Global Diversity and Inclusion in Engineering Education:

Developing Platforms toward Global Alignment

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***Abstract*—This paper presents an investigation of global scale diversity and inclusion efforts within engineering education. The content is an expansion of work that was shared at the 2015 World Engineering Education Forum's first special session on "Diversity & Inclusion in Global Engineering Education." Diversity and Inclusion (D&I) are contextualized topics that shift objectives from country to country. The role of D&I in engineering education and practice has gained prominence in recent years due to the fact that engineers are facing increased need for global collaboration and are expected to be able to work in highly diverse teams and within different cultures. D&I initiatives in the field of engineering generally include gender, ethnicity, and national origin, and may include persons who are economically underprivileged and persons with disabilities. While the prominence of D&I has increased, international learning outcomes and collaborations within these efforts are limited. Within a global community a common platform, presented here as a theoretical framework for decontextualized D&I, would allow for the sharing of best practices and maximize learning opportunities and impact. By examining models from around the world, we can begin to structure, consolidate, optimize, and disseminate the global benefits of D&I. In this work, various programs are reviewed as success cases because they have increased the numbers of underrepresented students who enroll in and graduate from STEM programs. The potential for solidarity amongst Diversity & Inclusion initiatives and programs in different regions of the world is explored. Efforts are made to determine what can be learned from synergies across D&I activities.**

Index Terms—Diversity, Inclusion, Global, Collaboration, Broadening Participation, Underrepresented Minorities

I. INTRODUCTION

Access and competitiveness within the knowledge economy shapes economic development in a world which is increasingly more globalized [1]. This globalization is inspiring need for more knowledge, knowledge creation, and knowledge management, all of which will become critical to address, survive, and excel in international contexts [2]. The knowledge economy, an economy in which knowledge is acquired, created, disseminated and used effectively to enhance economic development has emerged from the traditional economy. A knowledge economy is said to require long-term investments in education, innovation, information and communications technology, and an appropriate economic and institutional regime that allows efficient mobilization and allocation of resources [1]. Technical acumen must be supplemented with professional skills to develop 'adaptive engineering leaders' capable of addressing the multiple challenges of an evolving world [2]. Today's engineers are expected to be able to work in highly diverse teams, and within/across different cultures. Engineering education must respond to these challenges with effectiveness and efficiency to develop the engineering professional that globalized economies need. Economies can be globally competitive when *all members of their societies* are able to access education and careers within the science, technology, engineering, and mathematics (STEM) community.

However, access to STEM careers is not inclusive; that needs to change. Obtaining full and equal inclusion of all members, requires 1) confrontation of the issue, and 2) thoughtful consideration of factors that negatively impact access and participation within STEM education and careers. Negative factors include, but are not limited to implicit biases, and condescending attitudes from those in supervisory positions [3].

Once it is determined that negative factors cannot be ignored, the road to inclusion requires parties with authority to develop mechanisms that will offset these factors. Transcending barriers to participation and access within STEM is possible, and the work that addresses challenges and potential solutions are topics to research within the area of "Diversity and Inclusion," also referred to as "Broadening Participation."

Diversity and Inclusion (D&I) are important to ensure the success of engineering in front of these needs, especially for innovation through diverse perspectives, the mobilization and allocation of human resources, and the development of cross cultural awareness and acceptance. The practice of D&I is contextualized topic, manifested differently in settings based on local, national, or regional contexts, which can include politics, socio-cultural history and dynamics, and economics. The National Science Foundation, within the USA, describes broadening participation of underrepresented groups, e.g., Alaska Natives, Native Americans, Blacks or African Americans, Hispanics, Native Hawaiians and other Pacific Islanders, and Persons with Disabilities, and notes that identification of a particular group as underrepresented may vary by discipline (e.g., women are underrepresented in some fields) [4,5]. For example, women have been significantly underrepresented in engineering fields, typically making up only 10 – 20% of the engineering workforce. In Africa, women represent even fewer of the engineering professionals with South Africa having around 10% women and Kenya only 8% [5]. While young women only represent 7 – 12% of engineering students in sub-Saharan Africa, their percentage in North Africa and the Middle East is comparable, and in some cases higher, than in some countries in Europe [5]. In some Arab States, women account for more than half of the engineering student population, but the number of female engineering graduates who go on to work in engineering professions in the region is much lower [5]. In other instances, women are effectively playing the role of engineers in their communities, as holders of informal local knowledge of environmental sustainability and recycling, but their expertise has yet to be recognized [5].

While the need for ensuring full demographic representation within the knowledge economy and the STEM workforce is presumed, the methods for ensuring educational and workforce diversity and inclusion and the extent to which these are practiced around the world are not fully understood. The global engineering education community has unified and excelled, leading to significant advancements [6], however, the consideration of D&I on a global scale has not seen similar consolidation and scaling. There is an increasing need for global collaborations and engineering workforce mobility within this area. This work seeks to establish considerations and a framework which will facilitate increased global collaboration.

Earlier work [7], introduced international and global level D&I efforts within the STEM fields and engineering education. This paper includes similar content building on that work to include perspectives on diversity resulting from formal sessions with global STEM leaders at the 2015 World Engineering Education Forum, in Italy. This paper also includes additional constructs for inclusion. Definitions and a brief overview on Diversity and Inclusion in engineering are presented. This is followed by a review of the decontextualized, common practices exhibited within D&I initiatives and programs resulting in a theoretical framework. In order to show the potential impact of D&I programs, two institutional level efforts, a USA and international case, are presented with discussion on the structure and dynamics which provide for success. This paper presents an introduction to a unified, international discussion on diversity and inclusion within the STEM fields.

II. LITERATURE REVIEW AND BACKGROUND

Diversity and Inclusion within engineering are primarily based on increasing the participation of underrepresented groups in engineering and STEM fields. The definitions provided within this section are derived from within the USA context, with some supplemental information from other regional contexts.

The American Society of Mechanical Engineers (ASME) defines diversity as "the ways in which we differ as individuals or organizations, and the commonalities and similarities that justify and motivate all people and entities to work collaboratively together in order to achieve mutually beneficial outcomes [8]." While focus is generally placed on gender and ethnicity, it also includes characteristics such as age, physical appearance, physical ability (disabled or differently abled), thought styles, religion, nationality, socio-economic status, belief systems, sexual orientation, education, worldview, problem-solving orientation, and learning style [9,10], people in rural, isolated or deprived areas, and migrants, refugees and asylum seekers [11]. Dr. William Wulf, former president of the National Academy of Engineering, defined diversity in engineering with these words, "When I say diversity, by the way, I do mean what most people assume: the representation of women and underrepresented minorities. But I also mean "individual diversity," the breadth of experience of an individual engineer. Both, I believe, are critical" [12].

Inclusion, as defined by the Higher Education Academy, means "the enabling of full and equitable participation in and progression through higher education for all prospective and existing students [13]." ASME defines Inclusion as "the creation of opportunities and the elimination of barriers that allow all people to participate in and contribute to ideation, planning, projects, programs, processes, teams, organizations, social activities, fun or any other meaningful opportunity, that helps achieve successful outcomes [8]."

D&I initiatives are sometimes referred to as the science of Broadening Participation (BP), where individuals from underrepresented groups, as well as institutions and geographic areas that do not participate at rates comparable to others, are invited into STEM careers [9]. Figure 1 provides the NSF's formal description.

