



## **Building Global Infrastructure for Diversity and Inclusion in Engineering Education**

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Dr. Reed coordinates campus-wide initiatives designed to enhance and support faculty diversity at UMBC. Working collaboratively with the Leadership Team in the Office of the Provost, the Deans, and Faculty Leaders from the Executive Committee on the Recruitment, Retention, and Advancement of URM Faculty, the ADVANCE Executive Committee, the STRIDE Committee, and the faculty leaders of UMBC's Community-Based Faculty Groups, Dr. Reed develops, implements, and evaluates programmatic interventions designed to recruit, retain and advance diverse faculty at UMBC. Dr. Reed also routinely disseminates best practices learned from UMBC's diversity initiatives at national and international venues. Dr. Reed is on the advisory board for the Mid-Atlantic Higher Education Recruitment Consortium.

### **Dr. Renetta G. Tull, University of Maryland, Baltimore County**

Renetta Garrison Tull is Associate Vice Provost for Graduate Student Professional Development & Postdoctoral Affairs at the University of Maryland, Baltimore County (UMBC: An Honors University in Maryland), where she is the Co-PI and Founding Director for the National Science Foundation's PROMISE: Maryland's Alliance for Graduate Education and the Professoriate (AGEP) for the 12 institutions in the University System of Maryland, and Co-PI Louis Stokes Alliance for Minority Participation (LSAMP) Bridge to the Doctorate at UMBC. Dr. Tull has worked with thousands of students from Alaska to Puerto Rico, and in Latin America through graduate school preparation workshops that have been sponsored by AGEP, The National GEM Consortium, National Society of Black Engineers, Society for Hispanic Professional Engineers, Society for the Advancement of Chicano, and Native American Scientists, American Indian Science and Engineering Society, and the Alliance/Merck Ciencia Hispanic Scholars Program. She has presented workshops on graduate school admissions, "The Success Equation," STEM initiatives, and PhD Completion in Panama, Mexico, Ecuador, Colombia, Puerto Rico, and schools around the United States. Tull is on the board of advisors for the PNW-COSMOS Alliance to increase the number of American Indian/Alaska Native (AI/AN) students who complete STEM graduate programs, and is a speaker on "GRADLab" tour with the National GEM Consortium, giving talks across the US on Saturday mornings during the Fall. Tull researched speech technology as former member of the faculty at the University of Wisconsin-Madison. She has co-authored several publications on achievement in STEM fields, and is a mentoring consultant for Purdue, Carnegie Mellon, Cornell, MIT, and other schools. She co-leads the "ADVANCE Hispanic Women in STEM" project in Puerto Rico, and the Latin and Caribbean Consortium of Engineering Institutions' (LACCEI) "Women in STEM" forum. Tull was a finalist for the 2015 Global Engineering Deans Council/Airbus Diversity Award, and has presented on diversity in the US, Latin America, Europe, Australia, India. She is a Tau Beta Pi "Eminent Engineer."

### **Dr. David A. Delaine, Universidade de São Paulo**

David A. Delaine is a progressive engineer who has strong interests in the intersections of engineering, education, and society. He has obtained a Ph.D. in electrical engineering from Drexel University, in Philadelphia, USA. He is currently serving his second term as an executive member of the International Federation of Engineering Education Societies (IFEES). In this role he serves as a Vice President, representing Diversity and Inclusion. He is currently performing research as a Fulbright Scholar postdoctoral researcher at the Escola Politécnica da Universidade de São Paulo for his project titled "An Action Research of Boundary Spanning Intervention on University-wide STEM Educational Engagement" where he will attempt to optimize community/university relations for broadening participation in the STEM fields. David is a co-founder and past president of the Student Platform for Engineering Education Development (SPEED). He has ambitions to significantly broaden the global pipeline of STEM talent and to unify the needs of the engineering education stakeholders in order for engineering education to more accurately reflect societal needs. Diversity and inclusion, university/community engagement, educational research methods, action research, and student led initiatives fall within the scope of his growing expertise.



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Rovani Sigamoney is a chemical/environmental engineer from South Africa who started in the platinum refinery/mining sector and then moved on to researching bioenergy systems and biofuels for Africa.

She joined the United Nations Educational, Scientific and Cultural Organisation (UNESCO) HQ in Paris, France in 2007 and later ran the Chemistry programme and International Year of Chemistry 2011 and thereafter the Engineering programme. The Engineering Programme is working with countries, international partners and program experts to strengthen engineering education through curricula development, hands-on training and capacity building. In line with UNESCO's global priorities on Africa and Gender Equality, it focuses on women and Africa. Rovani is passionate about women in engineering and encouraging more youth to pursue careers in engineering.

