AC 2012-4703: A MODEL FOR DIVERSITY AND EQUITY

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A MODEL FOR DIVERSITY AND EQUITY: DIVERSITY IN ENGINEERING GRADUATE EDUCATION

Abstract

A model of Diversity and Equity for building inclusive excellence in graduate engineering education is proposed as a systemic action plan for achieving high diversity and equity impacts in women and underrepresented minority (URM) STEM graduate education. The proposed model is implemented through the following six strategic dimensions:

- *Foster institutional leadership engagement that maximizes receptivity for diversity and equity by focusing on the systemic, organizational, and structural realignments necessary to support all the other five dimensions*
- *Establish criteria for institutional high diversity impact, climate, and culture that support all graduate students and engages all of its diversity in the service of graduate students.*
- *Establish a multi-campus outreach framework for URM motivation for STEM fields.*
- *Develop multi-campus partnerships for URM capacity building and access into PhD program.*
- *Build a graduate student-centered community and professional development opportunities by developing a structure for effective community engagement and mentoring partnership with all stakeholders for the production of increased number of URM STEM PhDs.*
- *Evaluate Diversity and Equity outcomes and reward departments that make highest impact in closing student equity, diversity or educational outcomes gaps.*

A mathematical diversity model that presents diversity impact as a linear function of the intentional actions or performances in Access (A), Retention Rate (R_r), Graduation Rate (G), Quality (Q), Climate (C), and Receptivity (R_e) is presented with the corresponding diversity contribution coefficients. The Engineering Research Center (ERC) is shown as a case example of a purposeful development and utilization of organizational resources to improve graduate engineering education through multi-campus approach. A summary of the diversity portion of the ERC's strategic plan and progress in the past three years in relation to the milestones for "High Quality Diversity Effort" is highlighted. The key performance indicators show that ERC through its partnering institutions is making measurable impact in capacity building for a STEM workforce as seen in the broad involvement of underrepresented minority students and faculty in center activities. Project CARE was used as case example of college transition program that was implemented based on the proposed model activities. The results show that Project CARE contributed to 86% educational growth and performance improvement among URM students who scored lowest on the pre-test. The program was effective in preparing high school students for college level math and science instructions, as well as enriching their academic performance skills and abilities to excel in their senior year of high school.

A MODEL FOR DIVERSITY FOR EQUITY:
DIVERSITY IN ENGINEERING GRADUATE EDUCATION

Introduction

Both the U.S. population and the student bodies in U.S. academic institutions are becoming increasingly diverse. Labeled as the "underrepresented majority," the most recent data projects that URM will constitute almost 32% of the American population by 2020 and will outnumber white males at 30.1%[1,2]. Comparison of 2000 and 2010 data in Table 1 shows the percent change of 43% for Hispanic American, 12.3% for African American, and 5.7% for Whites.

In order to make significant progress in increasing the educational attainment of all students and for the U.S. to meet its workforce needs, there is an urgent need to address disparities in educational opportunity and achievement among Americans. The high school graduation rate has decreased for all racial and ethnic groups over the past two decades, and differences between racial and ethnic groups persist. A growing number of high school students drop out of school completely. For high school graduates, 73% of whites, 56% of blacks, and 58% of Hispanics enroll in college the next fall following graduation[8]. Enrollment is also linked to household income. The enrollment rate for students from middle-income families (from $50,001 to $100,000) is 78% compared to 52% in lowest income group ($20,000 and below) and 91% for students from families in the highest income group (above $100,000)[3, 4]. In the high unemployment period, the number for minorities enrolling is expected to decrease further. Unless the number students graduating from high school are well prepared for college education in the STEM field increases, the number transitioning to graduate school will not increase.

In 2009, underrepresented minority students (blacks, Hispanics, and American Indians/Alaska Natives) accounted for 12% of students enrolled in graduate engineering programs (Table 2) compared to 63.4% of Whites. In the same year, underrepresented minorities accounted for 9% of all engineering doctoral degrees earned that year (Table 3). Although there has been an improvement in the production of URM PhD, large disparities still exists given the under-representation of minority faculty in academia. Major barriers to increasing graduate students and faculty diversity is identified as a three-body "pipeline" problem that requires comprehensive intervention from pre-college to PhD. First is the K-12 pipeline problem due to the under-preparation of students at the pre-college level math and science, resulting in fewer students transitioning to college. Second, the college pipeline problem due to the K-12 pipeline results from fewer students graduating from college and transitioning to graduate school. Third, at the academic professoriate level is the graduate pipeline challenge resulting from fewer graduates completing PhD in the STEM areas and transitioning to academic careers.

Studies sponsored by the National Science Foundation show that although the preparation for college is improving for African American students, the percent of high school graduates who enroll in college has not increased due to deficiencies in quantitative literacy in K-12 curricula and the lack of activities that relate science, technology, engineering and mathematics (STEM) to real world experience[4]. The American Association for the Advancement of Science Project 2061 has noted that merely "covering" the topic is not sufficient to assure that the material will actually help students retain important ideas within those topics[5,6]. As a national trend, bridge programs are often used to enhance the academic preparation of students falling below reading and math proficiencies. Unfortunately, some of these programs have proven to be insufficient in closing the achievement gap caused by the weak high school math and science backgrounds and the lack of critical and analytical thinking skills. Project CARE developed by Wosu et al[7] identified low Academic Performance Improvement (API) skills (such as critical thinking, analytical reasoning, quantitative literacy, communication, and problem solving skills) at the pre-college level as the major cause of the poor preparation that hinders attraction to and enrollment of students from the underrepresented group into STEM fields. Common reasons cited were the less-than-challenging mathematics and science K-12 instruction and students' poor study skills. The Project CARE strategy of the solution of the identified problem is based on the premise that enrichment of the *Academic Performance Improvement (API) skills* will minimize the barriers that hinder students' performance and attraction to STEM careers and that the enrichment of these skills is needed to prepare students for science and engineering should begin earlier, during the middle and high school grades.

The above problem has been shown to have a direct effect on the production of URM PhD in the STEM field. The question of accepting responsibility for producing more minority PhDs to fill the gap in the professoriate continues to generate important debate. As a result, among the nation's research and graduate level institutions, minorities account for less than 5% of the total number of faculty even though nearly 60% of minority PhD students have initial intentions of becoming faculty members as compared to 47% of white PhD students[8-11]. While African Americans constitute 12% of college enrollments, their 5.3% representation in full-time faculty positions illustrates the gap that needs to be filled. Research clearly indicates that the problem lies with the low URM PhD production. The number is small due to the limited qualified students in pipeline, high dropout rate, low graduation rate, and substantially lower GPA than whites. It is clear that unless the number of URM PhDs is increased, representation of minorities on faculties nationwide will not be achievable, no matter how extensive the recruiting effort or how well those few who attain positions are treated[12-14].

There is also the lack of motivation and interest for PhD programs among minorities. Minority students are the least likely to want to continue toward a PhD after the BS and the most likely to have low motivation for the Professoriate, especially in majority white schools[10]. *Survey data of Doctoral Education and Career Preparation* by Golde and Dore[11], further looked into how well doctoral students are being prepared for the professoriate and showed that of the 574 chemistry students surveyed, 41.7% said their interest in a faculty career declined while in graduate school, 36.5% have interest in faculty positions, only 19.8% had a definite interest in faculty positions, and lower than 14% of these had interest in faculty careers in research universities. The proportionate inclusion of underrepresented minorities in science and engineering in the professoriate is critical because our sources for the future science, technology, engineering and mathematics (STEM) workforce are uncertain, the demographics are rapidly shifting, and diversity is an asset that leads to innovation[14].