> *"Creating opportunities and developing innovative strategies to broaden participation among diverse individuals, institutions, and geographic areas are critical to the NSF mission of identifying and funding work at the leading edge of discovery. The creative engagement of diverse ideas and perspectives is essential to enabling the transformative research that invigorates our nation's scientific and engineering enterprise. Broadening participation infuses science and engineering excellence into varied individual, institutional, and geographic networks and provides for the discovery and nurturing of talent wherever it may be found [9]."*

Figure 1. The National Science Foundation's description of Broadening Participation [9]

From an engineering education research perspective [14], Diversity and Inclusion is defined as research on how diverse human talents contribute solutions to the social and global challenges and relevance of the profession. The goal of the research is to uncover processes and environments that promote understanding of how we can achieve and sustain a diverse engineering community. Affirmative action programs represent similar and parallel work within this area. While affirmative action provides for diverse representation within any workforce, D&I consider these practices more holistically, seeking an organizational culture that values these principles [15].

With respect to D&I, the goal of the NSF is to create a "broadly inclusive engineering community which seeks and accommodates contributions from all sources while reaching out especially to groups that have been underrepresented; serving scientists, engineers, educators, students and the public across the nation; and exploring every opportunity for partnerships, both nationally and internationally [9]."

III. THEORETICAL FRAMEWORK - DECONTEXTUALIZED D&I

This section considers the dynamics of D&I in a decontextualized context. The characterization, barriers, mechanisms, and structures of D&I efforts are presented in an objective manner to allow for the development of transferable knowledge regardless of context. Within a global community, this unified framework allows for the sharing of best practices and maximizes learning opportunities. The ideas within this section represent a common denominator for diversity and inclusion. These commonalities can be leveraged to improve global discussion towards improving diversity in engineering education and practice.

A. Characterizing Systems which provide for Diverse Inclusion and Participation in STEM

Program origins and rationales for participating in diversity and inclusion efforts, the academic spectrum, and outcomes/targets/goals can be utilized to characterize D&I practices.

1) Program Origins and Rationales

A review of the historical and global emergence of affirmative action policies performed by Moses [16] structures the differing program rationales and actions within France, India, South Africa, and the USA and examines the social context surrounding each. Diversity and inclusion efforts can run parallel to or be a subset of affirmative action efforts. The Moses analysis is performed through a synthesis of federal and state legislation, court decisions, news media sources, and research-based scholarship. Each country's affirmative action rationales have different ideological origins which Moses was able to structure into four categories: remediation – compensation for past discrimination, economics – a method to help disadvantaged people contribute to economic efficiency, diversity – increasing educational and economic output through leveraging multiple perspectives, and social justice – greater racial integration, equity and justice within democratic societies shown in Table I replicated from [16].

TABLE I.
THE RATIONALE AND ORIGINS FOR D&I PROGRAMMING, REPRODUCED FROM [16]

Rationales for D&I	
Social Justice	Focus on racial integration, elimination of institutionalized inequalities, and equity in democratic participation
Remediation	Focus on the societal need for more disadvantaged people to be educated and to join the workforce and contribute to the economy
Economics	Focus on the remedial rationale is a moral justification aimed at righting past wrongs and emphasizing compensatory, corrective action to rectify unfair treatment by race, ethnicity, and sex.
Diversity	Focus on the significant educational benefits of having diverse classrooms and campuses, specifically that they improve research quality, learning experiences, problem-solving abilities

2) Diversity and Inclusion across the Academic Spectrum:

Efforts within D&I can span the academic spectrum starting at primary education (young children) to continued and adult education (professional engineers). These efforts include best practices in student preparation [17], recruitment [18], admissions [19], financial assistance [20], and academic enrichment [21], as well as corporate and professional programs [22]. Special attention must be paid to transition points along the academic spectrum, because underrepresented groups leave the engineering path at each of these transitions at alarming proportions [9, 23].

Many differences exist within the structure and titles granted to the educational spectrum in different countries and regions (ex. Baccalaureate programs across Europe, K-12 in the USA, and Fundamental Education into superior education in South America). For the purpose of normalizing this discussion early childhood education is referred to as primary education, teenage education is referred to as secondary education (generally ending around 18-20 years of age). Moving forward, university and college education or other parallels is referred to as higher education, which is broken into undergraduate and graduate education.

In some cases, these programs have been designated into four categories [10]; 1) pre-college prep, 2) undergraduate transition, 3) graduate recruitment and transition, and 4) graduate education and beyond. Programs also exist to diversify the professoriate [24] with more culturally competent members able to more effectively welcome students from all backgrounds. This is done by improving the numbers of women and underrepresented minority faculty, increasing the number of such faculty who are tenured, and promoting the numbers of women and minorities in upper-level administrative positions [10]. The structure of D&I across the academic spectrum is shown in Table II.

3) Outcomes, Targets, and Goals:

Indicators for successful efforts in D&I have received sparse attention [9, 25]. Parity between population demographics and STEM participation, a greater share in participation (including specific numerical targets), critical mass of an under-participating demographic (so that few students do not represent entire race) have been utilized as targets. Not only should underrepresented demographics be well represented among the ranks of students, faculty, and workers, but their academic and professional attainments should mirror those of the general population [9]. Indicators and metrics for Diversity and Inclusion can be structured across differing levels: individual level, institutional level, and funder level [9]. *Individual* level indicators include (a) participation, (b) retention, persistence, and success, (c) experiences, and (d) attitudes. *Institutional* level indicators include (a) staffing, (b) policies, programs, and institutional commitment, (c) accountability and rewards, (d) monitoring, tracking, and using data for improvement, and (e) collaborations. These indicators are needed for assessment, especially for innovation through diverse perspectives, the mobilization and allocation of human resources, and the development of cross cultural awareness and acceptance. Increased understanding on how to measure diversity and its impact is necessary in order to understand the role diversity plays in advancing

TABLE II.
D&I ACROSS THE ACADEMIC SPECTRUM

Appx. Age	Education Level	Primary Focus	Points of Emphasis
6	Primary Education	Academic Development	
7			
8			
9			
10			
11			
12			
13			
14			Transition Point
15	Secondary Education	Pre-College Prep Undergraduate Transition	
16			
17			
18			Transition Point
19	Undergraduate Education	Graduate Recruitment/ Professional Development	
20			
21			
22			Transition Point
23	Graduate Education	Faculty Recruitment/ Professional Development	
24			
25			
26			
27			
28			
29			
30			Transition Point
31	Professional	Professional Development	
32			
33			
34			
35			

solutions, influencing society, and contributing to innovation, critical thinking, creativity, teamwork, entrepreneurship, leadership and global competencies [10].

B. *Common Barriers to Full Inclusion and Participation in STEM*

In providing for Diverse and Inclusive STEM environments, many barriers must be overcome to obtain broad participation from all demographics of our society. Various barriers to obtaining full inclusion and participation within STEM fields are briefly summarized within this section.