She previously worked at the United Nations Environment Programme (UNEP), Paris on a biofuels strategy and also at the Wuppertal Institute of Climate Change in Germany on a policy document for the European Parliament on the security of energy supply.

# **Building Global Infrastructure for Diversity and Inclusion in Engineering Education**

## **Introduction**

In the 21st century, the global knowledge economy faces numerous challenges. In order to surmount these challenges, we must encourage the full participation and equal regard of all diverse talents. In engineering education this broadening of participation is of paramount importance, as this field grapples first-hand with how to effectively address many global challenges. Unfortunately, STEM fields, engineering, in particular suffer from a lack of diversity due to gendered, ethno-racial, and cultural biases, often implicit, that circumvent the full inclusion of members from underrepresented groups [1]. This lack of diversity threatens to impede engineering's ability to tackle these pressing societal challenges. As such, the field of engineering is at a critical crossroads, at which it is imperative that thought-leaders from multiple nations across academia, industry, and the government, come together to build a global infrastructure that increases diversity and inclusion in engineering education.

This paper describes one such diversity effort that took place at the 2015 World Engineering Education Forum (WEEF) in Florence, Italy, that resulted from prior meetings and conversations at the 2014 WEEF meeting in Dubai, UAE, the 2015 ASEE meeting in Seattle, WA, USA, and at UNESCO, which in concert expand on the International Federation of Engineering Education Societies' (IFEES) increased emphasis on inclusion. This new effort, the September 2015 WEEF special session: "Diversity & Inclusion in Global Engineering Education- Initializing Global Scale Collaboration," was designed to educate and spur a diverse international audience of engineering students, professors, deans, and corporate representatives from Nigeria, Turkey, South Africa, Switzerland, the United Kingdom, the United States, and other countries, to collective action toward fostering practices for the diversification of engineering. In two interrelated sections, this paper 1) reviews the educational component and 2) shares the resulting outcomes and recommendations of this session. The first section summarizes the framing of the issue through literature and data on diversity and inclusion, followed by a description of an interactive training on explicit and implicit biases at the session. Section two is action-oriented and builds upon the educational awareness and training as outlined in section one. This second section describes our novel use of Structure-Behavior-Function (SBF), an approach from systems engineering, as an empowering tool that leaders can implement to broach the subject of diversity, and foster actions that lead to respect, appreciation, equity, and inclusion of individuals from underrepresented backgrounds, especially ethnic and racial minorities, within their respective countries. As a continuation of conversations from the special session at WEEF in Italy, this paper offers recommendations that can assist global stakeholders in countries outside of the U.S. to develop locally supportive climates for people from all backgrounds (students, faculty, and staff) who seek and share engineering education. Further, faculty within the U.S. can use these recommendations as they train their students to be culturally competent, and globally relevant engineers.

## **Framing the issue**

As we examine primarily issues that affect people from various racial and ethnic backgrounds, it is important to define how diversity is being used in the context of this paper. We are using the

designation “underrepresented” to describe racial groups that the National Science Foundation from the United States has defined as racial and ethnic groups historically underrepresented in STEM disciplines: African Americans, Hispanic Americans, American Indians, Alaska Natives, Native Hawaiians, and Native Pacific Islanders. Underrepresentation in engineering in the United States can be observed at several points along the engineering education pipeline, e.g., undergraduate college and university enrollments and graduation rates, postgraduate enrollments in master's and doctoral programs. An example of the disparity can be seen in the numbers of undergraduate students who are enrolled in engineering programs in the U.S. In 2011, there were 471,920 undergraduate students enrolled, and of those, 16.2% were from racial groups that are underrepresented in STEM, based on NSF’s definition [2]. These types of disparities have been highlighted at international engineering education conferences to demonstrate underrepresentation in the U.S. context. Table 1 was presented in a plenary session at the 2016 International Conference on Transformations in Engineering Education in India by one of the authors of this paper to show that the number of doctorates conferred in engineering over the years has not reached parity. Comparing the number of people with doctorates from The Survey of Doctorate Recipients’ longitudinal biennial survey, to the number of people in the population, Table 1 shows that collectively, based on 2013 data, 46,535 more engineers with doctorates from Hispanic, Black, and American Indian groups would be needed to reach parity with their respective population demographic [3]; [4]; [5].

