides a clear treatment of the discussion of gender as distinct from sex. Connell notes that gender is not a supposedly biologically-obvious division between men and women, but instead the way human society collectively makes relevant these reproductive distinctions between human bodies in a social context. For us, the context is engineering education. In its

simplest form, gender reflects the set of characteristics, behaviors, and practices that we think of as “feminine” or “masculine” – characteristics that any individual biological male or female may or may not embody.

Race, like gender, is not a biological category but a social one. And unlike sex, race has no biological basis, despite a long history of attempts to find one and despite the phenotypical biological expressions (e.g. skin color, facial structure) we have come to interpret as markers of race. Instead, we prefer to use a theory of racial formation to understand how race functions in contemporary US society.<sup>22</sup> Omi and Winant describe race as socially-constructed categories that we have collectively come to apply to human bodies, that are based on social conflicts and group interests. In other words, “race” is a socially created way of placing individuals into groups, and that grouping process is not “objective” but rather carries with it a whole set of historical interactions. Omi and Winant go on to describe *racial formation* as the socio-historical process by which racial categories are created, inhabited, transformed, and destroyed.

It is important to note that in engineering education we seem to regularly talk not about race but “race/ethnicity.” Omi and Winant explore the paradigm of talking about race through a lens of ethnicity, noting its reliance on a logic of immigration to define ethnic groups as different from racial groups. However, ethnicity with regards to whiteness in the US has largely been erased through decades of historical processes including through immigrant waves of desirable and undesirable Europeans to the US.<sup>23</sup> In contrast, the ethnic heritages of many individuals of color have been erased through histories of colonization and slavery. Instead, they are identified (by others as well as perhaps themselves) as black or Native American; they are racially identified, not ethnically identified.<sup>1</sup>

The social constructs that define gender and race are often referred to as schemas. A schema is an organized pattern of thought or behavior that helps us categorize the people, objects or events in our environment.<sup>24</sup> They are part of human nature in that they help us orient ourselves, know what to expect, and make predictions. In the context of gender and race, schemas assign different psychological traits to different identities. When activated, schemas influence how we see other people, and shape our expectations of their behaviors and skill sets. When activated subconsciously, these schemas produce implicit bias in our behaviors, a bias that is unconsciously applied with real consequences, such as preferential treatment for those positively influenced, and psychological stress for those negatively influenced.<sup>25</sup> These biases manifest themselves in many ways, one of which are microaggressions: small slights, slurs or snubs that accumulate over time to affect the way individuals experience their environment.<sup>26</sup> In engineering, for example, they can manifest through the questioning looks a black male receives when he walks into an advanced mathematics course – looks that ask, without words, “Are you sure you’re in the right room?”<sup>27</sup> Similarly, the surprised tone that accompanies a compliment on a white female student’s computer code implies “I didn’t think a woman could do that.”

Given, then, that gender and race are social constructs, we turn to the terms “gendered” and “raced.” Pawley<sup>28</sup> argues that for something to be gendered it means that the experience of an

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<sup>1</sup> The authors wish to note that while we will employ race as an overarching social construct when referring to engineering education research, we acknowledge that it is often the case that some individuals self-identify with specific ethnicities and that this is an important, but not fully actualized construct in engineering education research.

object, or a job, or an organization, is different for people of different genders; this is the same for race. For example, public bathrooms are gendered because men and women use different spaces, even though they use the same spaces in private homes. Churches are raced both through individual parishes and between different denominations, as churches at each level have different racial compositions rooted in deep race-related patterns and histories, including histories of legalized racial discrimination and oppression.<sup>29</sup>

We can now use this common foundation of gender and race theory to think differently about common experiences we see in engineering classrooms. We can start to see that the dominant images<sup>30</sup> of engineering demonstrate that the values of the majority have been made “default”<sup>31, 32</sup> and any deviation from these values brings gender and/or race into a discussion where there had purportedly been none before. But in fact, the absence of discussion more often effectively treats everyone as a white male, erasing differences rather than achieving intentional equality. As instructors we can listen to students and colleagues who report daily incidences of microaggression,<sup>26, 27</sup> and start to see how our basic interactions on a university campus are inherently about race and gender in different ways.