The youth from underrepresented communities have *limited awareness of the STEM fields*, the careers they include, and the potential for these careers to be rewarding. *Negative stereotypes of STEM* persist in many communities impacting participation especially from underrepresented demographics. Male driven, nerd or geek characteristics surround these fields often making them less desirable [26]. STEM careers are rigorous and demanding requiring substantial academic preparedness to ensure success. Underrepresented students entering these spaces often come from underserved backgrounds which *lack sufficient infrastructure to provide a strong academic foundation*. In support of cognitive and academic development, the use of non-cognitive mechanisms are critical to enabling students and practitioners to manage or cope with ongoing periods of frustration, anxiety, and other negative stressors that often hinder achievement and success in STEM fields. Developing resiliency among young, marginalized students leads to academic persistence and the pursuit of STEM careers. Underrepresented students often find that they may be amongst a very limited number of peers from the same demographic or alone within STEM education [27]_leading to *struggles with feelings of isolation and/or limited sense of belonging*. This can cause students a lack of academic identification, where students do not identify themselves as being a part of the school and field they are a part of, and stereotype threat, where negative stereotypes of a group of people can reduce an individual to such ideas [28]. These can negatively impact student success and retention. A history of underrepresentation correlates to a *limited number of available mentors from within the community*. Mentors serve to provide guidance, and a sense of belonging. Lack of solid mentorship exacerbates the other barriers, including a shortage of diversity among faculty members, which can affect the sense of community for URMs persisting in STEM disciplines and attaining degrees [29]. At Predominantly White Institutions (PWIs), the numbers of faculty members of color continue to be disproportionately low, particularly in STEM disciplines. The available mentors of color in these environments are extremely limited and the demands on those available to assist students of color in these institutions are high [30]. A *lack of cultural competence* results in limited promotion of quality services to underserved, racial/ethnic groups through the valuing of differences and integration of cultural attitudes, beliefs, and practices [31]. The consequences of limited cultural competence include [10]: declining interest in engineering careers, sagging membership in professional associations, citizen distrust of engineering expertise, and even more formidable challenges in competing successfully with other disciplines to recruit, enroll, and educate a diverse student pool. The statistics of URM participation in STEM often parallel the socioeconomic status of these demographics resulting in a *"Digital Divide" and limited access to necessary educational resources* (often technology) [32]. This translates into limited access to resources necessary for strong academic performance of URM students. Access to computers, internet, and other educational resources can provide a substantial hurdle to academic readiness and retention. *The cost of higher education* can be a crippling factor within the pursuit of a degree of higher education [33]. Family income has been linked as a major indicator of educational attainment [34] leaving the underprivileged with an uphill climb. *Virtual barriers* reflect the atmosphere being created at many PWIs, where the goal is solely minority "representation" without the associated intellectual credibility being ascribed to the URM students [30]. Virtual barriers create environments where URM students are granted university admission, yet upon entering have limited resources available to overcome the other challenges. A l*ack of dissemination of best practices and alignment within the global D&I research community* limits broader success within the academic community. There are many efforts, though program assessment, numbers or data have been disseminated scarcely [35]. This barrier is mostly impactful at a directorial/administrative or program leadership level, yet limited infrastructure for sharing best practices prevents programs from being optimized based on research informed outcomes. Virtual barriers can also run parallel to *varying perceptions of the* *importance and institutional buy-in* to diversity and inclusion [36]. Institutional leadership, differing cultures, or other factors may lead to perceptions of limited importance of student body diversification via inclusion of underrepresented populations. *Implicit Bias*, or hidden or unconscious biases, are not plainly expressed, and/or easily recognized, yet everybody has them [37]. These biases have been shown to impact recruitment processes and are result in discriminatory practices. The barriers are summarized in Table III:

TABLE III.
SUMMARY OF BARRIERS TO D&I WITHIN THE STEM DISCIPLINES

Barriers	
Awareness of STEM Disciplines	Limited awareness of the STEM fields, the careers they include, and the potential career rewards
Negative Stereotypes	Negative perceptions of who can and does perform STEM work, and what those efforts consist of
Cognitive and Academic Development	Limited academic and cognitive preparedness, especially in science and mathematics
Utilizing Non-Cognitive Skills	Limited ability to overcome stressors, which minimizes retention of STEM students
Isolation and Sense of Belonging	Small representation within STEM education can isolate marginalized students and lead them to question participation
Limited Mentorship and URM Faculty	Limited mentorship/role models can exacerbate challenges from other barriers
Lack of Cultural Competence	A lack of socio-cultural and socio-emotional understanding hinders services to under-participating and underserved groups
Resources and the "Digital Divide"	Limited access to resources and technology important to education
Finances	The cost of higher education can eliminate access for underprivileged groups
Perceptions of Importance of D&I	The value of increasing diversity through inclusive practices is not a priority
Virtual Barriers	A goal of minority "representation" without the associated intellectual credibility being ascribed to underrepresented students
Implicit Bias	Subconscious biases enable preferential or discriminatory behaviors
Dissemination and Collaboration	Challenges in the alignment of D&I knowledge and the dissemination and incorporation of best practices

C. Mechanisms effective for providing for Diverse and Inclusive Community

Several mechanisms exist to overcome the barriers presented in the previous section. These mechanisms can be categorized to include capacity building, community building, and structure building (programmatic alignment/unification).

Capacity building includes efforts which seeks to improve the cognitive and academic abilities of underrepresented participants [38]. Programs that help students adjust to the academic rigors of the current and upcoming educational challenges are critical towards broadening participation. Bridge programs, and programs which teach best-practices for academic success are effective. Awareness of STEM practice, education, and research help students focus their attention on positive aspects of these careers and align them with the appropriate academic tracks for STEM readiness. Efforts to help combat negative perceptions and develop positive associations to STEM careers can be included within Capacity Building.

The issue of having a welcoming and supportive climate where students can succeed, as addressed within *Community Building*, has been linked to retention [39]. Successful programs have been able to link research to practice by incorporating concepts of developing "encouragement-based" alternative or counter spaces for training activities such as research symposia, and professional development conferences based on concepts from Critical Race Theory and "LatCrit" theory [40, 41]. Carlone & Johnson's work on STEM identity discusses a strong connection to the discipline of study, promoting an increase in one's competence, performance, and recognition [42]. They define recognition as: recognition of yourself as a scientist/engineer, and/or others' recognition of you as a scientist/engineer. This sense of recognition ties back to the McMillan and Chavis concept of membership [43]. The conceptual framework of McMillan and Chavis' "Psychological Sense of Community (PSOC)," along with professional development programming to engage and retain underrepresented graduate students [44]. It also draws upon social science theories to inform its practices and activities so that students can be encouraged to pursue STEM careers, with an emphasis on preparation for the professoriate. PSOC, the primary construct, examines McMillan & Chavis' four designations that constitute community [43]: 1) Membership 2) Influence, 3) Reinforcement/integration and fulfillment of needs, and 4) Shared emotional connection. Issues related to "cultural presence" are highlighted and include culturally grounded resources, such as diverse scholars from other universities around the country who come together to serve as "Images of Possibility" and "Mentors-in-Residence." Retention theory is useful to tie research outcomes to D&I practice [45]. Additional theories include Tinto's theory of individual departure [46], Giuffrida's self-determination and job involvement theories [47], and Padilla and colleagues' heuristic knowledge model [48] all effective in increasing community and sense of belonging.

Structure Building or programmatic alignment/unification involves providing for networks, resources, and infrastructure that provide for the successful implementation and continuity of D&I efforts. Attention to and linking of programs between academic transitions and alignment between resources are necessary to provide for continuous support alongside the academic development of underrepresented students. It is noted that academic and job placement are processes that require active engagement. These structures include the following elements: Financial assistance, Historically Black Colleges and Universities (HBCUs), Minority Serving Institutions (MSIs), or Hispanic Serving Institutions (HSIs), flexible admission systems for obtaining critical mass and parity [11], credit accumulation and transfer between differing types of institutions[11], and awareness and programs designed to broaden the "pipeline" of potential STEM students.

The mechanisms for these structures are summarized in Table IV. The table presents groupings for building capacity, building community, and building structure. Each grouping requires expendable effort.

TABLE IV.
SUMMARY OF MECHANISMS FOR EFFECTIVE D&I WITHIN THE STEM DISCIPLINES

Mechanisms	
Capacity Building	Efforts directed towards the development of cognitive and academic skills
Community Building	Efforts directed towards the development of non-cognitive skills and sense of belonging
Structure Building	Efforts directed towards the development of structural elements necessary for institutions and programs to meet the needs of URM students

D. Structures for Full Inclusion and Participation in STEM

Our framework considers 6 processes and structural categories that allow for implementation of the effective mechanisms: legislation/legal efforts and policies, institutional programs and alliances, recruitment and academic placement, curriculum aligned interventions, short-term interventions, and academic research. These categories contain overlapping processes, but are useful in providing structure to the framework presented. These categories are defined and explained in this section.