**Table 1: The total number of U.S. citizens with doctorates in engineering in the U.S. from a longitudinal study as of 2013, compared to the number of citizens in the U.S. population**

	Engineering Doctorates N=150,600	United States Population N=316.5 million
Hispanic (Latino)	<b>2.9%</b> n=4,400	<b>17%</b> Need 25,602
Black (African-American)	<b>1.92%</b> n=2,900	<b>13.2%</b> Need 19,879
American Indian (Native American)	<b>0.13%</b> n=200	<b>0.7%</b> Need 1,054

### Societal Issues and Bias

It is unfortunate that some people from underrepresented groups have experienced discrimination and have been targeted because of their racial and ethnic backgrounds. The U.S. has a longstanding history of institutionalized discrimination, including the enslavement of African Americans, the removal of Native Americans from their ancestral lands, the removal of Hispanic/Latinos from their properties in the Southern U.S. states, and immigration quotas directed at non-white immigrants. Indeed, it was not until the second-half of the 20<sup>th</sup> century, with the passage of the Civil Rights Act, and the relaxation of immigration restrictions, that these overt discriminatory practices toward ethno-racial minorities became illegal. Notwithstanding this progress, issues of discrimination have (re)surfaced, for example, police brutality directed toward African Americans [6], the increased deportation of Hispanic/Latinos, and heightened surveillance and profiling of individuals from Middle Eastern or South Asian countries. Ethnic and racial discrimination is not limited to the United States. Reports from Australia revealed that race debates escalated following discriminatory insults directed at Adam Goodes, former star

player of the Sydney Swans football team. Debates about the treatment of Goodes, an indigenous Australian, raised the issue of treatment of indigenous, aboriginal groups [7]. The presence of discrimination has not been limited to police brutality in the streets, nor insulting comments on the sports field. Racial, ethnic, and gender biases that undermine the talent and performance of people from underrepresented groups have also been experienced in academic spaces and in the workplace [8]; [9]. However, Twitter campaigns such as #ILookLikeAnEngineer, and research articles such as Carlone & Johnson's (2007) work on STEM identity have sought to address negative perceptions about the abilities of people from underrepresented groups by addressing stereotypes [10]; [11].

### **Explicit and implicit bias: Definitions and applications**

After defining our use of underrepresented minorities and sharing examples of racial, ethnic, and gendered bias, within the U.S. and Australian contexts, we facilitated interactive bias awareness training. We included training within our workshop to equip the audience with a shared language to name, recognize, discuss, and challenge everyday instances of unintended bias pervading engineering academic spaces. As our overall goal for the session was to initialize a global collaboration to advance diversity and inclusion in engineering education, it was crucial that our audience be empowered to continue these conversations following the session. This training consisted of two parts: 1) a definition of biases, explicit and implicit, including examples of consequences of implicit biases within a variety of contexts and 2) an interactive activity through an anonymous PollEveryWhere.com survey in which audience members shared their experiences with implicit bias within engineering spaces.

In part one of the training, we defined bias as habits of mind--preferences, inclinations, or patterns of thought. Biases play a pivotal role in shaping how we navigate judgments in our everyday lives. Some biases are *explicit*, in that we are fully aware (conscious/intended) of the systematic patterns/preferences behind our decisions. In hiring an engineering faculty member, for example, search committee members have an explicit bias, a systematic preference, that eligible candidates must have a PhD in engineering. In their review of resumes, search committee members consciously exclude candidates without a PhD from consideration. Other biases are *implicit*, in that we are unaware (unconscious/unintended) of the habits of mind we employ in our judgments. We described implicit biases as habits of mind that are 1) ordinary, 2) learned from culture, 3) pervasive, and 4) often conflicting with consciously endorsed beliefs [12]. For the purpose of our workshop, we were primarily concerned with implicit biases, in particular implicit bias related to gendered, ethnic, racial, national, cultural, sexual orientation, socioeconomic, religious, and ability identities. We aimed to model for our audience how these implicit biases contribute to the underrepresentation of certain groups in engineering. We highlighted the importance of cultural contexts in the formation of biases. We argued for example that underrepresentation in a Chinese engineering academic space, and the implicit biases involved, may differ radically from South African or U.S. engineering academic space. We stressed that as increasingly globalized field, it is critical that we, as engineers, are attuned to the locally relevant contexts of underrepresentation in our spaces, yet become globally competent in drawing connections and parallels between our local and global contexts of engineering academic spaces. .