In student teams, gender and race relationships are produced and reproduced as individuals interact. Schemas and implicit bias are applied and student experiences are affected by this application. Even on a team that is composed exclusively of white men, the interactions that students have with each other can reinforce dominant images and schemas. When white women and women and men of color are also present in teams, gender and race relationships are produced and reproduced differently. They can be subtle, including behaviors and perspectives that affect how students talk, take up space, take up group roles, write in a certain tone, and come to decisions.<sup>33</sup> The problems they think are worth solving, and acknowledging when an adequate solution has been reached, the time they have available for teamwork, the spaces available to them for doing teamwork – these are also influenced by gender and race.<sup>34</sup> Even when the team experience itself is positive, under-represented students often come to the experience knowing that they must first manage and overcome stereotypes,<sup>12, 35</sup> creating an added psychological burden that can increase anxiety and inhibit learning. The players may not be able to articulate how or why, but this does not mean that racial and gendered interactions aren’t happening, and instead points to the embedded nature of the ideas of gender and race.

### **Social Science Research Relevant to Team Experiences of Under-Represented Students**

The academic impacts of these social constructions of race, gender, and engineering are clearly evident in the data: a large body of social science research reveals that gender and race influence academic outcomes for engineering students. Research shows that men and women, as well as people of different races, differ in factors that predict engineering success. For example, there is evidence that women have lower engineering self-efficacy than their male counterparts,<sup>36, 37</sup> and that they don’t see the increases in self-efficacy from team-based projects that men do.<sup>38</sup> Other work shows that demographic groups differ on factors such as engineering identification, meaning “belonging” in engineering, with those groups that make up the majority in engineering (white students and male students) showing stronger identification with and belonging in engineering.<sup>39, 40</sup> Many of these differences are likely produced at least in part by stereotyping and differential treatment of students from different groups; students from groups favored in

engineering (such as white students and male students) may develop stronger identification with and sense of belonging in engineering compared to those less favored (such as women and racial minorities), due to their more positive experiences in engineering.<sup>41</sup>

There is some evidence that individual differences in factors that predict engineering success lead students from different groups to engage in different tasks.<sup>42</sup> In support of this, Meadows and Sekaquaptewa<sup>43, 44</sup> showed that women on first year engineering project teams exhibit less active participation than men regardless of the representation of women on the team. In this work, student behaviors in 246 videotaped engineering group project presentations were analyzed. A gender gap in active participation was noted, reflecting stereotypes of men as engineering experts and women as supporters and organizers. Specifically, men were disproportionately more likely to present the technical content than women, to speak longer than expected (given an equitable distribution of speaking time among all team participants) and longer than women, and to field more audience questions than women. Focus group findings revealed that women were more likely than men to take on organizational or secretarial tasks such as note-taking and report writing on the group project team. In addition, a survey of senior women engineering students showed that women persist in supportive roles throughout their undergraduate engineering experiences. This gender gap in active participation may be detrimental to all students: it puts female students at risk of diminished learning outcomes compared to male students, and male students may fail to develop organizational and written communication skills important to successful teamwork. In support of these findings, Dasgupta, Scircle and Hunsinger<sup>45</sup> found that female first year engineering students placed on gender-parity and female-majority teams demonstrated less anxiety and increased confidence and engineering aspirations than their counterparts placed on male-majority teams.

Other research shows that men and women may differ in engineering outcomes particularly under circumstances that highlight the stereotype that men have superior aptitude for engineering than women. For example, when women are the sole representatives of their gender in a group, women's performance is lower compared to when other women are present in the group; this effect is particularly strong when the performance task is one in which men are stereotyped as stronger performers.<sup>46-48</sup> A large research literature has documented the effects of *stereotype threat* on women's outcomes in STEM related domains. Stereotype threat is defined as the experience of being in a situation in which one may be judged or perceived in terms of negative stereotypes about one's group. The concern that is raised about possibly appearing as stereotype-confirming to others is enough to disrupt performance in that domain. For example, several experiments have demonstrated that the math test performance of women may be undermined by the perceived threat of a poor performance seeming to confirm others' stereotypes about women's weak math ability. In testing situations where the relevance of the stereotype to the situation is reduced (by describing the test as gender-fair, for example), the math performance of women equals that of men.<sup>49</sup> Other studies have shown the influence of minority status and stereotype threat on women's performance in engineering as well.<sup>50, 51</sup> Race-based stereotype threat has also been shown to diminish performance for racial minority (e.g., black) students being evaluated on tests of academic aptitude.<sup>52, 53</sup>