Lack of role models and mentors in the already low critical mass of URM faculty exasperate the problem. Minority students in search of PhD granting institutions usually wish for faculty role models in the classroom who can inspire them for graduate studies and ultimately become faculty members. In their recent study on these issues, Nelson and Rogers [13] concluded that the "presence of science and engineering minority faculty is a crucial factor in encouraging and ensuring the continued interest of young minorities in science and engineering." It was noted that their presence is equally important to attract some of those students to the professoriate to serve future generations of minorities. Thus, the tension between seeking mentors of similar backgrounds and the lack of availability of such mentors continues to create challenges in the advancement of minorities in majority institutions. Many university leaders agree that black students are hesitant to pursue studies and a career in fields where no leaders of the same race are evident. Students need to see faculty achieving in their fields to serve as role models for student success. Synergy between increasing black student enrollment and increasing black faculty members will generate momentum leading to broader participation. [14] Finding solutions to these problems is crucial because of the ever-increasing diversity in the U.S., expected large-scale retirements from the STEM disciplines, and the need to ensure a stable future STEM workforce to maintain U.S. competitiveness in science and engineering. Nelson and Rogers write, "If significant progress is to be made within the next couple of decades, new and totally different approaches to solving problems facing women and minority faculty will be needed.[13]"

This paper presents a comprehensive multi-dimensional approach to addressing the above three-body pipeline problem that result in low production of URM PhD and under-representation of URM faculty in STEM. The model premise is that multi-campus recruiting pipeline, graduate mentoring, retention system, and institutional receptivity will increase the URM PhD production in the STEM field.

Table 1. US Population by Race: 2000 and 2010

Hispanic or Latino origin and race	2000		2010		Change 2000 to 2010	
	Number	% of Total Population	Number	% of Total Population	Number	% of Total Population
Total Population	281,421,906	100.0	308,745,538	100.0	27,323,632	9.7
Hispanic or Latino	35,305,818	12.5	50,477,594	16.3	15,171,776	43.0
Not Hispanic or Latino	246,116,088	87.5	258,267,944	83.7	12,151,856	4.9
White alone	194,552,774	69.1	196,817,552	63.7	2,264,778	1.2
Race						
Total Population	281,421,906	100.0	308,745,538	100.0	27,323,632	9.7
One Race	274,595,678	97.6	299,736,465	97.1	25,140,787	9.2
White	211,460,626	75.1	223,553,265	72.4	12,092,639	5.7
Black or African American	34,658,190	12.3	38,929.319	12.6	4,271,129	12.3
Native American or Alaska Nat.	2,475,956	0.9	2,932,248	0.9	456,292	18.4
Asian	10,242,998	3.6	14,674,252	4.8	4,431,254	43.3
Native Hawaiian and Other Pacific Islander	398,835	0.1	540,013	0.2	141,178	35.4
Some other race	15,359,073	5.5	19,107,368	6.2	3,748,295	24.4
Two or More Races	6,826,228	2.4	9,009,073	2.9	2,182,845	32.0

Table 2. US Engineering graduate enrollment by and race/ethnicity: 2009

Field	U.S. cit/permanent resident	White	Asian	Black Amer	Hispanic Amer.	Native Amer.	Unknown /ethnicity
All Engineering	73,031	46,428	9,602	3,872	4,764	312	8,053
Aerospace	3,605	2,485	377	108	195	16	424
Chemical	4,022	2,809	536	172	225	14	266
Civil	11,750	7,884	1,136	528	915	59	1,228
Electrical	15,936	8,908	3,041	900	1,072	54	1,961
Industrial	9,511	5,305	977	826	717	61	1,625
Materials	2,949	2,119	362	112	145	11	200
Mechanical	11,893	8,334	1,225	431	749	43	1,111
Other	13,365	8,584	1,948	795	746	54	1,238
Percentages by Race (%)		**63.6**	**13.1**	**5.3**	**6.5**	**0.4**	**11.0**

Table 3. Earned masters in engineering degrees, by race/ethnicity: 2000–09

Citizenship, race/ethnicity	2004	2005	2006	2007	2008	2009
ALL-U.S. cit/perm resident	18,282	19,034	18,972	19,276	19,749	20,940
White	11,763	12,198	12,084	11,949	12,077	12,428
Asian/Pacific Islander	3,016	3,094	3,186	3,355	3,494	3,929
Black or African American	853	869	883	926	977	971
Hispanic American b	1,130	1,145	1,094	1,220	1,243	1,317
Native American /Alaska	85	82	87	73	86	89
Unknown Ethnicity	1,435	1,646	1,638	1,753	1,872	2,206

Table 4. Earned doctoral degrees in engineering by race /ethnicity: 2000-09

Citizenship, race/ethnicity	2004	2005	2006	2007	2008	2009
ALL-US Cit/Perm Residents	2,347	2,452	2,714	2,994	3,180	3,374
White	1,633	1,696	1,818	1,973	2,112	2,235
Asian/Pacific Islander	346	372	470	508	501	504
Black/African American	99	101	110	117	128	139
Hispanic-Latino /American	101	98	105	138	130	153
Native American	8	6	7	8	15	19
Unknown Ethnicity	160	179	204	250	294	324

SOURCE: National Science Foundation, National Center for Science and Engineering Statistics, Survey of Graduate Students and Postdoctorates in Science and Engineering, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov.Science and Engineering Indicators 2012

Model Description and Objectives

The equity scorecard designed by Bensimon focused attention on educational equity and serves as a data-driven, information-tracking model to drive and assess the diversity change process in higher education.[25] The proposed scorecard assessed educational excellence by considering ethnicity and gender in relation to factors such as the dean's list, four-year graduation rates, the top ten percent in GPA distribution, and pass/fail rates in gatekeeper courses. The scorecard evaluated institutional viability by considering the faculty and staff's ethnicity, gender, and institutional rank, and identifying how these are related. In a study commissioned by the AACU to help campuses implement change, Inclusive Excellence Scorecard was introduced[16] as a tool that "allows campuses to pinpoint where they are doing well and where they need improvement on a set of Inclusive Excellence goals." IE scorecard builds on the Diversity Scorecard of others.[17]

In this paper, *Diversity and Equity* are the key performance indicators that result from the intentional intervention actions by an institution or organization for the *inclusion* of all students, staff, and faculty in the institution's academic mission. The proposed model for diversity and equity in graduate engineering education is designed as a synergistic plan for capacity-building through best practices across campus and programs. Production of increased number of women and URM graduates in STEM fields is achieved through broad-based partnerships and outreach programs targeted at K-12 to PhD levels. The model builds on the previous works on the subject[17-20] but focuses on the actions or parameters that have the highest potentials of maximizing Diversity and Equity as outcomes rather than actions as in previous models.

Key Performance Indicators

The six performance indicators or variables in the model are Access (Preparation, Recruitment), Retention (Perseverance), Quality (Excellence), Graduation (Degree), Institutional Climate, and Institutional Receptivity. Institution in the context of this model can be an academic department, school or college, or any organization in which the diversity and equity are being measured. Thus, the Diversity and Equity indicators are described below:

Access (*A*): *Access* is the provision of educational opportunities (through admissions, scholarships, recruitment, and preparatory programs) to every individual, especially women, disabled and underrepresented individuals. Related to Access is *inclusion* that refers to the intentional actions to provide URM access to educational opportunities, regardless of diversity and to the maximum extent appropriate. In the case of individuals with disabilities, inclusive actions may involve bringing the support services to the individual and requires that the individual benefits from being in the program. The Individuals with Disabilities Education Act (IDEA) requires that a significant effort be made to find an inclusive placement. Possible measures of *access* and *inclusion* include such items percentage of URM students enrolled in engineering, percentage of URM faculty and staff, percentage of tenured URM faculty in engineering, percentage of URM receiving scholarships and financial support, etc.

Retention (*R*): Refers to the persistence of underrepresented students, faculty and staff to continue or achieve their educational goals or professional careers in engineering. Related to retention is the ***Graduation rate (Degree)*** defined as the proportion of URM students that graduated after a specific period (typically six years) relative the number that entered or the number of engineering degrees awarded to URM relative to total number awarded for the specific year. Possible measures or indicators of *Retention* include such items as the percentage of URM students retained in engineering field, the percentage of URM students completing their freshman year; percent of URM student completing their degree goals. For faculty, retention can be the percentage of URM faculty tenured in a department, etc.

Quality (Excellence) (*Q*): With reference to Diversity and Equity, *Excellence* is the level or *quality* of preparation (SAT, GPA, GRE, etc) and *achievements* (Academic Honors and Awards received, percentage of URM achieving above GPA of 3.0, etc) of historically underrepresented students. For faculty, excellence is the level of scholarship achieved by a faculty. Research showed that serious engagement of diversity in the curriculum increases students' positive attitudes and awareness of diversity, satisfaction with college, and commitment to education in general [17]. Institutionally, it means providing academic and professional development support structures that "make excellence inclusive." This could require maintaining high admission and academic achievement standards but paying attention to the cultural differences and abilities learners bring to the educational experience. This means fostering an academic culture that challenges and moves all students to higher levels of achievement to ensure reduction in achievement disparities. Intentional presence of diversity in both the formal and informal curriculum of higher education institutions was identified as a critical element of Inclusive Excellence model.[16] Student quality or excellence can be measured by SAT, GRE scores of incoming students, percentage high-achieving URM students achieving above 3.0 GPA in engineering and percentage of URM graduates that continued to graduate school or percentage of freshmen class in the top 10% of their class. For faculty, excellence can be measured by the academic honors and career awards received by faculty and number of publications.