Legislation/Legal Effort and policies provide for the designation of mandated goals or targets, whether legal or instituted by other means, towards minimizing inequalities in D&I. The establishment of the HBCUs within the USA and the use of name-blind review of applications are examples. Legislation and legal efforts often lead to the establishment of institutional programs and alliances. *Institutional Programs and Alliances* are top-down efforts which seek to set align and mobilize resources, leadership, and other mechanisms towards accomplishing D&I goals. Often, these programs serve as umbrellas which encompass the mechanisms presented in this work. This paper uses two institutional level programs as case studies in the following sections to demonstrate how programs and alliances can address broadening participation through linking programs, using indicators, refining practices over time, and leveraging "inter-institutional collaborative partnerships" [30]. *Recruitment and Academic Placement* serve as active invitations and provide alignment with career and academic opportunities for underrepresented students. Recruitment can be necessary to engage students, seek to prevent exclusion or feelings of a lack of membership among participants who can contribute to the STEM community. *Curriculum Aligned Efforts* are efforts which lead to direct curricular changes designed towards broadening participation in the STEM fields. Cooperative education, community engagement, and service learning can provide deeper linkage to real world activities as well as provide income for students concerned with providing for their families. *Targeted Interventions are* programs and initiatives which seek to impact behaviors, perceptions, or attitudes of participants, towards a specific goal and within a designated time period [49]. Barriers for diverse student are addressed through interventions by reducing obstacles of transition through conferences that address these points and by developing nurturing spaces on and off campus for workshops that facilitate a welcoming environment. Lastly *research efforts* [50] within D&I lead to the development of new knowledge as well as transferable outcomes that work to develop the scientific knowledge on effective dynamics providing for a diverse and inclusive institution. The structures are summarized in Table V.

TABLE V.
SUMMARY OF STRUCTURES FOR EFFECTIVE D&I WITHIN THE STEM DISCIPLINES

Structures	
Legislation/Legal Efforts and Policy	Efforts which establish legal precedents or institutional policies directed towards enhancing diversity through inclusive practices
Institutional Programs and Alliances	Efforts established within institutions or collaborative networks for the implementation of D&I programming
Recruitment and Academic Placement	Efforts which locate potential qualified URM candidates and/or locate them within academic opportunities often with supporting funds
Curriculum Aligned Efforts	Efforts designed to make the curriculum more appealing and more suited to the culture and interests of URM students
Targeted Interventions	Efforts designed to minimize a particular set of barriers or amplify the benefits of a set of mechanisms
Academic Research on D&I	Academic research directed towards establishing knowledge beneficial to the enhancement of D&I within STEM education

IV. ONGOING DIVERSITY & INCLUSION INITIATIVES WITHIN THE USA

A. The National Science Foundation:

The National Science Foundation (NSF) has several programs that are designed to broaden the participation of those persons who are underrepresented in particular disciplines. While there are a variety of agencies in the USA that have initiatives that are designed to broaden participation in STEM, NSF has a specific Directorate for Engineering (ENG), and a Directorate for Education and Human Resources (EHR), both of which have programs that serve all of the engineering disciplines. The NSF's program on "Broadening Participation in Engineering (BPE)" funds initiatives that develop a diverse workforce of engineering graduates [20]. The website discusses NSF focus on research that is directed toward underrepresented racial/ethnic minorities. The NSF's BPE program cites a 2010 census snapshot of demographics of diverse groups of USA citizens, stating that "Hispanic Americans are at 16% of the US population; African Americans constitute 13.6%, American Indians/Alaskan Natives represent 1.7%, and Native Hawaiians and Pacific Islanders are at 0.4% [55]," yet these populations are underrepresented in the STEM fields. The EHR's Division of Human Resource Development (HRD) has initiatives to enhance "the quality and excellence of STEM education and research through broadening participation by historically underrepresented groups - minorities, women, and persons with disabilities." HRD's broadening participation programs address a variety of diverse audiences including, but not limited to, women faculty (ADVANCE), graduate students (Alliances for Graduate Education and the Professoriate – AGEP), and undergraduate students (Louis Stokes Alliance for Minority Participation – LSAMP) and graduate students (NSF Bridge to the Doctorate) [56]. The LSAMP and AGEP efforts are reviewed more closely in the following sections.

In this section, we will examine models from two programs that are sponsored by the National Science Foundation (NSF) in the USA to broaden the participation of groups from underrepresented populations, The Greater Philadelphia Region Louis Stokes Alliance for Minority Participation (LSAMP) program for undergraduate students, and the Alliances for Graduate Education and the Professoriate (AGEP) program for graduate students. LSAMP focuses on providing scholarships and mentoring support for students who are from underrepresented backgrounds, and pursuing a degree in STEM fields. The AGEP program does not have fellowships, but rather provides programmatic support for underrepresented graduate students, and in some cases, postdoctoral fellows, and support for alumni who are early-career faculty. There are 8 alliances of universities in the USA that have AGEP transformation (AGEP-T) programs, and there are 110 LSAMP awards, some of which include a "Bridge to the Doctorate" component for students beginning graduate school. The National Science Foundation's description presents LSAMP as a "portfolio of programs which seeks to increase the number of students successfully completing quality degree programs in STEM. Particular emphasis is placed on transforming STEM education through innovative academic strategies and experiences in support of groups that historically have been underrepresented in STEM disciplines: African-Americans, Alaskan Natives, Native Americans, Hispanic Americans, and Native Pacific Islanders [57]."

This cluster of programs enables the seamless transition from STEM baccalaureates to doctorates and entry to the STEM professoriate. LSAMP emphasizes development of broad based regional and national alliances of academic institutions, school districts, state and local governments, and the private sector to increase the diversity and quality of the STEM workforce. Eligible LSAMP undergraduate students may receive continued support for up to two additional years of STEM graduate study through the Bridge to the Doctorate (BD) Fellowship Program. The Bridge to the Doctorate provides significant financial support for matriculating candidates in STEM graduate programs at alliance universities [57]. The LSAMP program contributes to STEM workforce development, and because of its focus on U.S. citizens in STEM, the program facilitates talent that contributes U.S. economic stability and national security. Nationally, for the 2011-2012 academic year, all alliances of the LSAMP program graduated 36% of seniors and produced 31,864 minority degrees in the STEM fields [58].

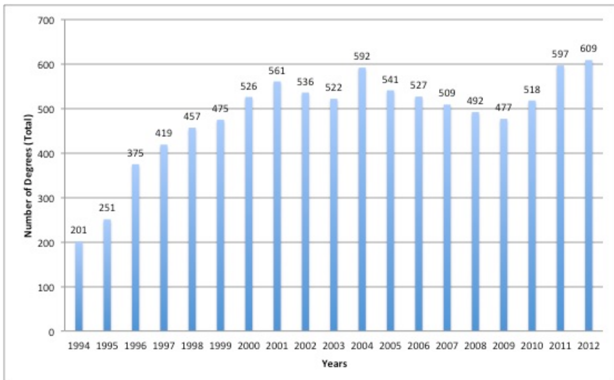
1) Case 1 – Inclusion of Undergraduate Students: The Greater Philadelphia Region Louis Stokes Alliance for Minority Participation

Universities apply for LSAMP programs through a competitive proposal process. There are several of them throughout the USA, and the program has been successfully implemented since 1991 [59]. One of the early LSAMP programs from the early 1990's that has track record of alumni with PhDs is the "Greater Philadelphia AMP" in Pennsylvania, USA. Looking more closely at the LSAMP Philadelphia alliance allows us to understand more about the direct implementation of the program within context. The alliance's mission is stated: *"The Philadelphia AMP is dedicated to increase and sustain the baccalaureate degree production of underrepresented students, as defined by the NSF, in STEM, and subsequently, their movement to graduate school to attain doctoral degrees. Through synergistic collaboration, the Philadelphia AMP, as a tri-state, nine-institution consortium, utilizes its operational infrastructure to expand available options to enrich programs at partner institutions and beyond."*

The goals for the Philadelphia LSAMP program are as follows [60]: Increase the minority STEM B.S. degree production to, at minimum, 700+ degrees annually, increase the number of students participating in undergraduate research from 50 to100 students annually, move at least 30% AMP graduates (210 students) into graduate STEM education, directly serve at least 90% of minority undergraduate STEM population, continue to increase Alliance minority progression and retention rates in STEM, and to document, publish, and disseminate effective practices, and the results of Alliance activities. International development of LSAMP participating students is an additional program goal. Between May of 2011 and August 2012, 36 Philadelphia AMP students participated in international research activities. The B.S. degrees awarded to the Philadelphia AMP students from the program inception to 2012 are shown in Table VI.