Equally important, the experiences of under-represented racial minority students in engineering also varies across different racial groups, depending on factors such as the specific stereotypes



about their group as well as their degree of (under-)representation in the field. Often low numbers in quantitative studies force aggregation of racial groups (e.g. Hispanic, black, Native American), but more recent work highlights important differences. For example, Native American students are among the most severely under-represented racial groups in engineering. There is a well-documented achievement gap in STEM between Native American and white students<sup>54</sup> that is caused in part by marginalization. From 2000 to 2009, 0.6% of undergraduate students enrolled in undergraduate engineering programs were Native American,<sup>55</sup> while in 2010 Native Americans made up 0.9% of the population in the United States.<sup>56</sup> Tribal Colleges and Universities (TCUs) have increased the number of STEM-related degree programs available to Native American students in North America,<sup>57</sup> but only 7% of students enrolled in TCUs were pursuing STEM degrees in 2009 – 2010.<sup>58</sup>

Due to their severe under-representation in higher education, Native American students are the group least likely to see role models from their own racial group at home or in undergraduate engineering programs.<sup>59</sup> This lack of representation of “people like me” in the field, combined with exposure to stereotypic images of one’s group in media, is demotivating for Native American students.<sup>60</sup> Indeed, the lack of same-gender or same-race peers has been seen to lower motivation to enter STEM settings<sup>61, 62</sup> and many STEM settings are replete with environmental elements that welcome whites and men only.<sup>63</sup>

Experience of whiteness and professionalism is intertwined, and the “cognitive load of impression management”<sup>64</sup> meaning that students of color and white women – people who don’t fit into the dominant images – spend extra effort wondering if “they did that because I’m [fill in the blank]”. They may experience a general sense of discomfort, of poor fit, but may not be able to point to its cause.

In considering such effects, it is important to note that variations by sex occur within racial categories, and vice versa. That is, black women do not inherently share the experiences of black men, nor do their experiences necessarily match those of white women. Demographic factors (including not only sex and race, but also sexual orientation, socio-economic status, and more) interact in ways that are not simply additive (i.e. black women  $\neq$  black men + white women), but instead, multiply in ways that are not easily defined or categorized.<sup>65, 66</sup>

It is also important to recognize that students are not simply passive players, but instead can actively respond to, manage, or leave the contexts in which these challenges occur. Some individuals respond to marginalization by putting in extra effort to be accepted in their field. In a study of first-year women who were highly identified both with their gender and with engineering, they typically “shrugged off” their gendered experiences of engineering group work and found alternative supports and validation, persisting until their peers recognized their strengths.<sup>12</sup> Other studies show that some African American students choose a proactive stance, volunteering for difficult or challenging tasks early to “prove” themselves – in essence “nipping stereotypes in the bud.”<sup>27, 35</sup> Again, identification may play a crucial role here in supporting such moves. In other cases, especially for those who experience lower senses of belonging or identification, the marginalization can decrease self-efficacy and make persistence less likely. Students from under-represented groups likely face a constant struggle to overcome stereotypes and prove oneself, whereas majority group students do not. This may result in under-represented

students being more likely to self-select away from STEM to fields that are more welcoming to their demographic.<sup>39</sup>

The responsibilities for addressing these challenges, however, do not lie solely, or even predominantly with the student. Unconscious biases on the part of educators may be an important, and even primary, source of differences in students' experiences across and within race and sex categories, which can be evidenced in both differential treatment of students by teachers<sup>67</sup> and in the development and enactment of policies and procedures that favor some groups of students over others. Engineering instructors may be unknowingly contributing to and reinforcing group differences in teamwork experiences, through several means. We need to reflect on how social norms in functioning teamwork have been based on white, male dominant images which can conflict radically with our expectations for appropriate behavior from non-white, non-male teammates. For example, we might think of Sheryl Sandberg's point<sup>68</sup> that women who direct teams using prototypically male behaviors are considered "bossy," whereas men who conform to those behaviors are seen to demonstrate leadership potential. Through our reinforcement and policing of teaming behaviors, we are likely reinforcing gendered and racial codes about what being "polite" or "professional" means. It can be challenging to imagine how to do otherwise.