Institutional Climate/Culture (*C*): Graduate academic culture can be defined as the shared, learned, symbolic system of morals, values, and beliefs that shapes and influences policies and people's perception and behaviors in a department. Academic culture for graduate education has a distinct environment reinforced through rituals, traditions, norms, and structures that differs from undergraduate education. With reference to diversity, some key characteristics of academic culture could include clear expectations and communication for high academic achievement to enrolled students, a focus on quality research and scholarly contributions to the discipline, expectation of faculty and students to explore new knowledge and higher learning; expectations of infusion of diversity experiences, cross-cultural elements, and diverse perspectives into the graduate curriculum and admissions decisions.[21-22] Williams and others[16] defined Campus *climate* as referring to "how students, faculty, and staff perceive and experience an institution's environment." Others have defined climate as "the development of a psychological and behavioral climate supportive of all students.[19-20, 24]. For the purpose of this project, *Institutional Climate* is the result of institutional culture and can be broadly defined as the perceived or dominant "environmental" conditions (attitudes, behaviors, and standards) of an institution's workforce and student body with respect to the access for, inclusion of, and the level of sensitivity to individual differences, potentials, group needs, similarities, and abilities. Institutional Climate can be measured by the percentage of seniors who rated the institution or school racial climate as good to excellent; percentage of seniors who rated their relationships with faculty in the school as good to excellent; percentage of seniors who rated their relationships with other students in the school as good to excellent; the percentage of students who have good to excellent sense of belonging; percentage of students in agreement that they are respected regardless of gender; percentage of students in agreement that they are respected regardless of their diversity (race, ethnicity, sexual orientation, religious beliefs, etc.).

Institutional Receptivity (*Re*): Refers to the intentional "support that can help create a more accommodating and responsive campus (*school*) environment for students drawn from underrepresented groups.[25]. This dimension addresses the school commitment to establishing accountability processes to ensure meaningful and consistent support, willingness to allocate sufficient resources to ensure success. High receptivity ensures that non-compliance is met with real consequences or that significant contributions are appropriately rewarded. Institutional Receptivity can be measured by the percentage of URM in leadership position or responsibilities, and the level of resources allocated to diversity efforts relative to the overall total. Some research-based reasons why many diversity plans fail include insufficient integration into core goals for educational excellence—both at the student level and at the institutional level [16]; a lack of a comprehensive and widely accepted assessment framework to measure diversity outcomes [25]; an inability to translate the vision for change into language and action that can be embraced at multiple levels of the institution [26]; failure to establish accountability processes to ensure that non-compliance is met with real consequences[24;] low levels of meaningful and consistent support from senior institutional leaders throughout the change process[16]; and resistance to allocating sufficient resources to ensure that the vision for change is driven deep into the institutional culture [27]. Institutional Receptivity addresses these issues and refers to the institutional openness and willingness to create a more accommodating and responsive campus climate for all. Institutionally, it is the intentional "support that can help create a more accommodating and responsive campus (*school*) environment for students drawn from underrepresented groups.[28]"

Model Implementation Strategies

The full implementation of DE Model requires each institutional unit to be engaged in providing a clear understanding of the targeted goals for access, retention, graduation, quality, climate and receptivity and identifying the levels of inequities in the desired outcomes. Intentional efforts to foster high diversity outcomes are implemented through the following six-strategic dimensions designed to close the diversity and equity gaps in educational outcomes:

- *Foster Institutional Leadership Receptivity for Diversity and Equity goals.*
- *Establish criteria for high diversity impact, climate, and culture that support all graduate students.*
- *Establish a Multi-Campus Outreach Framework for URM motivation for STEM education.*
- *Develop the Multi-Campus Partnership for URM Access into PhD program.*
- *Build a Graduate Student-Centered Community and Professional Development Opportunities.*
- *Evaluate Diversity and Equity outcomes and reward departments that make highest impact in closing students' equity, diversity or educational outcomes gaps.*

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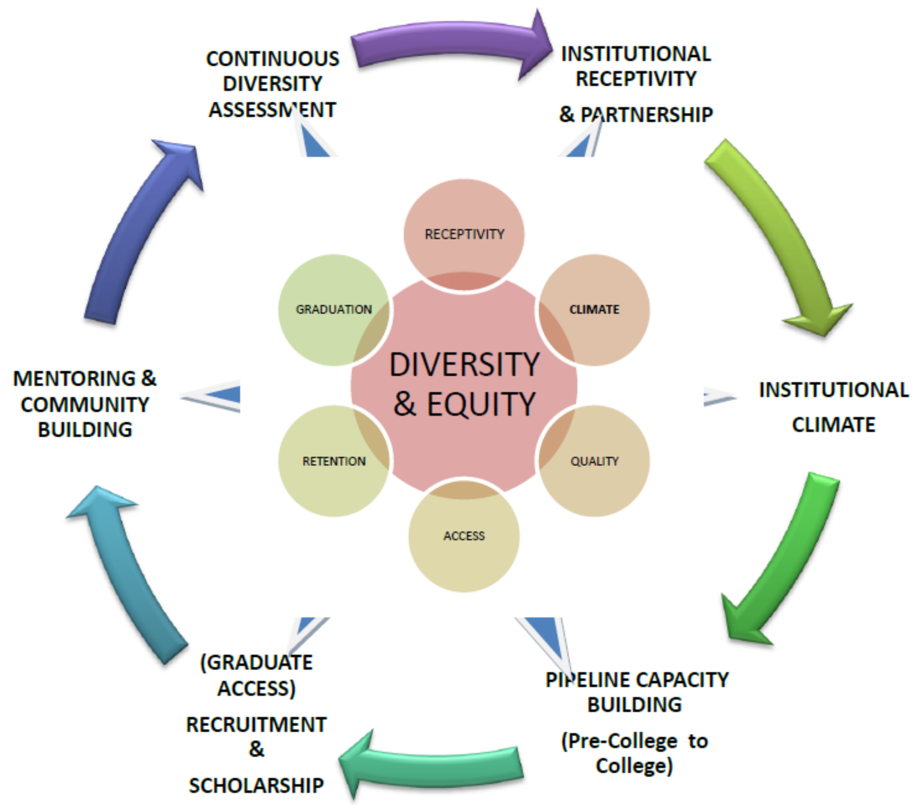

Figure 1. The implementation strategies to achieve high diversity and equity impact relative to performances in Receptivity, Climate, Quality, Access, Retention, and Graduation (Degrees).

Figure 1 shows the implementation strategies and the performance measurement framework for Access, Retention, Graduation (Degrees), Quality, Climate, and Receptivity for high Diversity and Equity Impact. The Diversity and Equity as an outcome results from the performances or interventions of the inner six integrated dimensions supported by the outer dimensions. Each of the dimensions and the strategies to measure them are described below:

Dimension 1: Foster Institutional Leadership Engagement that maximizes Receptivity for diversity and equity.

This *Institutional Receptivity* dimension focuses on the systemic, organizational, and structural realignments necessary to support all the other five dimensions. It addresses the institutional commitment to establishing accountability processes to ensure meaningful and consistent support, willingness to allocate sufficient resources to ensure success in diversity, equity and inclusion initiatives; high institutional receptivity ensures that non-compliance is met with real consequences or that significant contributions are appropriately rewarded. Typical actions include:

Articulate a Broad Diversity Vision and Specific Criteria for Comparison with Comparative and Aspiration Institutions:

At the core of effective diversity management is the articulation of a meaningful vision or mission statement for diversity that reflects the institutional commitment to diversity and equity goals. The institutional units must also develop meaningful and consistent support for Diversity and Equity in words and actions through allocation of sufficient resources. The leadership must appoint and designate high level institutional leadership personnel with tenured faculty appointments to unify the vision for change deep into the institutional culture with appropriate language and expectations that can be embraced and duplicated at multiple levels of the institution. At the unit or college levels, there is the need for an Associate Dean with faculty appointment to lead the efforts specific to that unit and align the unit goals to institutional commitment and strategic plan. Most institutions or academic units have a list of five or more other institutions or units that they compare themselves with or institutions they aspire to be like, based on certain criteria such as enrollment size, Carnegie classification,(public/private), ranking, research expenditure, and location (Urban/sub-urban). Diversity performance data such as URM graduate enrollment, retention, graduation, climate, resources for diversity can be compared against those of the comparative and aspiration institutions. Efforts must be made to measure units' contribution to diversity goals and a reward structure established to reward faculty and departments that make greatest impacts.