Discussions around bias and prejudice can be contentious and individuals often struggle with 1)

acknowledging their own implicit biases, and 2) how to have conversations with colleagues and students about this topic. To overcome this obstacle, we reiterated to the audience that having biases do not make us bad people, because as humans we are imperfect beings, whose judgments are not always correct. Additionally, we asserted that although understanding the unconscious processes behind our unintended biases mitigates some of the personal blame we may feel about having such biases, we nevertheless have a shared responsibility to reduce its effects [13]. To further reduce possible discomfort audience members may experience as we progressed in our discussion of this topic, we provided examples of concrete consequences of implicit biases reproducing inequality in various institutions. Using the United States as an exemplar, we cited literature documenting how implicit ethnic, and racial biases toward African Americans and Hispanic/Latinos, the two largest ethno-racial minority populations in the United States, led to disparities in their medical treatment [14], longer and disproportionate sentencing in the criminal justice system [15], their association with crime due to media portrayals of African Americans and Hispanics as criminals [16], underperformance in higher education [17], and their underrepresentation in the labor market [18], most notably in STEM academic spaces [19]; [20].

After providing examples of the material consequences of implicit biases, we returned to and adapted our original hiring scenario to illustrate the consequences of implicit bias in engineering academic spaces. We proposed that within a U.S. faculty search, implicit bias occur if search committee members unintentionally excluded candidates who received engineering PhDs from historically black colleges or universities (HBCU). Here the implicit bias is the search committee members’ unconscious stereotype of HBCUs as less prestigious institutions as opposed to an Ivy League or Research Intensive University. Or perhaps it was an South African faculty search, implicit bias may occur in a search committee member preferred the resumes of male engineers or female engineers based on gender cues in the resume and cover letter. Here the implicit bias is the assumption that men are more qualified engineers than women. Again, in the U.S. and South African examples, the search committee member may explicitly share their commitment to diversity and inclusion in the hiring process, but their actions do not align with their intentions due to implicit bias.

### **Implicit bias in engineering brainstorm**

Having laid a foundation, we shifted to the interactive Implicit Bias Brainstorm using Polleverywhere.com to invite audience members to share their experience with implicit bias. We asked the following question: “What type(s) of implicit bias have you experienced and/or witness in engineering. Table 2 provides a summary of the examples of bias anonymously shared by the audience.

**Table 2: Implicit Biases Experienced or Witnessed by the Audience**

Identity	Implicit Bias Example
Gender	Use of the pronoun “he” to generalize engineering profession; crediting a woman’s idea to a man; boys receiving additional support in class, complimenting a woman on her looks and not the content of her presentation; mistaking a man for the boss when the boss was really the woman; suggesting that an all-female team needed adult (male) supervision

Race	Denial of job opportunities; racist jokes in the office; being told grant award was not earned, but due to equal opportunity laws
Gender/Race	Believing that browned-skinned women are “exotic” rather than smart
Ability	Assuming a student with a physical disability also has a mental disability
Geo-Spatial/Cultural Location	Assuming the women cannot work in the Middle East; failure to recognize that cultural norms vary around the world and using politically incorrect comments that do not make sense or offend in local contexts
Language	Assuming someone with an accent or who speaks slowly is not smart and/or unable to complete an assignment

As a large group we discussed our experiences and learned that implicit biases related to language, gender, race, ability, and geo-spatial location are a shared theme in engineering education, but the manifestations of these biases differ depending on the local context in which they occur. Overall, this activity helped us develop a common language for discussing this issue, connecting with this issue on global and local levels, and becoming more aware of the detrimental effects of implicit biases in engineering education.

### **Structure-Behavior-Function (SBF): A tool to reduce implicit bias in engineering education**

After the audience identified examples of implicit bias in engineering education, it was crucial to share tangible actions and steps that audience members can take to reduce the effects of implicit bias in engineering education. Given the diversity of the audience, however, it was first necessary to frame the discussion from a practical, uniform, and familiar perspective. Again, for our work to be successful, it was critical that we develop a shared language to communicate about this topic. Consequently, we adapted the structural, function, and behavioral (SBF) model [21] an approach from systems engineering, commonly used to consider future design considerations for complex systems. In our translational adaptation of the framework, engineering education figures as the complex system that requires a (re)design. Specifically, SBF enables us to systematically pinpoint those emergent patterns that promote or hinder broader participation of diverse groups in engineering.