### **Promising Strategies**

From the point of view of both the institution and the individual educator, there are several promising approaches to improving the experiences of marginalized students on engineering teams. There are things we can all do with respect to our own beliefs, the environment we create in our courses, and the ways in which we design and structure group assignments.

#### *Personal Beliefs*

Any strategies for change must begin with ourselves and our beliefs – with how we see and understand the ways in which identity markers shape individuals' experiences in engineering and beyond.

1. Recognize the very real ways in which individuals' visible (e.g. race, sex, visible disabilities) and invisible (e.g. class, sexual orientation, invisible disabilities) identities impact their experiences in group-learning environments.

Perhaps most importantly, we need accept and to acknowledge the challenges faced by under-represented students in group settings. We need to understand that it is easy to ignore circumstances that marginalize under-represented students, and that it's important to learn to see beyond the cultural norms to which we are accustomed. Such acknowledgement requires us to become aware of implicit bias, gender and racial schemas, as well as learning about the ways in which discrimination is both internalized and institutionalized.<sup>69</sup> Awareness can develop first through self-education (e.g. reading studies such as those noted in this paper) as well as through listening openly to experiences that differ from our own, including the voices of students as well as colleagues. In learning to listen, though, members of the dominant groups (e.g. whites, males) need to first educate themselves, rather than expecting women and individuals of color to explain

their experiences, since demands for others to “teach” us about gender and race can serve to reinforce the existing hierarchies.

Strategies including perspective taking, individuation, and increasing opportunities for cross-racial contact have been shown to be effective in raising awareness about stereotyping and reducing bias.<sup>70</sup> *Perspective taking* involves an individual taking the perspective in the first person or role-playing the part of a member of a stereotyped group.<sup>71</sup> This process reduces automatic group-based evaluations as the participant examines a situation from a new perspective, establishing an increased psychological closeness to this group. *Individuation* involves obtaining specific information about an individual group member as a strategy for evaluating that person based on personal rather than group-associated attributes. This action serves to prevent stereotypical inferences. Finally, increased opportunities for individuals to engage with different others in positive interactions (*increasing opportunities for cross-racial contact*) reduces the potential for implicit bias by potentially altering cognitive representations or stereotypical evaluations of the group.<sup>72</sup>

Importantly, as suggested earlier in this paper, acknowledging the challenges also means that we acknowledge that we represent a failing of the *system*, not of the students. That is, women and students of color experience group environments differently not because they lack sufficient skills or resources, but because cultural and social norms create barriers not typically experienced by students from dominant groups.<sup>73</sup>

## 2. Recognize the privileges and challenges in our own positions

Recognizing the experiences of others is important, but not sufficient with respect to our own beliefs. We can begin to effectively counteract biases in our environment by acknowledging our own privilege, which whiteness scholar Peggy McIntosh<sup>74, 75</sup> defines as a system that provides unearned advantages to some groups, and unearned disadvantages to others. Becoming aware of this system and one’s own location within it could begin by reading others’ accounts of becoming aware of privilege – through blogs, scholarly articles, books, workshops, or other materials and practices that help each individual develop their own reflections on gender, race, and other identities such as sexuality, nationality and citizenship, religion, language, and so on. McIntosh<sup>75</sup> describes an activity called “serial testimony” that she facilitates for groups: pairs of people are given one minute each to “[bear] witness, [give] evidence; [speak] the truth of one’s own experience and perspective; [bear] responsibility for one’s own thought” by exploring the places they feel they have unearned disadvantages *and* unearned advantages. She suggests that, while white people (of all genders) and normatively masculine men experience benefits from existing power structures of white and male privilege, they would experience benefits from dismantling it too – e.g., more equitable relationships with more people, not being feared anymore by others. McIntosh<sup>74</sup> suggests that, among the many benefits for people with great privilege to exploring one’s own privilege location is that “it feels good to stop being resented or hated”. Making a climate that is more supportive of more types of people will also benefit privileged people in that they also will have more choices of how to perform – as not all men are the same (subordinated masculinities) and not all white people are the same (as whiteness varies by class, nationality, language, and other things). Yet one more benefit specific to engineering

contexts in particular could be that we would develop a more secure foundation for being able to work with all kinds of people across the globe.