Integrate and Emphasize Diversity in Academic Leadership and Operations:

Institutionally, this calls for broad collaborations with university leaders and administrative units-Deans and their units, Office of General Counsels, Human Resources personnel, all Student Support Services, and other related offices to ensure understanding of the Diversity and Equity goals and unification in the implementation of the services to support the goals. The institution and the units' deans must development a clear statement of commitment to diversity and ensure that the diversity goals are reflected in institutional documents, including the mission statements of sub-units. Creation of a high leadership diversity committee or steering committee is part of institutional commitment to diversity to external stakeholders and useful in initiating discussions with Board of Trustees to support and advance diversity efforts. There is a need for intentional efforts for increasing the numbers of URM in leadership position or responsibilities. There is need to develop and utilize institutional resources to enhance student learning by establishing an environment that challenges each student to achieve academically at high levels.

Monitor progress in achieving institutional diversity goals: *using a comprehensive and widely accepted assessment framework to measure diversity outcomes.* This requires a level of openness to ensure that key performance indicators are clearly defined, relevant institutional data collected and analyzed using metrics appropriate for measuring progress in Diversity and Equity goals, appropriately disseminating information to all stakeholders about the progress achieved or not achieved in meeting institutional Diversity and Equity goals, and rewarding best practices for high impact accordingly. One performance indicator could be assessing if composition of the faculty enhances diversity and adequately reflect the racial and ethnic composition of the student body.

Integrate Diversity and Equity goals into core academic mission for inclusive educational excellence—both at the student level and at the faculty institutional level. Intentional presence of diversity in both the formal and informal curriculum of higher education institutions was identified as a critical element of Inclusive Excellence.[28-29] Activities could include study abroad programs to enhance global education, Annual Faculty Diversity Seminar offered to redesign courses to be more inclusive in terms of race and gender. Such seminars can be used to enhance course curriculum by addressing key aspects of diversity in both classroom content and course pedagogy within the course content. The seminars can also help faculty restructure courses to reflect diverse perspectives, understand how to manage issues related to diversity in the classroom, improve teaching by incorporating diversity materials and new classroom activities, or be aware of how to integrate learner differences in diverse population.

Dimension 2: Establish criteria for high diversity impact, climate, and culture that support all graduate students.

The primary purpose of this *Climate* dimension is to foster an inclusive academic climate that recognizes the cultural differences learners bring to the educational experience. Strategically, it calls for institutional actions that provide a positive behavioral climate that supports all students moving to a higher level of excellence. At the units' levels, it calls for fostering a welcoming community that values diversity and inclusion, respect and appreciate of culture, race, ethnicity, gender equality and difference, and engages all stakeholders to maximize students learning, workforce and student satisfaction, and faculty productivity. A variety of activities, workshops and seminars need to be created to provide diversity education that fosters a welcoming community and engages all of its diversity in the service of student teaching and learning. Typical actions include:

Effective academic support at departmental level: Designate academic support staff at each department level to handle all diversity related issues at that level whenever possible. Ensure that the designated staff takes extra effort to provide the needed nurturing and acceptance of the students and make sure they are included in department activities. Integrate more diversity activities into engineering curriculum by requiring that all freshman and first year graduate students take two-hours of diversity education.

Faculty Diversity through New Teaching Post-Docs and Assistant: Host orientation for new TAs each fall and provide ongoing training seminars for teaching assistants wanting to develop their teaching skills. Provide training to new Teaching Post-docs and Assistants to help them develop and improve their teaching skills. Survival Skills and Ethic programs can help post-docs and TAs to enhance their career growth and success at present and future**.**

Foster a sense of belonging for minority students in the department: Most students have an easier time succeeding in graduate school if they feel that they belong and are valued members of the department. Strategically, this will mean increasing the commitment to attract diverse facultyand a diverse student body, and teaching all department members about the value of cultural diversity to the department's mission. The leadership must pay regular attention to the minority students, seek them out, and instill in them a sense of belonging. Faculty should help minority students understand the culture of the Research University and mentor.

Require faculty to promote and sustain a graduate-level academic culture: This can be done through orientation programs for new graduate students with an emphasis placed on the unique and distinct culture from that of undergraduate education; engagement of students by building strong student/student interactions and strong faculty/student interactions – in and outside of classroom through planned group work, social activities, collaborative learning opportunities, establish faculty graduate education committee or council to guide the implementation of graduate programs and establishment and evaluation of student learning goals with emphasis on critical, analytical, and creative thinking; provide opportunities for students to participate in professional/disciplinary organizations, and provision of meaningful contribution to graduate student financial support including graduate student research assistantships, and participation in graduate student orientations, department graduation celebrations, graduate student awards, and recognition at commencement ceremonies.

Dimension 3: Develop Outreach programs for increasing URM motivation for STEM.

The K-12 pipeline problem is that fewer and fewer youths are not adequately prepared for and interested in STEM education. Addressing this challenge requires STEM units in an institution to recognize their roles in creating opportunities at the departmental levels for inclusive access for STEM education through pre-college education and outreach programs embedded in faculty research and research centers. AAU Committee on Graduate Education recommended that to increase URM diversity in graduate programs, "departmental recruitment and admissions policies should include provisions designed to increase the participation of talented students from groups underrepresented in their graduate programs by partnering with undergraduate institutions and K-12 schools to encourage talented minority students to prepare for and pursue graduate programs; universities should consider both individual and consortial strategies to reach minority students as early as possible in their educational lives.[30] Typical actions include:

Pre-College Education and Outreach programs- Faculty and center staff could visit local schools for STEM related activity as well as hosting student, teachers and family members, especially from underrepresented groups; connection with local schools as well as statewide. Units will need to form partnerships with selected high schools across the State to identify and mentor gifted students in selecting engineering at as a viable option. Visits to these schools to make technical research presentations, hosting design contest coaching, and hosting women and minority students from local schools are some of the ways that more students are exposed to engineering. Outreach program and their STEM camps are formatted from a developmental perspective. The content for camp teaching and learning are largely focused upon specific and exciting engineering research areas as tissue engineering, bioengineering, nano-engineering, etc., with applications to societal needs. Students need to see the connection between engineering and human needs.

Develop College Enrichment program to increase URM Quality and Access into STEM fields. Although URM students can be motivated for STEM education, majority of such students still need some level of academic enrichment and STEM preparatory activity to close the proficiency gaps in math and science and thereby better prepare them for STEM education. Programs such as Project CARE, developed and implemented by Wosu et al.[7] at the University of Pittsburgh

Swanson School of Engineering identified deficiencies in analytical and critical thinking skills at the pre-college level as major causes for the poor preparation and low enrollment of students from the underrepresented groups into STEM majors. Project CARE solution strategies focused on the enrichment of the Academic Performance Improvement (API) skills (critical thinking, analytical reasoning, quantitative literacy, communication, and problem solving/study skills) to minimize the barriers that hinder students' performance and attraction to STEM careers and to begin preparing students for science and engineering earlier, before 9th grade, and continuing through high school, and providing support services for these students through college until they graduate.

Project CARE offered academic year and summer residential pre-engineering programs that targeted members of groups traditionally underrepresented in engineering to enrich their cognitive critical and analytical reasoning skills needed to succeed in engineering education. The primary mission was to create a systemic change in the pipeline for increased access to an engineering career for underrepresented students by helping them with early skills development that will positively impact the quality of their academic performance (math and science content, GPA, class ranking, SAT) by the end of the high school senior year and be academically prepared to qualify for direct admission to a competitive engineering school. Project CARE served as a catalyst for higher performance and curriculum enhancement to ensure that they were academically prepared to enter a quality engineering program after high school graduation.