We initiated this segment of the conversation by categorizing some of the structural, behavioral, and functional components within engineering education. For example, there do exist structural components (e.g. departments, social networks, formal learning environments) that may encourage or discourage diversity and inclusion. The function (or purpose) of the engineering education system and its respective components that reflect its function may be identified as the types of resources, tools, supports, and people (e.g. professors, students, staff) that allow the system to operate and which may facilitate or obstruct diversity and inclusion. With this said, these structural and functional components can shift or be manipulated to change the system, but may or may not produce the desired effect of promoting and sustaining diversity and inclusion. It is not until the entire system identifies the behavioral components (e.g. beliefs, dispositions, preferences, or understanding among constituent groups) and acknowledges the influence these

behavioral components play in the full execution of change that the system can reliably undergo a redesign. For engineering education to make significant changes to influence the composition and broaden the participation of diverse groups in the field of engineering, it will require a hard look at the intersection between the structural, functional, and behavioral factors that perpetuate the challenges of implementing effective diversity and inclusion strategies. Once appropriately characterized, it is feasible that various strategies could be implemented using evidence-based best practices.

### **Applying SBF to act and support others in overcoming implicit biases**

After providing an overview of SBF, and modeling its application to diversity and inclusion efforts within the system of engineering education, the collaborators facilitated a second interactive activity. Unlike the previous activity, in which the audience identified implicit bias, the purpose of this activity was to move the conversation from thoughtful reflection to more action-oriented steps that can positively impact diversity and inclusion in engineering education. Due to time constraints, this activity was narrowly focused on identifying some of the behavioral components that perpetuate biases in the participants' respective contexts. We then asked the audience to describe the ways in which they could take action and be supportive in addressing the identified bias challenges that currently exist in the structural and functional makeup of the system of engineering education. Here, we reminded the audience that while implicit bias does call attention to the fact that everyone has biases, that does not give allowance or level the playing field for marginalized groups within the system of engineering education. A higher form of vigilance and advocacy is necessary to significantly reduce the negative impact of biases. Having provided this reminder, we asked the audience to respond to two specific questions:

- 1) In your daily function within engineering education, what ways can you **ACT** to overcome biases affecting your environment?
- 2) In your daily function within engineering education, what ways can you **SUPPORT** others in overcoming the biases affecting them?

We then organized the audience into groups of 3-4 individuals for the activity. Each group discussed the first question for 10 minutes, followed by a 10 minute large-group debrief, followed by a 10 minute discussion of the second question, and a final 10 minute large-group debrief. In the follow-up discussion a common theme around the need for additional training for leaders and management on how to tactfully and constructively broach and act on the subject of implicit biases. A second theme emerged around the need to be more inclusive in the formation of research collaborations and mentoring relationships, and to develop intercultural competence to work across differences in these globalized professional relationships.

This activity proved powerful in offering an international community of engineering education stakeholders a lens through which to view and begin changing behavioral issues related to bias in the context of their particular professional roles. The biggest takeaway from this activity, however, is the urgent need and desire for more hands-on training on how to confront implicit bias and create an inclusive climate in engineering education. Although an initial step, we believe this activity offers an example platform by which individuals from across international boundaries and professional functions can have thoughtful and productive discussions about diversity and inclusion in engineering education.

## Recommendations

This work provided a platform to open the conversation about biases, experienced and observed. This paper serves as a reference to the workshop, but more importantly, it is designed to serve as a resource to address and explore issues of racial bias, without the overhead of discomfort. We provide the following recommendations for conversations about racial bias in engineering:

1. ***Have an open discussion about diversity challenges in order to increase awareness.*** This paper, or other resources can be used as a catalyst for the conversation.
2. ***Allow open and honest dialog, where all responses are valued.*** Plan to let the data speak for itself and inspire action to achieve equity.
3. ***Identify systemic constructs that prevent or obscure inclusion.*** Multi-modal approaches, e.g., oral conversation, anonymous electronic polls, anonymous comments on uniform notecards, give all participants an opportunity to contribute.
4. ***Carefully reflect and choose colleagues who will adopt “champion” roles to support inclusion.*** Be sure that the audience includes people in positions of power in order to effect change in policies as appropriate.
5. ***Encourage the champions to be comfortable with their role.*** Champions can encourage of collegial behavior modification among those who are consciously or unconsciously stalling inclusive excellence in engineering at all levels (e.g., undergraduates, graduate students, postdoctoral trainees, faculty hiring, research collaborations)
6. ***Request a level of commitment from participants.*** Participants can commit to being advocates, catalysts and change agents who take actions against bias and for inclusion within the department, at the university, on regional/national/global levels. Remind colleagues of written statements and commitments to develop a more inclusive engineering profession from leading international engineering organizations such as ASEE’s letter of commitment from engineering deans, the Global Engineering Deans Council/Airbus diversity initiative, and SEFI’s (European Society for Engineering Education) conference theme of “Diversity in Engineering Education.”

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