We invite you to make your own dawning awareness of your privilege – along whatever lines – visible to your students and colleagues. When we inevitably make mistakes, we ought to own the mistakes and learn from them; it is less helpful to try to avoid making them in the first place by retreating and returning to the state where whiteness and maleness is default.

### 3. Broaden our definition of sufficient evidence

In the broader picture of educational research, is it important to consider the kind of data we need to make decisions. While we often seek statistical significance, we generally undermine the importance of the experiences and stories of those for whom the numbers are small.<sup>76</sup> We discount the intersectionality of individual identities and miss those important experiences. As a field, how do we also learn to use small numbers of “data points” to make decisions that influence classrooms? For example, that you don’t have the number of students in your class to make statistically significant claims about the appropriateness of certain pedagogical choices related to teamwork doesn’t mean you don’t act to improve the learning of those you do have. We must learn both how to learn from small numbers as well as large numbers, and make choices to learn with and without generalizable claims.<sup>28</sup>

#### *Course Environments*

As we begin to recognize and shift our own beliefs, we also have the power to shift the norms and expectations of our environments, including within our classes as well as across our organizations.

### 4. Actively promote an egalitarian environment

Once we accept the presence of race and gender schemas in engineering environments, our own positionality within those schemas, and their influence on student teamwork experiences, we can begin to work on changing the climate in our classrooms to actively establish environments that are more welcoming to students from all groups.

Given a position of power in the classroom, faculty (including graduate teaching assistants) can proactively set a tone of fairness, in which racism and sexism (explicit or implicit) are neither expected nor tolerated. Such messages are powerful; one study showed that a message setting a social norm of egalitarianism in a college of engineering led to increased appreciation of diversity in engineering and greater intentions to speak out against racism among male first year engineering students.<sup>77</sup> Faculty members can help produce an egalitarian social norm by developing a culture in which students feel comfortable disclosing experiences of bias or harassment, and recognize that such disclosures will be heard, respected, and addressed. This may be an especially important message to relay to white students and men who by their majority status largely determine the climate for diversity in their engineering settings. Finally, faculty should hold their colleagues to the same standards of unbiased interactions on teams to which we hold students. The expectation should be that interactions between faculty are

characterized by mutual respect, acknowledgment of the value of one another's ideas, and recognition of our own positions and privileges.

Pragmatically, there are a variety of things faculty – particularly white and male faculty -- can do on a daily basis to displace whiteness and maleness as “default” to which everyone else needs to align. For example, we can avoid discussions about professional attire that are aimed only at men, or that are hypercritical of women's clothing choices. We can be explicit about the “cultural” dos and don'ts of professional interaction in the academy (rather than assuming that everyone “knows” them – an assumption often based on class norms), and be sensitive to the male and white bias of those standards. There are also existing tools to help us in this regard; for example, the Toronto District School Board published a guide for interrupting problematic behaviors publicly and naming them for the benefit of everyone involved.<sup>78</sup> We can also use the CATME tool (catme.org) to help build teams in sensitive and research-grounded ways, including avoiding isolating white women and students of color on teams. We can encourage teams to use tools to asynchronously get their work done, rather than compel them to meet in person, so teamwork is not biased in favor of people who live on campus, and against those who have evening obligations like jobs or care-taking responsibilities.

### *Course and Assignment Design*

The strategies described above help create a climate in which diverse students can have successful group-learning experiences, but it is also important to move beyond the general climate to structuring courses and assignments in ways that support such learning.

#### 5. Utilize identity-based interventions to support marginalized students.

In thinking about how to improve the teamwork experience for students, we need not start completely from scratch. Social scientists have identified and tested many intervention strategies aimed at improving outcomes for marginalized students, and many can be adopted for the engineering team setting. These strategies include identity-based interventions, which are designed to reduce stereotyping by drawing attention to commonalities across groups. For example, concern about gender stereotyping was reduced when participants wrote about the ways men and women are alike rather than different.<sup>79, 80</sup> Other interventions focus on reducing attributions for feeling stressed to situational factors as opposed to doubts about one's abilities, and increasing motivation by encouraging students to perceive stressful academic situations as a challenge, not a threat.<sup>81-85</sup> Self-affirmation interventions have shown that allowing students to re-affirm their core values (such as family) can buffer minority students against the psychological threat of stereotyping, by increasing their sense of self-worth and providing them the psychological resources for effective coping with stress.<sup>86, 87</sup>