To make a solid improvement in the performance of pre-11th grade participants in algebra, trigonometry, functions and graphs, and general quantitative literacy skills, intensive *Foundational Mathematics* classes were offered to help students solidify their basic (Algebra I and II) mathematics skills and give the students opportunities to develop the problem solving skills necessary to succeed in an engineering major; *Engineering Tools* classes using engineering projects facilitated by faculty and graduate students, hands-on-engineering in a cooperative learning environment were used to interactively expose students to various math and science areas and their relation to engineering.

To prepare the pre-12th grade participants for the college level calculus and chemistry, *Foundational Mathematics***,** designed as an introduction to pre-calculus covering functions and graphs, trigonometry, identities/equations and analytical geometry and their integration to calculus and engineering, was offered. The course emphasized problem solving/logic and used other non-traditional tools to increase critical thinking skills, develop reasoning and logic in the problem solving skills, and integrated problem solving and critical thinking skills into college level calculus and chemistry courses as a foundation for an engineering education.

To acquire competence in problem solving and technical communication by the end of the 12th grade, a *Technical Writing/Research/Reading course was offered* to enhance students' technical writing and engineering communication skills and give them an opportunity to explore scientific writing techniques.

Students' early awareness of engineering careers and provide informal experiences that promote the students' interest in an engineering degree were increased using the following support initiatives: *Academic and Tutoring Support* to provide academic advising, tutoring, and academic assessment and remediation in science and mathematics, and counseling on the choice of a compatible engineering major; *Career Exploration Workshops* to help students take career interest inventories, learn about engineering and science careers through guest speakers and discuss financial aid options; *Parental Involvement* activities (such as social events and workshops) were sponsored to enhance a parent's ability to monitor their child's academic performance and assist with college planning.

Dimension 4: Develop the Multi-Campus Partnership for URM Access into PhD program.

This is a graduate *access* and *inclusion* dimension strategy designed to build capacity bridges between a PhD granting institution and multiple graduate pipeline programs and non-PhD granting institutions to identify top students early, cultivate talent for advancement, develop a communication plan that keeps them informed, and ease the transition into PhD program. At the units' levels, this means developing an effective model for creating a multi-campus bridge program and academic culture that support the identification and preparation of eligible URM undergraduates for the PhD-track in STEM fields. Multi-campus recruiting pipeline, graduate mentoring and retention system, and professional development program for URM graduate students need to be established to develop a systemic multi-campus framework, aligned with collaborating institutions to support the recruitment, retention, and PhD graduation of URM students. This dimension fosters the opportunity to recruit gifted students into PhD programs before other competing factors intervene. The following strategies in increasing the number of URM in STEM PhD programs have been shown to work:

Pre-PhD Scholar Program- Building early Bridges for Graduate School Placement: This is a BS/MS/PhD Triple Degree Program agreement with some selected local and national minority four-year colleges. The program focuses on creating a pipeline for students who wish to pursue PhD degrees by admitting promising students as "PhD scholars " as early as in the under-graduate junior year. The "burn-out factor" that tends to discourage students to continue into PhD after undergraduate education is minimized. Also, the strategy creates the opportunity to recruit these gifted students into PhD before other competing factors. Two cohorts of students can be targeted:

Pre-PhD Scholar I (3-3-4) open to highly gifted students who wish to transfer to a partnering PhD institution at the end of the summer term following the junior year. Students must complete two summer internship rotations in the graduate institution. Such options will guide the students in following a six-year plan to complete the BS/MS degree requirements in three years and continue and complete the PhD program after additional four years. Student receives the BS degree from host institution at the end of the second year in the graduate institution;

*Pre-PhD Scholar II (4-2-4***)** is the regular PhD track and open to selected students in the program who wishes to start their graduate studies after completing their BS in the host institution. The difference is that students are offered opportunities and additional pre-graduate school preparation through two summer research internships before completing the undergraduate education. The students follow a six -year plan to complete MS/PhD requirements. Prospective scholars are identified at the end of the sophomore year and required to spend two summers at the PhD institution, with the first summer at the end of the sophomore year and the second summer at the end of the junior year. Scholars who meet the departments' specified criteria are offered early provisional admissions as "Pre-PhD scholars." Prospective students in both options must commit to continuing into, and completing the PhD in order to receive a full Diversity Fellowship.

The program **c**ultivates URM undergraduates for PhD program through participation in carefully defined projects and graduate education transition activities with guidance and interaction with faculty, staff, and graduate students in the department. In the summer research internship orientation, Faculty members work closely with the students for the 8 week period. Structured mentoring activities in advanced research are used to motivate and develop students for graduate education. Additionally, students attend weekly mentoring sessions with the Minority Engineering Program (MEP) director or Diversity Dean, complete a journal quality paper on research findings, participate in the University's ethics forum, and present research results to faculty and graduate students. The program also implements faculty academic year mentoring mechanism in collaboration with the host institution to assist in meeting the course needs of students. The host faculty mentor also assists in keeping track of students' performance, graduate school aspiration and residency. The program has structured guidelines on graduate school requirements and assists the students in meeting those requirements.

Research Experience for Undergraduates (REU) - Successful REU models are identified and used in preparing and retaining prospective URM graduate students and on achieving success in doctoral programs. Active undergraduate research experience is one of the most effective strategies for attracting talented undergraduates to STEM and motivating them for graduate education and STEM careers The undergraduate research experience objective is to create more opportunities for multi-disciplinary approaches to problem solving and expose students to research presentation techniques. Undergraduate students from partnering institutions are recruited to apply for undergraduate research experiences at PhD institutions for the sophomore and junior summers. The REU activities to be assessed for impact of URM retention and success in PhD programs include: Faculty-guided research projects, seminars for professional development of researchers including such topics as ethics, proposal writing, intellectual property rights, technology transfer and communication, and training and guiding students in developing graduate (MS/PhD) research proposals for fellowship applications, such as the NSF Graduate Research Fellowship Program, NDSEG Fellowship, and private corporation or foundation fellowships. Multi-disciplinary research projects designed as a team/collaborative learning process are used to increase diversity and explore other applied areas of research. Each student is required to prepare a publication at the end of the ten-weeks and present the work in a national conference within a year.

Discovery Graduate Recruitment Weekend Event: Discovery Graduate Engineering event is a program typically designed to host underrepresented students from partnering pipeline institutions (HBCU/MI and non-PhD granting institutions). The event typically consists of department tours with graduate students and faculty members, dinner and lunch with various faculty members, and presentation by faculty designed to highlight the research focus areas in the departments. The purpose of the program is to offer URM and women students the opportunity to meet faculty, explore research opportunities, interact with current graduate students, visit the research facilities, and have a campus feel of the University culture.

Strategic Partnerships: Partnerships with HBCUs/MIs, non-PhD granting institutions, and national laboratories and the PhD-granting institutions are very critical in creating direct access to top juniors and graduating seniors through annual recruitment tours, and admission to competitive programs and fellowships that will not be available otherwise. An MOU between institutions allows exchange of students and faculty between the two campuses, cross-registration in courses delivered through distant learning, and joint faculty mentoring of graduate students from both universities. Membership in National Graduate Engineering for Minority Consortium (GEM) also fosters direct access to top student pool for admission and allows member institutions to work with industrial partners to leverage supports for engineering education for underrepresented minorities. Typical partnerships include: *Partnerships with students' organizations*: (National Society of Black Engineers (NSBE), Society of Women Engineers (SWE), Women in Engineering Program Advocates Network (WEPAN), Society of Hispanics Professional Engineers (SHPE)) of underrepresented groups are developed for effective dissemination of information and mailing of fellowship packages to prospective graduate students. Other partnerships include: *Partnership with LSAMP:* LSAMP activities include transitional bridge programs, research opportunities for undergraduate students, an annual student research symposium, and workshops on preparation for graduate school, research career options, and recruitment and retention of minority STEM faculty. Stakeholders at partner institutions, including McNair programs, LSAMP liaisons, HBCUs, STEM graduate students, postdoctoral fellows, and faculty members of color are consulted to gain a better understanding of unique challenges in finishing graduate programs and transitioning to faculty positions.