By calculating the earning potential of the Philadelphia Alliance's minority B.S. STEM degree recipients using NSF's Division of Science Resources Statistics, National survey of Recent College Graduates data from 1994 – 2006, based on disciplines, median full time salary, and time in-service, the alliance was able to determine earning capacity within the job market. The analysis indicates that the $21.9 million in NSF funding resulted in $2.2 billion in income capacity of the graduates, illustrating a solid return on investment.

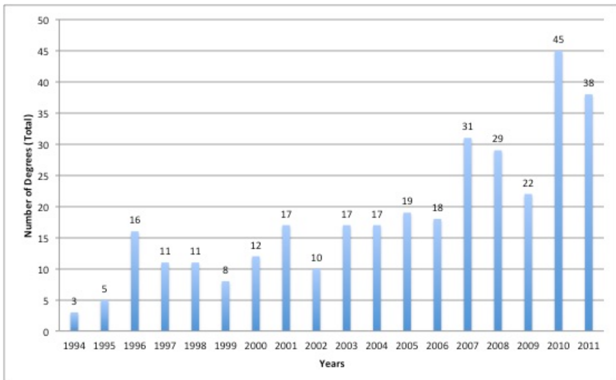
TABLE VI.
STEM BACCALAUREATE DEGREES AWARDED TO STUDENTS IN LSAMP PROGRAMS IN THE US, NATIONALLY, [60]



a) NSF Bridge to the Doctorate (LSAMP BD)

While the core focus of the LSAMP program and the Philadelphia AMP alliance is undergraduate students, the program also contains the NSF Bridge to the Doctorate (BD) which is designed to increase the number of URMs in the professoriate. This program includes financial assistance and close support and mentorship [60]. The LSAMP Bridge to the Doctorate grant is awarded to LSAMP alliances or groups of institutions that have had at least 10 years of successful recruitment activities, professional development programming, and retention of underrepresented STEM undergraduate students. Formerly called "Senior Alliances," these senior LSAMP programs have developed reputations for successful broadening participation efforts on their campuses, and are trusted to work with students through the next phases of attaining the advanced degree. The LSAMP BD programs on each campus recruit students in cohorts of 12 graduate students, starting in the first year. The program provides two years of funding, with the expectation that the university (usually through the students' respective academic department) will fund the students' remaining years. The LSAMP BD initiative is assisting with increasing the number of STEM PhDs. The production of doctorates from LSAMP programs are shown in Table VII, however, those numbers are growing as there are more students in the pipeline who are slated to finish their doctorates over the next five years [60].

TABLE VII.
DOCTORAL DEGREES EARNED BY STUDENTS WHO WERE PART OF UNDERGRADUATE LSAMP PROGRAMS, [60]



2) Case 2 – Diversity & Inclusion of STEM Graduate Students: The PROMISE AGEP

The NSF's Alliance for Graduate Education and the Professoriate (AGEP) program can be the next step in support mechanisms for LSAMP BD students who attend universities with AGEP programs in place. The PROMISE AGEP, the Maryland AGEP program, is a unique university system-wide award, and is an exemplar that includes workshops and environments that serve as supplements to students' academic graduate programs, with the purpose of facilitating advanced degree completion and preparing students for academic careers [44]. AGEP Transformation awards are currently held by US institutions in the Pacific Northwest (PNW-COSMOS), Alabama (T-PAC), the Midwest (CIC), New York (Stony Brook – Brookhaven National Laboratories), Texas (Texas A&M), California, Michigan, and Maryland (PROMISE). Of the current NSF AGEP Transformation awards, the PROMISE AGEP for graduate students and postdoctoral scholars in the state of Maryland in the USA, is one of the more experienced alliances, having received the first AGEP award in 2002.

PROMISE has a long history of training diverse engineering students, involving diverse engineering mentors, and training students for graduate school at NSBE, SHPE, and AISES conferences. Many of the PROMISE professional development workshops have been co-developed and facilitated by former regional and national officers of NSBE, and the outcomes are regularly shared at conferences of the American Society for Engineering Education [44, 61]. The professional development workshop and activities celebrate diverse ethnic backgrounds, and encourage high achievement. This is done by providing academic and holistic training for writing publications, giving oral presentations, understanding advances in technology and pedagogy, advanced statistics, financial literacy, career-life balance, and psychological well-being [62]. PROMISE: Maryland's AGEP is an AGEP-T program that is part of an alliance that works to effect positive change in the retention rates of underrepresented minority graduate students in STEM fields. The University of Maryland Baltimore County (UMBC: An Honors University) in Baltimore, Maryland, USA, was the initial lead institution for the early PROMISE programs, and had as partners the University of Maryland College Park and the University of Maryland Baltimore which has a medical school. The current PROMISE AGEP: Maryland Transformation program includes all of the institutions within the University System of Maryland, two of which have LSAMP BD programs. UMBC's graduate students have also had the benefit of having other diversity programs on campus, such as the Meyerhoff Graduate Fellows Program that is sponsored by the National Institutes of Health, and the NSF International Engagement project that examines challenges to global participation for U.S. women with underrepresented ethnic/racial backgrounds [63].

The PROMISE AGEP engages and retains diverse engineering and other STEM students through primary use of the conceptual framework of McMillan and Chavis' "Psychological Sense of Community (PSOC). The PSOC's four designations the constitute community are used by the PROMISE AGEP to directly and indirectly invite students to actively participate and engage in contributing to STEM research. PROMISE uses Tinto's work as background to develop mechanisms to help new graduate students integrate into the graduate school community by assisting with the separation from the mindsets of the undergraduate experience, transitioning to a graduate culture, and demystifying the STEM culture for pursuit of the graduate degree. PROMISE encourages students to include family members in all activities [64], which supports Giuffrida's work on helping underrepresented students to maintain cultural connections. Padilla and colleagues' work defining barriers to students' success, is utilized to shape this program. Through these theories, the professional development activities of PROMISE have contributed to the retention of diverse graduate students in STEM fields. Two of the signature professional development activities include The PROMISE Summer Success Institute and The Dissertation House. The PROMISE Summer Success Institute particularly invites diverse engineering mentors to be "mentors-in-residence" to address the disparities in the engineering professoriate in order to attract more diverse engineering graduate students to the academy [44, 65].

The initiatives within PROMISE AGEP and activities at UMBC have contributed to the doctoral degree completion rates for underrepresented graduate students in STEM fields. The statistics for Black and Hispanic doctoral degree recipients in STEM are low, and were 3.1% and 3.4% respectively in 2013 [66]. Between 1992 and 2012, UMBC, which headquarters both the PROMISE AGEP and the Meyerhoff Graduate Fellows program has produced 92 underrepresented PhDs in STEM fields. The PROMISE AGEP was founded in 2002, and established activities and structure in 2003, so it's important to note that 76 of the 92 STEM doctorates awarded to underrepresented students at UMBC were conferred between 2003 and 2012 [3, 20]. The PROMISE AGEP has retention and professional development programs such as the Summer Success Institute and the Dissertation House that have been replicated and scaled at other schools in Texas, New York, and Puerto Rico. The success of this AGEP, and other programs like it at schools around the US, can be attributed to a strong culture of mentoring, attention to research, and opportunities for professional development [44, 61, 67, 68].