#### 6. Establish role models for appropriate collaboration

Research on students' experiences in project-based courses suggests that role modelling is an essential component of faculty practice.<sup>88-91</sup> That is, students perceive faculty as professional role models who enact the practices the students seek to develop. Role modelling appropriate collaboration behaviours has been shown to be effective in helping students work across

disciplinary boundaries,<sup>92, 93</sup> and intergroup contact theory, developed specifically to look at interracial dialogues also highlights the role of authority figures in establishing appropriate norms.<sup>94, 95</sup>

At the same time, peers also serve as powerful role models. Recent research in engineering student team settings has highlighted the power of stereotype-defying group role models. Consistent with a body of research demonstrating the positive influence of positive in-group role models and exemplars<sup>96</sup>, one study showed the benefit of exposure to an engineering project team in which stereotypic gender roles were reversed.<sup>97</sup> In this study, four person teams, composed of two male and two female STEM undergraduates, completed an engineering design task in a videotaped laboratory session. Prior to engaging in the design task, these experimental teams viewed a video showing a role model of a student team presenting their design solution and discussing their team experiences. For half the teams (the control group), the role model team shown in the video depicted a pattern of gender stereotypic role adoption, in which men engaged in technical aspects of the design process, and women engaged in supporting and organizational (i.e., non-technical) roles. The other half of the teams (the intervention group) saw a counter-stereotypic role model, in which women on the team engaged in the technical aspects and men engaged in the non-technical roles. Each participant's level of verbal participation (i.e., talking time during the design discussion) was assessed. Results showed that in the control group, men talked longer than women did. However, in the intervention group, this gender difference in talking time was eliminated. These results indicate that verbal participation can be equalized by gender when students see peer role models who break out of their gender stereotypic roles.

#### 7. Recognize diverse cultural norms and practices in designing assignments and projects

In considering strategies to improve the teamwork experience for students from under-represented groups, it is important to recognize the diversity in culture that exists among students. In cultural anthropology, culture is “an ordered system of meanings and symbols, in terms of which social interaction takes place,”<sup>98</sup> which aligns with the social constructivist perspective.<sup>99, 100</sup> meaning is created through interactions between people and the environment. Although philosophical debate exists over the relationship between culture, community, and society, people “live culturally”<sup>101-103</sup> and make sense of the world through the lens of culture.

One's culture influences one's worldview, and even cognitive processes,<sup>17</sup> making it important to pay attention to cultural differences in educational contexts. In support of this idea, cultural infusion programs have been developed that “positively impact a student's performance on a standardized achievement test in the area of math.”<sup>104</sup> Similarly, research shows that for some under-represented students, perceiving a field to be useful towards benefitting humanity, increases motivated and persistence in STEM fields.<sup>105-108</sup> For example, many Native American students respond more positively to science if it is linked to society.<sup>109</sup>

Culturally-relevant pedagogy,<sup>110</sup> which addresses student achievement while recognizing cultural identity in the context of learning, provides one foundation to promote persistence in STEM for students from cultures that value interdependence and collectivistic worldviews. This framework includes a number of considerations for researchers who are not from the culture under study,

including providing concrete experiences, caring, personal accountability, and cultural competences.

For example, the National Academy of Engineers<sup>111</sup> identified a number of commonalities among Native American tribes in the United States: “(1) a global, or holistic style of organizing information;<sup>112, 113</sup> (2) a visual style of mental representations of information;<sup>114, 115</sup> (3) a preference for a reflective style in processing information;<sup>116</sup> (4) a preference for collaborative approaches to tasks;<sup>117</sup> (5) and a preference for dialogue between teachers and learners in which prior knowledge and experiences are interwoven with new material to raise understanding to a higher level.<sup>117</sup>”

Within group-learning assignments, new curricula could be created that recognizes “the embeddings of culture in everyday practices.”<sup>118</sup> One example of a potential opportunity for cultural infusion is between the Navajo way of life, which is a holistic cycle of thinking, planning, living, and assuring/testing,<sup>119</sup> and an engineering design process (ask, imagine, plan, create, improve<sup>120</sup>). Thus the structure of the project itself can be described and presented in a way that carries cultural meaning for Navajo students.