On-campus Recruitment by Academic mentoring: Systemic faculty-student mentoring is effective in providing the bridge between undergraduate and graduate educational experiences. In such programs, high achieving undergraduates are assigned a faculty mentor whose role is to motivate and guide the student through a transition to graduate education. Academic mentoring is a collaborative process of academically challenging, encouraging and guiding the student to explore his/her hidden potentials to the fullest and to excel at what that individual desires to do. The goal of mentoring activities is to help a student develop an ambition for graduate education and to help shape that ambition into a reality. A well-informed academic advisor promotes academic achievement and improved performance in major courses. Students are encouraged to develop and follow a plan that (1) improves analytical skills, (2) complete university major requirements, and (3) prepares for graduate education.

Off-Campus Visits and Peer mentoring: There is the need to take PhD institutions and the opportunities available directly to the minority or non-PhD granting institution. This means planning recruitment visits to selected minority campuses and professional society meetings or minority organizations to disseminate information about graduate program opportunities, interview students and identify promising students. Students from other campuses are identified by direct contact with host faculty and review of preliminary applications. Exceptionally gifted juniors and seniors from these institutions who have shown some interest for graduate education are invited during such visits to participate in multi-day campus tours and activities with a prospective major research advisor and graduate peer mentor.

Scholarships and Fellowships**:** URM motivation for graduate education increases with full commitment for funding through fellowships. Institutionally, it means a commitment to providing the needed funds or helping graduate applicants find appropriate funding. Several fellowships exist to address the critical need to recruit and retain graduate and professional students. Each STEM college awards Graduate Diversity Fellowships to graduate students who contribute to the diversity of the college.

Create a Method for Tracking Graduate Applications through the Department: After identifying qualified students and encouraging them to apply, a method of tracking the applications is necessary for follow up and provide and early offer of admission and financial support; follow-up to track the student's performance and offer campus visits, if requested, help to seal the admission deal; review and revise admissions procedures to accurately reflect the requirements needed to succeed in the program, and to enable students with a wide variety of backgrounds to qualify for admission. Departments should anticipate that students will enter their programs with a variety of backgrounds, and these differences should not be ignored. This means reviewing the correlation between the success of the departments' graduate students (completion rate, placement in good jobs, mean time to completion, percentages entering the Professorate at major research institutions, etc.) and various admission criteria (GRE scores, grades, strength of letters, previous kinds of research experience or work experience, maturity/age of student, etc.). There is a need to match students with faculty and program activities that maximizes success and ensuring that students with a wide variety of backgrounds and experiences are able to enter and successfully complete their graduate education.

Make Financial Aid Decision as Early as Possible: Many minority students are the first ones in their families to seek higher education and often find the decision towards a PhD degree a challenge if they do not know with some degree of certainty who will fund their education. Departments must be prepared to provide full support to qualified minority students, covering tuition, fees, and complete living expenses. This may mean providing minority students with the financial support as early as possible and avoiding actions that will isolate a student or provide irrelevant experience. Departments should provide support in a way that not only increases but also expedites the student's involvement in the research life of the department.

Multi-campus plan for recruitment through academic mentoring: The use of existing faculty-student mentoring programs between undergraduates and graduate faculty at the PhD institutions can serve as an effective graduate transition strategy. Such programs provide undergraduate transition to graduate programs by placing the URM undergraduate within an enriched academic and research experience that motivates them to pursue PhD degrees in STEM fields. The activities include assigning junior/senior students to mentors who will train and motivate them to do advanced research in STEM field of interest to the students.

Preparing Students for Transition to Graduate Education: A strategy designed to motivate and guide women and URM students across collaborating institutions to decide on graduate studies before the end of junior year and how to research for prospective graduate school. Students need to understand the purpose of graduate school. First, students are made to be aware that graduate education is very different from undergraduate education and that the purpose of graduate school is to develop a deeper professional understanding of a chosen discipline through independent reading, study, and research. As an apprentice, students need to learn how to define research problems, design and carry out research projects to test the hypotheses, and disseminate the results. Student need to learn to approach graduate school as a full-time job, expect to read, be prepared to critically evaluate problems, take initiative for learning with a good degree of self-motivation. Three rules that students need to remember include: *Research Rules Graduate Student Life*-While undergraduate education is centered around classes, graduate school, especially at PhD level, centers around research and how to construct knowledge independently; *Perseverance keeps a graduate student alive*- Student must learn to persevere through all the stages of a typical PhD program: Course work Stage, Comprehensive Exam Stage, Committee Selection Stage, Dissertation Research Proposal Stage-Dissertation Research/Writing Stage, and Dissertation Defense Stage; and *Faculty makes the Final Call to keep Graduate student alive*-Student must understand the importance and critical role of faculty and faculty research mentors. Students need to learn that in undergraduate education, faculty critical role is that of a professor and degree completion is decided by set of department/school rules. At graduate PhD degree level, completion depends on faculty advisors and a committee made up of faculty. Their out-of-class activities, such as research, publishing, and grant writing, also influence student education and progress towards the graduate degree. Most graduate students are funded through faculty research. As such, students are expected to be very productive, measured by publication and productive activities in the lab. Spending 40 hour per week is not a measure of productivity but what a student is able to produce within the research.

Dimension 5: Create Graduate Education Community and Structured mentoring to Enhance Academic Retention, Growth, and Networking for all URM Graduate Students

This is a *retention* dimension designed to increase perseverance level to complete a PhD program and to create a cohesive chain between undergraduate recruiting, doctoral retention, PhD completion, and professional development. Institutionally, this strategy means establishing academic and social environments that challenge each student to achieve academically at high levels or each faculty to make tenure. It calls for providing inclusive academic support services, mentoring and community engagement activities to retain URMs and for production of increased number of URM in STEM PhD and postdoctoral programs. Departmentally, it means providing academic diversity in courses and program offerings within each field of study and paying attention to student intellectual and social development in a global context. At senior administrative levels, it means fostering policies that hold each member of the campus accountable for contribution of the learning and knowledge development of all students, the ultimate high graduation rates of all student groups, and continued professional growth, productivity, and retention of its faculty and staff. Typical activities that can increase the retention of URM students include:

Provide Structured Academic Faculty Mentoring of Graduate Students: Faculty academic mentoring is a process of helping graduate students achieve success through a relationship with a faculty mentor. Many URM graduate students, especially those from HBCU, usually find the academic environment in majority departments different from what they are used to and a usually find navigating their way through a graduate program a challenge. Some of these students are less likely to find URM faculty as mentors due to too few such URM faculty of similar cultural backgrounds; there are also low critical mass of URM within the department resulting in isolation the URM student. At the undergraduate level, structured mentoring program focuses on academic excellence and preparation of women and underrepresented minority students for a graduate education in engineering. Formal mentoring will involve matching a student with a faculty and engaging them in a one-on-one relationship that is non-threatening and non-judgmental but provides the challenge and "push" in the right direction. Typically, a mentor provides guidance, facilitates the navigation through politics of doctoral education. A mentor is viewed by URM as someone who believes in their ability or potentials and willing take an interest in helping them develop those potentials to the fullest. Academic mentoring is a collaborative process of academically challenging, encouraging and guiding a student to explore his/her hidden potential to the fullest. Faculty members receive training on effective cross-cultural mentoring and are encouraged to mentor URM students

***Forums for Minority Pre-Doctoral Candidates*:** These programs are designed to promote graduate education to prospective and current high-achieving URM undergraduate students and foster opportunities to familiarize students with academic programs, admission standards, and resources for funding graduate education

***Research internships with national energy labs and industries**:* Explore and develop an effective plan for research internship programs with National Laboratories and prospective energy partnering industries, such as the Department of Energy, NETL, PPG, and Westinghouse, that will increase the number of URM in energy related research at PhD levels.

Undertake site visits to build partnerships and programs: These site visits will allow the partners to learn about best practices at the other institutions and to meet with these university's provosts about establishing a regional postdoctoral network. Site visits will also allow for exchange of ideas on mentoring and professional development practices for graduate students and postdoctoral fellows.

Build a Graduate Student-Centered Community: This means developing a structure for effective community engagement and mentoring partnership with all stakeholders (graduate students, post-docs, faculty, staff, and administrators) for production of increased number of URM in STEM PhD and postdoctoral programs. It calls for large multi-campus research centers such as Engineering Research Centers (ERC) to recognize their roles in STEM workforce development and create professional development opportunities that build community among graduate students, postdoctoral fellows, and faculty members to motivate and build the capacities of the graduate students in departments that have low URM enrollments. Graduate Engineering Community Centers can be established to allow students to fellowship together and work in multi-cultural groups to provide group discussions, reduce isolation of any group, develop peer mentors and encourage academic activities. This is very critical in reducing isolation of any particular group of graduate students, especially in cases where the critical mass of these students is low. The expected outcome of this strategy is indirect peer mentoring, networking, and promotion of collaboration with diverse group. The center will also enrich the students ability to manage diversity in the school.