B. Institutional-Level, Student-Run Initiatives:

There are a few national student-run organizations within the USA that have missions to develop a pipeline of diverse engineers on the collegiate level with a focus on workforce development. These organizations include the National Society of Black Engineers (NSBE), the Society of Hispanic Professional Engineers (SHPE), and the American Indian Science and Engineering Society (AISES), all of which are based in the USA, but have local and regional organization structures (chapters) within universities around the world.

The National Society of Black Engineers (NSBE) is an organization within the United States that focuses on the achievement and development of Black engineers, and has as a mission: *"to increase the number of culturally responsible Black Engineers who excel academically, succeed professionally and positively impact the community."* The organization has programs that start at the K-12 (kindergarten - 12th grade high school) levels, undergraduate and postgraduate levels, and they continue to provide programs for career professionals. The largest portion of the membership is at the undergraduate level, and NSBE has within its organizational structure the mechanisms for accepting international members and international student chapters. The organization has active international student chapters in Canada, Ghana, Nigeria, Germany, Lithuania, Bahamas, Cameroon, and South Africa. The listed benefits of international members include free membership, and access to the NSBE network, events and magazine. The process for starting an international NSBE chapter can be found online [51].

The Society for Hispanic Professional Engineers (SHPE) in the United States has within its mission to be an organization that is *"empowering the Hispanic community to realize its fullest potential and to impact the world through STEM awareness, access, support and development."* SHPE has a chapter in Puerto Rico, but the authors have not found references to international chapters [52]. However, the Latin and Caribbean Consortium of Engineering Institutions (LACCEI), with headquarters in Florida, USA, has participating institutions in the mainland USA and Puerto Rico, as well as participating institutions in Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, France, Guatemala, Honduras, Jamaica, Mexico, Panama, Peru, Portugal, Spain, Taiwan, Trinidad & Tobago, Uruguay, and Venezuela [53].

The American Indian Science and Engineering Society focuses on the native peoples and their mission "to substantially increase the representation of American Indians and Alaskan Natives in science, technology, engineering and math (STEM) studies and careers," encourages us to consider a dialogue on broadening participation among indigenous peoples around the world. AISES has chapters throughout North America, within the U.S. in Canada: British Columbia, Alberta, Yukon Territory, Northwest Saskatchewan, Manitoba, Ontario, Quebec, Newfoundland, New Brunswick, Nova Scotia, and Prince Edwards Island [54].

Together, the NSBE, SHPE, and AISES programs represent engineering interest, advocacy, and training for portions of the underrepresented demographic of the U.S., particularly among undergraduate college students. Each organization provides members with opportunities to overcome the aforementioned barriers through utilizing the presented mechanisms. These especially include community of scholars, encouragement toward successful college graduation, access to employers for job opportunities, along with opportunities for outreach to local communities and younger members of their respective populations.

These characteristics of successful programs in the USA can be utilized to investigate models that have been developed by universities or organizations in other countries to support diversity and success in STEM.

V. EXEMPLARY INTERNATIONAL INSTITUTIONAL DIVERSITY AND INCLUSION EFFORTS

There are a number of Diversity and Inclusion programs around the world that have initiatives to increase representation among underrepresented groups. Among them are the STEM programs in Australia that serve Indigenous Australians – Aboriginal and Torres Strait Islander Australians [69], and student chapters of LACCEI in Latin America that also have chapters of the Student Platform for Engineering Education Development (SPEED) [70]. Some of the programs in Australia include: the University of Melbourne's STEM program for Indigenous underrepresentation [71], University of New South Wales' Indigenous Science and Engineering Program [72], Curtain University's Indigenous Australian Engineering Summer School (IAESS) [73], and the University of Sydney's Indigenous Australian Engineering Summer School [74]. To provide an in-depth example of the potential of international initiatives the UNESCO Engineering Programme and the initiatives within it are presented.

A. The UNESCO Engineering Programme

In this work, focus is directed at The United Nations Educational, Scientific and Cultural Organisation (UNESCO). UNESCO understands and supports the need for global diversity and inclusion. UNESCO, with 195 Member States, has two global priorities: Africa and Gender Equality [75].

Engineering at UNESCO has four major strategic objectives [76]: 1) to strengthen tertiary level engineering education and curricular innovation, specifically to develop engineering education models that advance sustainable development and capacity building; 2) to pursue engineering activities in an interdisciplinary fashion integrating technical, policy, and civil society aspects; 3) to seek partnerships with different sectors of society, including the private sector, higher education institutions, international and national engineering associations; 4) to incorporate gender mainstreaming into all engineering programs and policies. Within this strategic framework, UNESCO Engineering has sought to establish partnerships with multiple societal sectors including engineering professional bodies, industry, academia, civil society organizations, and Member States for implementing collaborative projects in the following areas: innovation in engineering education [77]; enhancing the interest and participation of youth in engineering, with a strong focus on women and girls, and; promoting engineering for sustainable development. UNESCO's analysis on future engineering capacity highlights an engineering skills gap that threatens industry and growth [78]. Aviation is no exception. There are not enough aviation engineers currently graduating to meet industry needs and nearly half of them switch to other careers once they qualify.

1) Case 1 – UNESCO Program – Women in Engineering

Given the current and future global need for engineering, it is imperative that all human resources are used. Historically, women have been significantly underrepresented in engineering fields, typically making up only 10 – 20% of the engineering workforce [5]. UNESCO has embarked on many different projects to stimulate and encourage more young women to pursue careers in engineering. UNESCO also addresses women's underrepresentation when it comes to studying or pursuing a carrier in the fields of science and engineering [5]. In order to better understand the obstacles keeping women in Africa and the Arab States from either taking an interest in engineering or pursuing a career in engineering, women engineers, policy makers, and professionals participated in a workshop at UNESCO. The workshop was co-hosted with the International Gas Union (IGU), with the support of Total, GDF Suez, Oman LNG, and Qatargas [79]. A roundtable on women in engineering in Africa examined STEM educational policies, curricula, teacher training and female participation. Another roundtable on women in engineering in the Arab States discussed the factors preventing women from entering the workforce in greater numbers despite the fact that a large percentage of engineering students are women. Three of these projects are highlighted here: The Science and Engineering Fair in Nigeria, and the Young Women in Engineering Acceleration Program.

2) Case 2 – UNESCO Initiative - Science and Engineering Fair in Nigeria

In June 2013, around 2,000 secondary school students, including 1,500 girls, participated in a week-long engineering and science event at the University of Nigeria, in Nsukka, UNESCO's first engineering outreach event in the country. A number of UNESCO's partners were involved in this event, such as the International Centre for Theoretical Physics (ICTP), Deyrolles, Engineers Without Borders-UK (EWB-UK), the Institute of Electrical and Electronics Engineers (IEEE), Intel, Microsoft and Nokia.

The event offered students the opportunity to learn about engineering by examining water, shelter, transportation, infrastructure and hydroelectric issues through various hands-on activities. Organized by UNESCO and EWB-UK, students had the opportunity to identify innovative solutions to contemporary development problems. In addition, UEI and EWB-UK also taught 120 undergraduates and teachers how to implement these hands-on activities in the classroom to ensure the continued interactive learning of young students. EWB-UK was able to start the new branch EWB Nigeria as a means of continuing to find innovative solutions to development challenges.