Further, design projects can be structured to blend culture and course material. In engineering outreach camps in the Navajo Nation, students were asked to write a story related to their culture (e.g., “Describe a day in the life of a Navajo middle school student”). Students then, learn the engineering design process and build a Rube Goldberg®-style chain reaction machine that tells the story they wrote. This not only helps the students connect with the engineering material, but also helps them describe what they did to family and friends.<sup>121-123</sup>

Assignments can also propagate stereotypes or projects. For example, much of our engineering literature is based on patriarchal assumptions, where women may be marginalized in teams. However, if students come from a matriarchal society, then the team-balancing strategies may be opposite. Gender-balancing teams can help when team members are from multiple cultures.

## 8. Address both process and product in scaffolding and evaluating group assignments

While the projects themselves are important, so are the processes students use to reach the project goals. Despite some faculty members’ beliefs that students learn teamwork simply by “doing it”,<sup>124</sup> students, particularly in diverse settings, require intentional scaffolding to help them learn to manage group dynamics, structure projects, and develop interpersonal skills. Sequencing the phases of a project and incorporating milestone tasks, work plans, group charters, and similar assignments can not only support collaborative learning, but also provide tools for faculty to encourage students to develop new skills and to ensure that the team is not marginalizing individuals through task assignments.

Such marginalization can occur particularly in long projects such as capstone design, where students may find the stakes quite high and thus adopt a task orientation where students ‘divide-and-conquer’, taking on or assigning tasks to those deemed most capable to carry them out. This is a perfectly reasonable response to a project assessed on its outcomes (and would be an appropriate strategy for a team of professionals). However, for most undergraduate learning

experiences, what the students *do and learn* is more important than the quality of the final prototype, and even at the capstone level faculty typically value process and product equally<sup>125</sup> and focus on student learning.<sup>90</sup> Strategies to support this learning focus can include asking students to articulate their learning goals for the course, and then asking teams to create a project plan to address those goals, a strategy which has been shown to close gaps in the types of tasks that students engage in by gender.<sup>42</sup> Also, the jigsaw classroom approach, in which each student must cooperate with peers to achieve individual goals, can be used as a technique to build empathy and compassion among students and to create a respectful learning environment.<sup>126</sup>

As part of understanding the learning processes that go on within teams, it's worth thinking about some implicit assumptions that students have about teamwork and leadership. For example, the model that students are perhaps most familiar with is teamwork through hierarchy, as seen in the military and the corporate world. Student teams differ from workplace and military teams in many significant ways (e.g. student teams are generally all novices, whereas in industry, young engineers would typically be working with more experienced colleagues to help them learn). Models of non-hierarchical collaborative teamwork exist (open-source projects such as Wikipedia, community organization such as the Occupy Sandy response, many families). Shared leadership models, such as these, may be more appropriate given the nature of the work as well as student needs.<sup>127</sup>

#### 9. Establish peer interaction patterns that support collaboration and reduce anxiety

While creating such process-based scaffolding can help students intentionally develop their skills, it's also important to do so in ways that offer all students safe spaces to learn. In design courses, instructors often use design reviews as a way to teach students to critique others' work. However, in some cultures, critique or confrontation can be uncomfortable. Thus, less-confrontational strategies for design reviews can be used to reduce presentation anxiety.

For example, presenting designs in an art show-style format where designs are posted to the wall can be less confrontational. Students are asked to visit all of the designs and leave feedback on post-it notes next to the designs. The feedback is often anonymous. Another method is to have students do speed design reviews, where teams hand their design to the next table and take a period of time to do a table-top design review. This small group discussion provides a more comfortable environment for discussion. After a period of time, teams pass designs on to the next table and repeat until all designs have been reviewed.

Another method for reducing anxiety is to provide students the opportunity to present often and non-judgmentally. Prepare students to present their work by having them present frequently throughout the design process. This helps reduce presentation anxiety about the "full design" and helps build comfort speaking about their work to the class. Similarly, these kinds of periodic reviews can be structured to ensure that all students have a voice and can be recognized for their contributions through techniques such as asking each student to present regularly in these informal sessions.