***Develop Graduate Engineering Diversity Association*:** This type of association fosters opportunities for students to provide group discussions, reduce isolation of any group in departments where the critical mass of URM students is low, develop peer mentors, encourage academic activities, and promote a sense of community for doctoral students of color. These organizations may be helpful in providing an orientation to life in the local community where the institution is located, or offering advice on how to navigate the services available on campus such as the library or financial aid office. At the departmental level, advanced graduate students can lead information sessions on how to choose courses, interpret academic policies, and develop relevant study skills to succeed in the first years of doctoral study. Network targeted to female graduate students can be designed to foster opportunities for women graduate students to academically network with female faculty and other female graduate students to encourage high academic resilience and performance.

Develop a Research and Professional Development Mini-Conference: Host an annual conference comprising of the PhD pipeline institutions to unify the recruitment and retention efforts across the span of undergraduate recruitment, doctoral retention, postdoctoral support, and faculty transition. The conference could provide opportunities to showcase research and network among faculty and their graduate student. Undergraduate pipeline institutions are invited to promote early identification of students for summer research internships at partnering institutions. In addition to research presentations, the conference could feature sessions on preparing for and applying to graduate programs, the responsible conduct of research, and developing manuscripts for publication. Undergraduates from regional HBCUs, LSAMP institutions, could be invited to attend as part of the graduate school recruiting effort. This conference could serve as a primary means of networking among students and faculty from different institutions while providing a place to showcase research and recruit graduate students, postdoctoral fellows, and faculty members.

Dimension 6: Evaluate Diversity Outcome through Institutional-wide Diversity and Equity Scorecard

Effective evaluation of diversity and equity outcomes is based on broad definition of diversity and equity and the general understanding of what that means by all stakeholders. The following functional definition is offered:

Diversity in all of its forms is the integrated differences and similarities (race, nationality/ethnicity, age, gender, sexual orientation, religion, socioeconomic status, abilities, culture, geographical location, etc) of individuals and academic programs in the central educational mission of an institution to achieving inclusive excellence.

Equity is the number or level of access and inclusion (recruitment and enrollment) of historically underrepresented students, faculty, and staff in an institution relative to a predetermined average, national or state number.

Institutionally, outcomes achieved are documented through Diversity and Equity Scorecard (DES). DES is comprehensive tool for assessing school-wide progress and effectiveness in achieving high diversity and equity impact through increased access, excellence, retention, scholarship, positive environmental climate, and success of all students and faculty, especially women and underrepresented students and faculty. To foster progress or change in the educational mission, a DES provides the outcome-based strategy for improving school effectiveness in closing students equity, diversity or educational outcomes gaps (access, enrollments, retention, excellence, graduation, global preparedness) for all students, and faculty or equity and diversity gaps (recruitment, retention, scholarship, excellence) for all faculty and staff in a positive environmental climate. By requiring measurable responsiveness and accountability, DES desired outcome is the promotion of organizational change.

The model hypothesizes that institutional diversity impact, *D(p)*, is a linear function of the intentional actions or performance targets in Access (*A*), Retention Rate (R_r), Graduation Rate (*G*), Quality (*Q*), Climate (*C*), and Receptivity (R_e) such that

$$D(p)=aA+bR_r+cG_r+dQ+eC+fR_e \qquad (1)$$

where *a, b. c. d, e,* and *f* are the contribution coefficients of access, retention, graduation, quality, climate, and receptivity, respectively, to institutional diversity.

The contribution coefficients can be determined by maximizing the function *D(p)* subject to appropriate constraints on the coefficients such that

$$\begin{aligned} &Maximize: D(p)=aA+bR_r+cG_r+dQ+eC+fR_e \\ &\text{subject to:} \qquad (2) \\ &a+b+c+d+e+f \leq 1 \end{aligned}$$

Alternatively, given a desired values of *D(p)* and performance percentage targets achieved, the coefficients can also be determined through a linear fit to Eq.(1).

Equity impact is defined as URM performance percentage target achieved relative to national or institutional baseline outcome desired for that target and can be expressed as:

$$[Access\ Equity]=\frac{URM\ \ Access\ Achieved}{Baseline\ Access\ Desired} \qquad (3)$$

Similar expressions are written for the other performance targets (Retention Rate, Graduation Rate, Quality, Climate, and Receptivity) achieved. The national baseline diversity variable desired can be the current state or national data. It is assumed that an institution or academic school or college would desire that its URM engineering diversity mirrors the state or national population percentage of the targeted minority group. For example, if the institutional national enrollment percentage of African American in engineering is 6% and population percentage is12% , the institutional desired enrollment outcome could be set at 12% to achieve a level of access equity of 0.5 compared to 1.0 true access equity. However, the use of national population as a baseline, though the best approach, is usually a challenging and difficult criterion to meet for majority institutions given current prevailing conditions. Instead of national baseline, an institutional baseline desired can be set between the national (baseline) population percentage of the URM group and the current institution performance percentage and expressed as:

$$[Institutional\ Baseline\ Access\ Desired] = \frac{(URM)_N + (URM)_I}{2} \qquad (4)$$

Where *(URM)*$_P$ is national population percentage =12 % in this case, and the *(URM)*$_I$ is the current institutional performance percentage target = percentage enrollment as indicator of access, in this example.

Results and Discussions

University of Pittsburgh implements a comprehensive diversity action plan that follows the model proposed in this paper. Large multi-campus research centers such as Engineering Research Centers (ERC) with North Carolina A&T State University (NCAT), University of Pittsburgh and University of Cincinnati has to recognized its roles in STEM workforce capacity building by broadly engaging graduate and undergraduate women and underrepresented minority students in community activities and building strategic relationships for integrating research, education, outreach, and diversity across the center. Although data of the progress made over the years are still being analyzed, some of the key accomplishments are highlighted below:

Multi-Campus in K-12 Out-reach Pipeline Initiative- In the last three years, the Engineering Research Center (ERC) institutions continue to implement multi-campus pre-College Bridge Programs to create access to STEM education through increase Recruitment of women and underrepresented minority (URM) students and economically disadvantaged students who pursue engineering, mathematics and science majors and subsequent careers. The college preparatory outreach program implemented at PITT resulted in 97% of the 34 high school graduate in the class of 2010 enrolling in college, 53%, enrolled in Engineering, math or science major, and 21% enrolled in Engineering fields, with 12% of these enrolling in the University of Pittsburgh.

ERC Young Scholars Program was initiated to give pre-college students opportunities to gain hands-on experiences while still in high school. Young Scholars were drawn from a high school embedded on NCAT's campus called The Early/Middle College at North Carolina A&T State University. Scholars also participated in the research activities in ERC faculty labs, engaging students in research related to coatings.[31]

Bio-Engineering Institute High School Camp at NCAT is the results of continued collaboration with Pitt Bioengineering and PTEI in building off of the success of first two years of the program. This 5-day commuter camp utilized faculty and mentors from NCAT and Pitt. Participants were recruited through advertising in the campus summer camp website as well as through the community service announcements website of the local newspaper. The participants were a diverse group of high school sophomores, juniors and seniors, derived from geographically disparate locations throughout North Carolina. The camp provided intensive, hands-on learning experiences for campers.