3) Case 3 – UNESCO Program –Acceleration Programme

During Mobile Learning Week in February 2015 Intel and UNESCO launched the Young Women in Engineering in Africa Acceleration Programme. There is a need to encourage more young women to study engineering, to enter the engineering profession, and to stay in the field. It is for this reason that Intel and UNESCO have embarked on the Girls in Engineering Scholarship in Africa Program. As part of the initiative, young women students in their second year of engineering undergraduate studies in South Africa are provided with a two-year scholarship which will enable them to conduct research with one of the Category II Research Institutes under the auspices of UNESCO or any other research laboratory in the country. A key feature is that these young women will also receive mentorship for prominent African leaders and engineers who are women themselves. The purpose of the Intel-UNESCO Scholarship for Young Women in Engineering is to reward the efforts of young women who are studying engineering at universities in South Africa who will contribute, through their innovative engineering research or project work, to the development of aspiring women engineers and the diffusion of engineering as a key driver for sustainable development.

B. Diversity and Inclusion among Young Engineers

UNESCO is working towards increasing the number of students studying engineering at the tertiary level so as to maintain and improve the socio-economic development of societies. To ensure the world will have enough engineers for future sustainable development, it is necessary to encourage and inspire youth to take on contemporary challenges in a multi-cultural environment. This program consists of 3 initiatives, the Airbus Fly Your Ideas Challenge, Engineering Week in Africa, and the UNESCO Youth Forum.

1) Case 1 – Fly Your Ideas Challenge

Sharing Airbus' ambition to inspire young people about sustainable innovation and engineering, UNESCO and Airbus collaborated for the Fly Your Ideas global student challenge [80]. This is an exciting opportunity to promote the need for more diversity among the global population of engineers, to better reflect the communities we serve and attract talented young people from all profiles and backgrounds into the industry.

"The diversity of these students' ideas is an inspiration. They remind us of the need to train more engineers to develop the skills needed to put science into practice", said Irina Bokova, Director-General of UNESCO, reflecting on the wealth of ideas submitted from over 15,000 students from 600 universities in 100 countries, who work in multicultural teams from universities across the world.

2) *Case 2 – Engineering Week in Africa*

The first ever Engineering Week in Africa took place from 1 to 5 September 2014 in schools across Africa. Its aim was to increase the visibility of engineering and its role in sustainable development, to encourage students to study engineering by supplementing STEM curriculum with practical engineering applications, and to incite more African countries to participate ensuring the sustainability of these efforts [81]. Kano and IEEE combined, donated forty (40) Kano kits for Engineering Week in Africa. The kits are for distribution to schools in Ethiopia, Kenya, Nigeria, South Africa and Zambia. Around 10 countries in Africa showed an interest in Engineering Week and some planned concrete activities around it. The official inauguration of this week took place at the University of Johannesburg and is the result of collaboration between UNESCO, the Department of Science and Technology (DST), the Federation of African Engineering Organisations (FAEO), and the Engineering Council of South Africa (ECSA). The meeting was opened by the Minister of Science and Technology of South Africa, Naledi Pandor. Activities that took place included a four-day exhibition, showcasing the nine different engineering disciplines as well as a conference on sustainable engineering. Each day more than 250 school children attended the exhibitions to participate on the hands-on learning tools, making this a total of more than 2000 school learners attending, majority of them being young women. Engineering Week in Africa 2015 is planned to take place in Zimbabwe from 15 to 19 September 2015.

3) *Case 3 – The UNESCO Youth Forum*

In 2013, UNESCO invited young people from more than 150 countries to celebrate the 8th UNESCO Youth Forum. The event entitled: "Youth and Social Inclusion: Civic Engagement, Dialogue and Skills Development," gave participants the opportunity to discuss and debate issues facing today's youth.

The Youth Forum was designed as a platform for youth to discuss the importance of skills development, civic engagement and social inclusion. From such discussions, young people from all over the world had the opportunity to propose policy recommendations to UNESCO's Member States. The youth also had the chance to engage with UNESCO's global partners on ongoing projects.

The UNESCO Engineering programme hosted a capacity-building session at this Youth Forum, entitled *Engineering in Action for Youth: Hands-on Experiments in Engineering.* The session agenda included several activities, led by UNESCO Engineering Initiative's (UEI) partners, Engineers without Borders-UK (EWB-UK), South African Women in Engineering (SAWomEng), Young Engineers/Future Leaders (YEFL), a standing committee of the World Federation of Engineering Organizations (WFEO), Airbus, the European Petrochemical Association (EPCA), Intel and Wikistage.

UNESCO places much emphasis on diversity and inclusion in engineering and thus the many different programs around the world aim to bring young engineers together so that they work collectively on sustainable solutions to the problems of the present and future.

VI. ANTICIPATED GLOBAL SCALE IMPACTS

Despite efforts from all around the world, the prospects for changes in practice that over time would diversify the engineering workforce have yet to reach the core of engineering [82, 83]. The presented barriers, mechanisms, and structures, as presented in Table VIII allow for the alignment of programs and the consideration for the dynamics outside of the local context within which they are implemented. These programs do not operate in isolation, and their successes may be assisted or sustained by the presence of other successful programs further facilitated through systematic alignment. Further, social science constructs can theorize reasons for their success. With this in mind, in this paper efforts are made to distill the appropriate research-based practices for engaging in engineering issues pertaining to D&I. Finding common ground in terms of facilitating constructive dialogue is important for the field of engineering; however, it is also imperative that recognition be given to the unique characteristics that define D&I in each respective global community, rather than trying to create a one-size-fits-all approach. This will lead to a coordinated effort among global communities to identify similarities in their D&I challenges and opportunities to develop strategies for reaching underrepresented groups at the student and faculty level.

TABLE VIII.
SUMMARY OF DYNAMICS OF D&I WITHIN STEM

<table>
<tr><th>Barriers</th><th>Mechanisms</th><th>Structures</th></tr>
<tr><td>Awareness of STEM Disciplines</td><td rowspan="3">Capacity Building</td><td rowspan="2">Institutional Programs and Alliances</td></tr>
<tr><td>Negative Stereotypes</td></tr>
<tr><td>Cognitive and Academic Development</td><td rowspan="2">Legislation and Legal Efforts</td></tr>
<tr><td>Utilizing Non-Cognitive Skills</td><td rowspan="4">Community Building</td></tr>
<tr><td>Isolation and Sense of Belonging</td><td rowspan="2">Recruitment and Academic Placement</td></tr>
<tr><td>Limited Mentorship and URM Faculty</td></tr>
<tr><td>Lack of Cultural Competence</td><td rowspan="2">Curriculum Aligned Efforts</td></tr>
<tr><td>Resources and the "Digital Divide"</td><td rowspan="6">Structure Building</td></tr>
<tr><td>Finances</td><td rowspan="3">Targeted Interventions</td></tr>
<tr><td>Perceptions of Importance of D&I</td></tr>
<tr><td>Virtual Barriers</td></tr>
<tr><td>Implicit Bias</td><td rowspan="2">Academic Researh</td></tr>
<tr><td>Dissemination and Collaboration</td></tr>
</table>

This work has the potential to facilitate global collaboration among the various constituents and engage individuals across multiple demographics. For example, one way to leverage the outcomes from this study would be to build off of the National Academy of Engineering (NAE) Grand Challenges [84] and develop an international initiative that provides the infrastructure for undergraduate/graduate students from various countries to collaborate on a yearly coordinated theme-based design challenge. Teams would be encouraged to focus the challenge on a given context and include an assessment of the sociocultural issues that affect the design problem. In essence, the challenge would be a service-learning project with global implications. To ensure broad participation from diverse students, membership in SPEED could be further expanded by providing outreach to students who are involved in programs like LSAMP. This would provide a platform for diverse students to move beyond dialogue to actual engagement through the juxtaposition of social and technical challenges - engineering for the 21st century with sensitivity toward empathetic/ethical practices.