## 10. Engage with teams in ways that validate and support all students

Finally, effective strategies to support learning in diverse groups also typically require active faculty engagement with each group. As faculty meet with groups either during or outside class, for example, we have a critical role to play in moderating group activities to ensure that all voices are heard. Effective strategies, drawn from the problem-based learning literature, can include calling on less vocal group members, re-voicing what each person has said to be sure that the group hears all comments, and summarizing discussions to capture all points of view, including those that dominant voices in the group may otherwise exclude.<sup>128</sup>

At the same time, faculty can use assignments such as the ones described above to monitor team dynamics, observe how assignments are made (e.g., tracking what who does regularly), and intervene if distribution appears inequitable – for example, by questioning strategies for assigning tasks, and suggesting alternate approaches. These strategies require an intentional approach to team dynamics, but all can be accomplished through a variety of small assignments such as weekly minutes, in-class presentations, regular meetings with reports from each team member.

## Conclusion

The most important and widespread assumption about engineering student teams is well-summarized by the opening sentence of Tolstoy's *Anna Karenina*: "Happy families are all alike; every unhappy family is unhappy in its own way." Its application to teams is usually unconscious: we assume that a student team that produces an output (prototype, final report, etc.) of appropriate quality was a well-functioning (*happy*) team. However, there are many ways that teams can fail as learning experiences for the participants while still yielding adequate output. And, of course, neither outcome serves our goal of training a future workforce with experience interacting to create an affirming climate in diverse work places.

As discussed throughout this paper, group-learning in engineering education is important, but challenging to implement effectively. In exploring this landscape, we can start to see that the dominant images of engineering are "raced" white and "gendered" male, demonstrating that the values of the majority have been made "default." This is especially apparent among diverse student teams, as stereotypes and schemas influence the participation and outcomes of all team members.

This paper described steps we can take to help address these issues in both our personal belief systems as well as our courses and assignments. Strategies for change in this context must be first addressed through raising our own awareness of our personal beliefs and our understanding of the role identity plays in shaping the experiences of unique individuals in engineering. This is accomplished by repeatedly engaging ourselves and others in the very real ways that identities (both visible and invisible) impact experiences in group-learning environments. We must educate ourselves by opening our minds to concepts like implicit bias and schemas while also opening our doors to our colleagues and students to share their stories and our classrooms to increased engagement. In raising our own awareness about others, we must also raise our awareness of ourselves and our own privileges and challenges. Only by acknowledging our own

privilege can we begin to effectively counteract biases in our environment. Steps in these directions enable a climate that is more supportive of more types of people such that all individuals have more choices of how to perform. In doing this, we develop a more secure foundation for being able to work across cultures and privilege and we begin, as a community, to recognize bias as it plays out in our research.

Recognizing and shifting our own beliefs can naturally lead to shifting the norms and expectations of our classes, institutions, and organizations. Given the position of power that faculty hold in the classroom, we can proactively set a tone of fairness, in which racism and sexism (explicit or implicit) are neither expected nor tolerated. By creating an inclusive environment in our classrooms, departments, colleges and other professional spaces, we increase the capacity of these spaces for safe, respectful and productive exchanges of ideas. This leads to environments where interactions are characterized by mutual respect, acknowledgment of the value of one another's ideas, and recognition of our own positions and privileges.

It is also important to move beyond the general climate to structuring courses and assignments in ways that support such learning. To support marginalized students, there are a number of proven identity-based interventions such as modeling, reducing threat and self-affirmation activities. As faculty, we can play an important role in modeling appropriate collaborations and can also invite peer facilitators through proper training to model egalitarian behaviors. At the assignment or project level, we can recognize the existence of diverse cultural norms and practices and incorporate these deliberately into the designs. And, through curriculum development, we can scaffold learning on teamwork in the same way we scaffold learning on technical content for students. Finally, as we assess learning, we can design both peer and faculty assessment in ways that reduce stress and support all students. Our implementation of new strategies may be facilitated by challenging our assumptions about group-learning, including for example, that teams must be hierarchical; that students can effectively "learn by doing" without support; that group products are the sole indicator of team success; and that we can't move forward with interventions until the effectiveness of such strategies are statistically proven beyond any doubt.

In sum, research on the engineering teamwork environment at the intersection of social psychology, race and gender theory and engineering education reveals important changes that we can all make to our classrooms and institution to enhance the group-learning experiences and associated learning outcomes for all students. We look forward to continuing to address these challenges and the resulting opportunities that may be facilitated by collaborations between engineering educators and social science researchers, who each bring important insights to these issues.

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