*ERC **N**ano-world tours Nano-to-Bio Summer Camp* initiatives engaged underrepresented populations in the excitement of STEM; Nano-to-Bio Summer Camp program also implemented high-school students. The participants reported high levels of satisfaction with their week-long experience and increased understanding of tissue engineering.[31]

ERC Multi-Campus REU Program fully engaged underrepresented undergraduate student in variety of faculty research experiences across ERC institutions. The undergraduate students recruited during the year were joined in summer by students recruited from partner and other regional institutions (community colleges and a Hispanic-serving university). REUs were limited to rising sophomores, juniors, seniors or recent graduates of community colleges, colleges and universities from accredited 2 or 4 year institutions. Targeted underrepresented populations were reached through our strategic partnerships with organizations including schools in predominantly minority-serving locations. Students were engaged in active summer research program with faculty and faculty graduate students, including a series of courses in different disciplines for undergraduate and graduate students. These students were exposed to cutting-edge technologies in biomedicine and nano-science. A Student Summit organized at NCAT enabled mingling and discussion between ERC students/faculty/scientists from all the partner institutions. Students performed research at the other universities (e.g. NCAT students worked at UC, Pitt students working in Hannover, UC and Pitt students at NCAT).[31]

ERC Diversity Efforts to Increase Diversity Produced Positive Results. ERC diversity plan aligns the center's mentoring of students at the undergraduate, graduate, and postdoctoral levels to prepare, motivate, and build PhD student capacity to pursue an academic career. Inclusive diversity efforts with women, underrepresented minority and minority-serving institutions effectively engaged women and URM in research and education. The following initiatives are related to involving women and minority students in ERC research and education[31]:

- The ERC's research and education and outreach activities, as well as the bioengineering program of NCAT are being widely publicized for student enrollment and faculty recruitment purposes.
- Recruitment campus visit to partnering universities continue yield qualified students in the PhD pipeline. An increased number of well-prepared students are interested or already pursuing PhD in Bioengineering and Mechanical engineering at the University of Pittsburgh. There are 16 other students in the pipeline committed to applying at graduation in 2013.
- Special efforts to promote diversity at alliance institution interaction among NCAT, UC and Pitt students at the Biomedical Engineering Society (BMES) Annual Conference in Pittsburgh fostered opportunity to increase students interest in research and graduate education
- ERC partners sponsorship National Educators Workshop resulted in increased participation of attendees from all over the US, including 3 international attendees and quality of the workshop and workshop speakers.[31]

Research Experiences for Undergraduates (REU) Program at NCAT fully engaged increased number of underrepresented undergraduate student in variety of faculty research experiences. All of these students have shown interest in engineering graduate education in the faculty research areas.

Assessment data of ERC outreach program suggest that campers experienced high levels of satisfaction with the one-week, commuter camp, and that campers gained enhanced understanding of complex concepts such as the relationship between human tissue and engineering. [31] Assessment data also indicate that those responsible for planning additional Nano-to-Bio camps may want to think about extending the length of the camp, as well as reformatting the camp as a residential camp, rather than commuter camp. Given camper feedback, increasing the number of guest speakers and exploring the possibility of more off-campus laboratory tours and field trips seems reasonable. Building from a mixed-methods point of view, future assessment strategies should include additional methodologies for data collection, including entrance and exit focus groups and content-specific, forced-choice (e.g., multiple choices, true/false) pre-/post instrumentation.

The Engineering Research Center (ERC) is shown an example of a purposeful development and utilization of organizational resources do enhance student learning, fostering multi-campus environment that challenges each student to achieve academically, and maximizing the strategic relationships and engagements for integrating Research, Education, Outreach and Diversity across institutions. Noted accomplishments include:

The ERC team is committed to building a successful diverse leadership, faculty, graduate and undergraduate student body. Effective actions taken in order to increase the diversity and multicultural knowledge included the intentional appointments of women and URM to the leadership teams. Efforts were made to reach the high-achieving African-American students who are eligible for admission into engineering PhD programs directly upon obtaining their BS degrees. Additionally, efforts are being made to reach out to female.

Project CARE increased the achievement of pre-11th grade participants in algebra, trigonometry, functions and graphs, and in general quantitative literacy skills. The survey and pre-and post-tests results overwhelmingly indicated that Project CARE succeeded in preparing students for college level math and chemistry instruction as well as enhancing their ability to excel in their senior year of high school. Most of the participants (93%) agreed that chemistry and the associated lab contributed to their educational growth and will be useful for their college career. 79% agreed that engineering tools contributed to their educational growth. Although 43% agreed that the pace of instruction in pre-calculus was appropriate, 67% indicated the pace was too fast. 86% agreed that the knowledge acquired contributed to their educational growth. Study and communication skills received the highest marks as the critical in sustaining education growth.

Project CARE increased students' early awareness of engineering careers and provided informal experiences that promote an expectation for excellence and interest in an engineering degree. The major engineering awareness activity during summer session was the Race Car

Project facilitated by the Mechanical Engineering Department. Over the course of the summer session students learned Solid Works, and designed model race cars on the computer. The cars were built in the prototyping lab, painted by the students and raced as a culminating activity for the project. This hands-on activity exposed students to typical activities of a mechanical engineering professional, enabled them to master a new computer program and challenged them to analyze car features that would contribute to the design of a racecar.

Pre-11th grade students surveyed agreed that *Logic/Problem-Solving Skills* contributed to their educational growth (100%) and be useful for their college career (94%) while 89% agreed that engineering tools will contribute to their educational growth. Although only 50% of the students agreed that the pace of instruction was appropriate, they agreed that concepts learned in college algebra contributed to their educational growth (83%) and would be useful in their college career (94%). Students also see communication skills to be important in educational growth (61%) and college career (83%). Survey results reveal that 93% of pre-12th grade student believe that the summer session instruction reinforced their problem-solving skills in math and science.

Analysis of the impact hands-on-science and engineering activities shows that inquiry based instructions in physics and chemistry showed that inquiry based approach to teaching science were more effective in students understanding of physics than chemistry.

*Project CARE improved students problem solving and technical communication skills***.** End-of-program survey results indicated that over 80% of the participants believe that enriching their critical thinking skills enhanced their problem-solving skills.

Project CARE motivated high school youth to follow their individual career interests in the fields of engineering and technology**.** The three year average shows 60% agreement that collaborative learning strategy improved their understanding of math, engineering projects helped 65% of the students gain better understanding of engineering concepts; over 75% agree that inquiry-based hand-on-experienced helped their understanding of lecture materials, and 73% agree that the use of technology (graphic calculator improve their interest and learning. In addition, 83% of the students reported continuous assessment through classroom assignments and testing exposed them to challenging applications or extensions of the course content.

The implementation of the proposed model has helped the Swanson School of Engineering to make considerable success in increasing the numbers of female and underrepresented students enrolled in its MS and PhD programs.

Conclusion

A model of Diversity and Equity for building inclusive excellence in graduate engineering education is proposed as a six-dimensional action plan for achieving diversity and equity goals in graduate STEM education. The proposed model is designed as a synergistic plan for capacity-building through best practices across campus and programs. A comprehensive discussion of each performance dimension-Access (Preparation, Recruitment), Retention (Perseverance), Graduation, Excellence (Quality), Climate, and Institutional Receptivity- and the strategies on their use are discussed in details. Establishing a multi-campus pipeline framework for a pre-college to PhD in STEM fields program means developing an effective model for creating a multi-campus bridge program and academic culture that support the identification and preparation of eligible URM undergraduates for the PhD-track in STEM fields. Providing graduate student-centered community is one effective strategy for developing a structure for effective community engagement and mentoring partnership with all stakeholders (graduate students, post-docs, faculty, staff, and administrators) for production of increased number of URM in STEM PhD and postdoctoral programs; fostering an inclusive academic climate is critical in increasing engagement of all stake holder. A critical element of institutional receptivity as the ability to provide organizational and structural realignments necessary to support all the other four dimensions is discussed.

A mathematical diversity model that presents diversity impact is a linear function of the intentional actions or performance targets in Access (A), Retention Rate (R_r), Graduation Rate (G), Quality (Q), Climate (C), and Receptivity (R_e) and the corresponding equity impact, and diversity contribution coefficients can also be determined.

The Engineering Research Center (ERC) is shown as an example of a purposeful development and utilization of organizational resources to improve graduate engineering through multi-campus approach. A summary of the diversity portion of the ERC's strategic plan and progress in the past year in relation to the milestones for "High Quality Diversity Effort" has been highlighted as a typical example of the use of the model. The key performance indicators show that ERC through is partnering institutions is making measurable impact in capacity building for STEM workforce as seen in the enrolment and PhD degree production of women and underrepresented minority students broadly involved in center activities with a significant number of women and underrepresented minority faculty engaged in ERC activities.

A three-year pilot Project CARE was used as an example of Preparation, Quality (Excellence), Recruitment dimension example and overwhelmingly showed that the contributed to 86% educational growth and 35% academic performance improvement among those students who scored lowest on the pre-test compared to 25% improvement among those that scored highest in the pre-test. The program was 65% effective in preparing high school students for college level math and science instructions, as well as enriching their academic performance skills and ability to excel in their senior year of high school.

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