While a contextualized understanding of D&I is important, it is also necessary to frame the conversation from a non-contextualized perspective. The rationale for this is to create normalization so as to focus on the fundamental elements that promote or hinder D&I in the engineering profession - a root cause analysis, per se. This approach may help to minimize emotional responses and allow individuals and communities to be objective in their assessment of the structural and functional factors of the profession that influence D&I. This work also requires a hard look at the behavioral factors that perpetuate the challenges of implementing effective D&I strategies in the engineering profession within specific global contexts. Ultimately, what has been described above is a systems engineering approach to solving the D&I challenge. Once the issues are appropriately characterized, it is feasible that various strategies could be implemented based on research-based practices.

Engineering Education organizations are making important, official statements about the importance of diversity at their regional and national levels. The European Society for Engineering Education (SEFI, French name: Société Européenne pour la Formation des Ingénieurs) had as a theme for their 2015 annual conference, "*Diversity in engineering education: an opportunity to face the new trends of engineering"* with sub-topics such as 1) Diversity in engineering education and of engineering institutions, 2) Gender and diversity in innovation teams in engineering education, and 3) Diversity and inclusion as business cases in technical research. The conference drew 285 participants from over 38 Countries. During the conference, participants had opportunities to learn about different methodologies for integrating Gender and Diversity into engineering and engineering education. SEFI noted in their annual report that the 2015 conference was the first time that the organization highlighted the topic of "Diversity" as the headline topic of one of their conference. SEFI further sought to define "Diversity" from an engineering point of view, which was part of a position statement on "engineering skills" which included a SEFI Diversity statement. SEFI took this step in order to demonstrate to their commitment to strategies that reflect diversity [85] The commitment speaks to one of the values that SEFI set: "Respect for diversity and different cultures" [86] SEFI's published Diversity Statement is within their position paper on engineering skills, and the organization states as a key common issue.

> *"Higher engineering education institutions should embrace diversity both in the students they attract, the academic staff they employ, and the inclusive programmes they deliver"*[87].

Figure 2. Diversity Statement from the European Society for Engineering Education

The American Society for Engineering Education marked 2014-2015 as the "Year of Diversity." The year of action-oriented events built upon earlier foundations for exploration of diversity by ASEE such as the Task Force for Diversity, developed in 2009, and the ASEE Diversity Committee, which was formed in 2011 [88]. In 2015, the Diversity Committee of the ASEE Engineering Deans Council addressed ethnic diversity directly through development of a document with signatures from deans of engineering across the United States. The Deans who signed the document committed to specific actions to engineering opportunity and access for women and other underrepresented demographic groups. The document states:

> *"While gains have been made in the participation of women, African-Americans, Hispanics, and Native Americans in engineering in recent decades, significant progress is still needed to reach a level where the engineering community fully embraces all segments of our increasingly diverse and vibrant society. In particular, we must further promote the pursuit of engineering education to all those who have been historically under-represented within our discipline; provide an educational experience that is demonstrably equitable and inclusive; and actively work to improve the broader engineering culture to fully engage the diverse generations to come* [89]."

Figure 3. Statement of Diversity within the American Society of Engineering Education's Deans Diversity Initiative Letter

The document goes on to discuss developing diversity plans for engineering programs, collaborating with organizations that serve populations that are underrepresented in engineering such as NSBE, SHPE, NACME, GEM, SWE, AISES, and WEPAN, committing to a pipeline activity with underrepresented students at the pre-college level. Further the deans commit to developing partnerships with engineering schools that serve populations that have students who are underrepresented in engineering, and they further commit to developing strategies to proactively increase the diversity of the faculty. At the time of this publication, 147 deans across the U.S. signed the document. ASEE provides deans with an open invitation to join the initiative [90]. Deans gathered at the White House in Washington, D.C. to sign the document at the first-ever "White House Demo Day," hosted by U.S. President Barak Obama on August 4, 2015 [91]. Globalized alignment and practice can help disseminate the successes of these initiatives.

Other potential outcomes might include designated resources to support the development and implementation of effective global strategies for D&I in the engineering profession. For example, ample funding from various international agencies could be allotted to research and evaluation in areas related to broadening participation of underrepresented groups in engineering. Agencies, such as the U.S. National Science Foundation, serve as leaders in this regard. A strong commitment from the Global Engineering Deans Council (GEDC) that clearly states and recognizes the value of D&I in all aspects of the engineering discipline would raise the level of visibility and set a tone of accountability within the culture of engineering education. This would provide a platform for other stakeholders (e.g. industry partners) to leverage and further promote D&I within corporate culture. And lastly, the International Federation of Engineering Education Societies (IFEES), the World Engineering Education Forum

(WEEF), and GEDC could pull together in support of the development of a global diversity index as a mechanism of tracking the implementation and progress of D&I efforts.

VII. STUDY LIMITATIONS

While this work establishes a decontextualize framework for Diversity and Inclusion, the intention is not to neglect the critical importance of the local contextual implementation of all efforts. A decontextualized framework can be effective in analyzing efforts objectively, while considering how these objective dynamics can lead to better results within each local context. The discussion presented and the literature used is slightly biased towards references towards the USA. While attempts were made to provide a balanced discussion with geographic and cultural representation, views from the USA are overrepresented in the literature.

VIII. BEYOND MARGINALIZATION: AN INTERNATIONAL CALL FOR THE "INCLUSION OF ALL"

While generating thoughts, discussions, and strategies for Diversity and Inclusion in general can seem like a benevolent activity for organizations and individuals, there can still be controversy in conversations regarding "who" is included in the discussions. In some circles, discussion of women is allowed, but discussions of race are shunned. The scholarship of "intersectionality" of race and gender has been particularly discussed in the context of African-American women in the U.S. by Kimberle Crenshaw [92] and Patricia Hill Collins [93]. This topic of intersectionality is now being more widely discussed in national STEM meetings as women from underrepresented backgrounds share their experiences of marginalization at various points along the academic pipeline, continuing into pursuit of the professoriate, and advancing in the career.

The question of racial inclusion globally, begs the question of inclusion in STEM and inclusion in engineering. Are people from all backgrounds invited to participate in engineering study, activities, and careers - including those from marginalized racial and ethnic backgrounds? As organizations seek to strategize to include more diverse groups to participate in making contributions toward solutions to the world's challenges, and to receive recognition for achievement of goals, it will be important to be sure that members of all backgrounds are included, including all marginalized racial groups within cultures.

IX. RECOMMENDATIONS AND CONCLUSION

A systemic approach to inviting underrepresented students is presented in a decontextualized framework. As a whole, the framework and D&I efforts are established to build communities and provides legitimate guidance towards success from both top-down and bottom-up approaches.

As stated by the NSF, broadening opportunities and enabling the participation of all citizens, women and men, underrepresented minorities, and persons with disabilities, are essential to the health and vitality of science and engineering [9]. Diversity has been shown to make any field more competent, especially engineering [10]. While diversity and inclusion can be viewed as a condition for morality and fairness, within the engineering and business community it is more often viewed as an asset which enhances team creativity, makes solutions more feasible, products more usable, and citizens more knowledgeable [94].

Omitting to engage in D&I practices has been consequentially noted to decline interest in engineering careers, sagging membership in professional associations, citizen distrust of engineering expertise, and even more formidable challenges in competing successfully with other disciplines to recruit, enroll, and educate a diverse student pool to completion of the baccalaureate [10].

Current trends in participation of underrepresented groups indicate that D&I initiatives with engineering education and the engineering workforce have yet to reach the core of engineering [82,83]. This is despite much research and good intentions of many of the important stakeholders within the engineering education dialog. Consolidating D&I best practices on a global level and optimizing research informed practice can perhaps be the additional stimulus needed for D&I to reach the core of engineering.

Science has no borders, follows no single politic. Elevating Diversity and Inclusion initiatives to a global level and normalizing across local contextual characteristics provides a common platform of scientific knowledge everyone can support.

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